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## Екология и устойчиво развитие

**Академик Тодор Николов**

Екологията е онази област на съвременното познание, която фокусира в себе си най-тревожните и жизненоважни проблеми, които стоят пред човечеството. Днес почти всички разбират от футбол и от екология, които заедно с думата корупция се срещат най-често в медиите. Извън шегата обаче малцина осъзнават, че в съвременния етап на развитие на природата и обществото екологията очертава жизнените адаптационни връзки и фундаменталните противоречия в коеволюцията (т.е. в паралелната свързана еволюция) на природата и обществото.

Известно е, че екологията изучава взаимоотношената между самите организми от една страна и между организмите и средата на обитание. Сложните процеси на взаимоотношенията между организмите и средата се управляват чрез саморегулиращи механизми, които са характерни за живите (самоорганизиращи се) системи. Това води и до относителното равновесие на отделните екосистеми и на биосферата в цяло.

Терминът екология е предложен от немския учен – естественик и философ Ернст Хекел през 1866 г. Съосновател на екологията е и датския ботаник Еужениус Варминг (Warming, E. (1895) ***Plantesamfund - Grundtræk af den økologiske Planetegeografi***. P.G. Philipsens Forlag, Kjøbenhavn. 335 pp.), издадена на английски език през 1909 г. Warming, E. with M. Vahl (1909) [\*Oecology of Plants - an introduction to the study of plant-communities\*](#). Clarendon Press, Oxford. 422 pp. (2nd edn 1925).

Днес екологията е една от най-интензивно развиващите се области на природознанието. Нещо повече, самото наименование като чели е станало “термин за всичко” – екология: биологична, екосистемна, акустична, хидрологична, антропологична, психологична, икономическа (екологични аспекти на икономическото развитие), социална екология, популационна екология, екология на поведението, обща екология – науки за средата и др. Екологията стана синоним на околна среда (environment, [environmentalism](#)), дотолкова че прилагателното “екологично” се възприема буквално като “приятелско”.

Доколко силно се нуждае съвременното човечество от «приятелска среда», която да е подчинена на два основни закона на екологията: закона на минимума и закона на поносимостта, се вижда от съвременното развитие на света.

Организмите не само изпитват влиянието на средата, но и сами много активно влияят върху нея. В. И. Вернадский казва, че «на земната повърхност няма химична сила, по-могъща по своите крайни резултати от живите организми, взети в цяло. . .» Организмите играят важна роля в кръговрата на веществата, в преразпределението на химичните елементи и тяхната миграция, при образуването на различни нови съединения. Установено е, че ако не е регулиращата роля на организмите, океанските води за около 17 млн. години ще се опреснят като речните. Така е било поне в миналото, защото днес човекът е главния фактор и неговото въздействие върху околната среда е най-голямо и най-опасно. Още повече, че докато в миналото саморегулиращите се механизми на живите екосистеми на въздействие **в/с/с** средата са довеждали до относителното равновесие в екосистемите, то днес влиянието на човека е без регулация (освен безумието и алчността, ако не се приемат като регулиращи механизми!).

В зависимост от степента на въздействие върху организмите факторите на средата могат да се поделят на три основни групи: стабилни, изменящи се и комплексни.

*Стабилните фактори* не се изменят в течение на дълги периоди от време. Към тях се отнасят силата на гравитацията, съставът и свойствата на атмосферата, хидросферата и литосферата, както и други геоложки стабилни фактори. Това в същност са най-постоянно действащите фактори, адаптацията към които е кодирана в структурата на ДНК в процеса на еволюцията на живота върху Земята. Към стабилните фактори трябва да се отнесат морските течения, които действуват продължително време и играят важна роля за преразпределението на веществата в басейна, за изравняването на температурите и разселването на организмите.

*Изменящите се фактори* са от два вида: а) периодично изменящи се фактори (с денонощни, сезонни и други изменения, свързани с движението на планетите). Тези фактори не оказват видимо влияние върху многогодишните изменения. и с редки изключения трудно се установяват в палеонтоложките обекти. Но към тях в процеса на еволюцията също се изработва адаптация, която е кодирана в структурата на ДНК; б) фактори, които се променят незакономерно, без периодичност (вятър, дъжд, влажност, храна, болести, паразити, хищници и пр.). Тези фактори оказват влияние върху особеностите на сезонните биологични цикли, върху измененията на числеността на популациите в различни области и през различни години, а също и върху разпределението на животните вътре в дадена област.

Третата група фактори са твърде *комплексни*. Те са междинни по въздействие между двете първи групи и оказват различно влияние върху организмите.

Разпространението на всеки организъм и възможностите за неговото развитие се определят от разгледаните фактори. Те обаче имат различна степен на влияние върху отделния организъм. Някои от тях са жизнено важни за него, към тях той е адаптиран. Промяната само на един фактор може да направи невъзможно съществуването на даден организъм. Според **закон на Либих** ограничителен фактор може да бъде някое вещество, чиито достъпни количества са близки до необходимия минимум. Установено е, че често развитието на организмите се ограничава не в зависимост от количеството на основните хранителни вещества, а от тези вещества, които са нужни в незначителни количества, или от някои микрокомпоненти. Ограничително влияние може да окаже не само недостигът, но и увеличеното количество на такива фактори като соленост, топлина, светлина и пр. От друга страна, за редица бързорастящи прикрепени морски безгръбначни животни ограничителен фактор може да бъде големината на субстрата за прикрепване.

Съществува и т. нар. **закон на Шелфорд** за поносимостта, според който разпространението и развитието на организмите се определя или от недостига (в количествен или качествен смисъл), или от обилността на всеки един от факторите, чието равнище е близко до пределите, които могат да се понасят от даден организъм. Съгласно този закон всеки организъм се характеризира с определен екологичен минимум и екологичен максимум, разликата между които се определя като предел на поносимостта.

Според Ю. Одум (1975) организмите могат да имат широк диапазон на поносимост към един фактор и тесен диапазон — към друг. Обикновено организмите с широк диапазон на поносимост към всички фактори са най-широко разпространени. Тесният диапазон на поносимост към факторите на средата е характерен за специализираните форми.

Въздействието на човека днес нарушава основните закони на екологията, т.е. на равновесието в природата. А не може да има устойчиво развитие на обществото, ако се нарушава равновесието в природата. Известно е, че в своето развитие всички природни екосистеми се стремят към относително равновесие. То никога не може да бъде абсолютно, тъй като се подчинява на динамичните закони на сложни природни системи. За определяне на това състояние на относително равновесие на екосистемите от началото на 20 в. в екологията започва да се използва термина **sustainability** (стабилност, устойчивост). Това е свързано с

**хомеостаза** – способността на биологичните системи да противодействат на измененията на средата и да запазят равновесие.

Когато се говори за стратегията на устойчивото развитие обикновено се има предвид двойката **икономика-екология**, но в повечето случаи не се познават основните принципи на екологията и закономерностите в развитието на екосистемите. Поради това ще си позволя да припомня някои основни положения от еволюцията на природните екосистеми.

Конкретното развитие на всяка екосистема се нарича еколожка сукцесия. Тя е представена от съобществата, които се сменят едно с друго в даден район. Еколожките сукцесии се обуславят от едновременно действие на биотични и абиотични фактори. Началното съобщество завоюва даден биотоп и открива фронта за други организми. Обикновено такова начално съобщество се развива на чист грунт. Сукцесиите могат да бъдат много сложни, тъй като отделни стадии могат да не се проявяват или частично да се заместват. Заместването на видовете в сукцесиите се обуславя от изменението на окръжаващата среда, при което се създават условия, благоприятни за други популации. Това продължава дотогава, докато не се стигне до равновесие между биотичните и абиотичните компоненти. Стабилизацията на екосистемата се нарича климакс (стабилно — климаксно съобщество). Климакското съобщество се намира в равновесие със средата на обитаване.

Развитието на екосистемите до стабилизация протича бързо и може да се нарече «тактика» на сукцесиите, която бихме могли да сравним със «стратегията» на дългата еволюция на биосферата през геоложкото минало. По този път «се засилва контролът над физическата среда (или хомеостаз със средата) в този смисъл, че системата достига максимална защитеност от резките изменения на средата. Развитието на екосистемите е аналогично в много аспекти на развитието на отделния организъм» (Одум, 1975, стр. 324).

В еволюцията на екосистемите могат да се отбележат следните основни етапи: 1) поява и развитие преди повече от 3,2 млрд. години на анаеробни хетеротрофни организми; 2) поява и масово развитие на автотрофни организми — едноклетъчни водорасли, които имат способността да фотосинтезират; те поставят началото на преобразуването на редукционна атмосфера в кислородна; 3) поява и развитие на многоклетъчни организми; 4) възникване на здрави скелети при безгръбначните; 5) възникване на гръбначните; 6) поява на сухоземни растения, последвана от завоюване на сушата от животните; 7) широка диференциация сред безгръбначните животни; 8)

последователна поява на земноводни, рептилии, бозайници, птици; 9) поява и развитие на покритосеменните растения; 10) поява на човека. Това е силно схематизираният ход на еволюцията на екосистемите. Еволюцията на организмите и на неорганичната среда са водели непрекъснато до формиране на все по-сложни екосистеми. Тук определяща е ролята на организмите. Одум (1975) справедливо подчертава, че естественият отбор е действал както на видово и подвигово равнище, така и на по-високи равнища, специално при (1) т. нар. свързана еволюция (**коеволуция**), т. е. взаимен отбор на зависими една от друга автотрофни и хетеротрофни организми, и (2) групов отбор, или отбор на био-ценотично равнище, който довежда до запазване на определени популации, благоприятни за съобществото в цяло.

Относително равновесно състояние (или по-правилно динамично равновесното състояние) на природните екосистеми съществува до намесата на някой фундаментален фактор, който засяга трайно и/или разрушава хранителните вериги (пирамиди) в екосистемите. Такива фактори са промени в състава и свойствата на атмосферата, намаляване или увеличаване на парниковите газове, активен продължителен вулканизъм, резки глобални климатични промени, изменения в конфигурацията на континентите и океаните, и на океанските течения.

В съвременността основен фактор на въздействие върху екосистемите (обикновено отрицателно въздействие) е дейността на човека. Днес човекът се е превърнал в най-мощният фактор, който оказва неприемливо влияние върху околната среда, което подкопава равновесието на основните екосистеми, както на континентите, така и на океаните. Вече се осъзнава, че това ще доведе до непоправими последици за живота върху Земята, а следователно и за самото човечество.

От началото на 70-те години на 20-ти век проблемите на екологията и икономическото развитие все по-често започват да се разглеждат като свързани в сложен възел. Ето някои важни моменти от това ново развитие на научното мислене и политиката:

1972 г. – Световна конференция по околна среда в Стокхолм.

1983 г. – Образуване на Комисията Брунтланд.

1987 г. – Отчет на Комисията Брунтланд "Нашето общо бъдеще".

1992 г. – Първа Световна конференция на ООН в Рио де Жанейро.

2002 г. – Втора Световна конференция за околна среда и развитие в Йоханесбург.

В знаменития доклад на Комисията Брунтланд “Нашето общо бъдеще” за пръв се използва термина “sustainable development”, който е деклариран като принцип на конференцията в Рио:

“В Декларацията от Рио – пише Морис Стронг, Генерален секретар - са включени 27 принципа, синтезиращи глобалните проблеми на човечеството, които трябва да се решават както в световен, така и в регионален и национален план. Всъщност декларацията се явява като продължение и допълнение на тази, приета през 1972 г. на Стокхолмската конференция на ООН по околната среда. Обаче нейният обхват е разширен и конкретизиран в съответствие с настъпилите през изминалите 20 години промени в планетарен мащаб, като най-същественият елемент се явява включването и на понятието **“развитие”**. Това означава, че самото опазване на околната среда не може да се разглежда като дейност сама за себе си, изолирана от икономическото развитие. Това са две взаимосвързани и взаимозависими величини. Дори като предопределящ фактор за намесата на човека в околната среда ще бъде съображението доколко планирана дейност би я замърсило или увредило, което косвено би имало отражение върху човешкото здраве. Всичко това следва да се пречупва и през утвърждаващата се концепция за **устойчиво развитие**».

В Принцип 1 се подчертава, че «Грижата за хората е в основата на **устойчивото развитие**»;

**Принцип 3:** «Правото на развитие трябва да се осъществява по начин, който задоволява справедливо нуждите на сегашните и бъдещите поколения, свързани с развитието и околната среда».

Терминът “sustainable» (равновесен, стабилен, устойчив) идва от екологията, където равновесното (стабилно) състояние на екосистемите се означава като “sustainable; sustainability”.

Така пренесен от екологията в глобалната политика терминът “sustainable development” изразява модел на използване на ресурсите, който има за цел да осигури потребностите на човека при запазване на природната среда, така че тези нужди да могат да бъдат задоволени не само в момента, но в неопределено бъдеще, т.е. **дълголетна устойчивост на природните екосистеми и резерви**. В този смисъл е и книгата на Албърт Гор - **Earth in the Balance**, Houghton Mifflin Co., 2000, p. 176.

От гледна точка на екологията и на теорията на еволюцията “Земя в баланс” значи коеволюция на човека и биосферата.

Изглежда вече е осъзнато, че човек е естествена част от биосферата, продукт на биологическата еволюция и опитите за

извисяването му като бог над природата може да има глобални разрушителни последствия.

Според Карл Сейгън () западната (християнска) цивилизация и западната наука постоянно са внушавали, че природата е само декор за нашата история и че е светотатство да обявим природата за свещенна” [2005, с. 174]

Библията. Първа книга Моисеева. Битие, глава 1:

“26. И Бог каза: Да сътворим човек по Наш образ, (и) по Наше подобие; и да господарува над морските риби, и над небесните птици, (и над зверовете) и над добитъка, и над цялата земя, и над всички гадини, които пълзят по земята”.

“27. И сътвори Бог човека по свой образ, по Божий образ го сътвори; мъж и жена ги сътвори.”

“28. И благослави ги Бог, като им рече: плодете се и множете се, пълнете земята и обладайте я и господарувайте... над цялата земя...”.

Вероятно затова човек живее с убеждението, че е своеобразен “наместник” на Бога и е призван да господства на планетата. В тази връзка е уместно да припомним индианската мъдрост: **“Не сме наследили Земята от своите предци, а сме я взели назаем от децата си”**.

На върха на хранителните пирамиди на екосистемите винаги има един вид, който обикновено е хищник и своеобразен монополист. Той може да предизвика криза в екосистемата, ако популацията му нараства непрекъснато. Това непременно довежда до криза в екосистемата. Благодарение на саморганзицията на живота екосистемата се стреми към равновесие и ако няма странични въздействия, то тя постига баланс. Още повече, че в природата никой хищник (освен човека!) не изстребва докрай жертвите си. По правило в естествените екосистеми популацията на жертвите се размножава по-бързо, отколкото популацията на хищниците. Единствено човек нарушава механизмите на естествената регулация и затова предизвиква кризи в екосистемите.

Като продукт на биологическата еволюция и социалното развитие човек по природа има стремеж към монополизъм. Това е характерно за неговото поведение. Още в началото на 20 в. В.И. Вернадский отбелязва, че човек е станал основен геоложки фактор на Земята и неговият монопол е безпрецедентен. Поради това екологичните кризи в историята на човечеството са станали неизбежни. Има основание да си задаваме въпроса дали живеем във времето на “разумния човек”, защото името *Homo sapiens* изглежда неподходящо, когато го отнесем към делата човешки.

Господстващата роля на човека на Земята се очертава в началото на палеолита, когато той открива огъня, лъка и стрелата. Изработването на оръдия на труда и на оръжия за ловуване безспорно допринасят за развитие на мозъка (интелекта) на човека, без да повлияят съществено върху развитието на неговия разум. Защото интелектът според великия Макс Борн прави разлика между възможно и невъзможно, докато разумът определя кое е смислено и кое е безсмислено. “Даже възможното може да бъде безсмислено” (Борн, 1981). Тревно е също, че човек се опитва да проникне в механизми, утвърдени от еволюцията преди милиарди години (например генноинженерните опити). “Пътят към ада е винаги послан с добри намерения”, но “човъркането” в гените трябва да става повече от внимателно, защото никой не може да предвиди последствията.

Една от най-големите кризи в ранната история на човечеството преди 12-10 ка, т.е. непосредствено малко преди началото на холоцена (неолитна криза) е свързана с масово изсичане на гори за разширяване на обработваеми площи.

През целия палеолит човекът е типичен ловец. Настъпилата криза в края на палеолита, която се засилва през неолита, причинява масово измиране на големите копитни бозайници и особено на хоботните (мамути), вследствие на тяхната специализация към гигантизъм. Това довежда до доста бързо изчезване на техните популации и с това причинява огромни затруднения при изхранване на човека. Човечеството е било изправено пред глад и деградация. Силно намалява общата численост на човешките популации, а някои локални популации измират.

Може би това е един от малките моменти от еволюцията на човека, когато представителите на *Homo sapiens*, откриват нови хоризонти – в случая за изхранване, първо чрез земеделие, а малко по-късно и чрез одомашаване на диви животни и развитие на скотовъдството. С това те променят своето поведение, разширяват своята ниша и полагат началото на една нова цивилизация, която достига до наши дни. Този поврат е бил определящ за оцеляването на човека до наши дни. С него обаче са свързани почти всички трудности, които изпитва днес човечеството и които издигат на преден план принципа за устойчивото развитие.

Кризата, която сега преживява планетата ни и която е свързана главно с въздействието на човека върху естествените екосистеми се подсилва от тенденцията към глобално затопляне. За преодоляване на тази криза има безброй много (в т.ч. и

смислени) идеи, но има и чудновати хрумвания като това на Ноам Мор (by Noam Mohr), изразено в неговата статия

“A New Global Warming Strategy: How Environmentalists are Overlooking Vegetarianism as the Most Effective Tool. Against Climate Change in Our Lifetimes” (August 2005).

Според Ноам Мор (физик от Йелския университет) основна част от парниковите газове (напр. метана) се излъчват от животновъдните ферми. Ако преминем към вегетарианска диета, то този източник на метан ще се редуцира до минимум твърди Мор.

Ще перифразирам един tv-професор, който казва: “чета и не вярвам на ушите си!”. Защото най-мощният източник на метан са заблатените области и особено газовите хидрати, които се намират под морски (океански) води. Освен това основната диета на човека (месо + растителни продукти) е формирана в голямата кухня на природата в процеса на хилядолетна еволюция, а не от рецепти на диетолози.

Тъй като метанът е вторият по въздействие парников газ, то според Ноам Мор изводът е прост: най-добрият начин за намаляване на глобалното затопляне е да се намали или елиминира напълно консумацията на продукти от животински произход. Просто като преминем към вегетарианско хранене ще намалим решително отделяното количество метан и ще спасим Земята от глобално затопляне.

Неолитната революция довежда до отделянето на човека от природата - за разлика от другите живи същества той излиза от естествения кръговрат на веществата в природата и с откриване на земеделието, скотовъдството, използването на различни полезни изкопаеми създава изкуствени геохимични цикли, включвайки въглеродородите, железните оксиди и др. елементи, достигайки до източници на ядрена енергия.

Дже при съвременните си постижения човек остава биологически вид, част от природата, макар че съзнателно или не той действа срещу природата. По характер и поведение човек днес не изглежда да се различава съществено от своя събрат от началото на неолита. Според някои автори даже неговата “психична конституция и агресивност”, оформени през ледниковите епохи, когато той се е борил със саблезъбите тигри, изправял се срещу агресивните себеподобни, и е ловувал мамути, не се е променила съществено (Мойсеев, 1996). А всичко това – характер, поведение, психична конституция и отношение към

себеподобните сега е сред главните трудности в преустройството на общественото съзнание в епохата на глобалните проблеми.

Неолитната революция довежда до отделянето на човека от природата, за разлика от другите живи същества той излиза от естествения кръговрат на веществата в природата и с откриване на земеделието, скотовъдството, използването на различни полезни изкопаеми създава изкуствени геохимични цикли. По този начин човек сам създава нови цикли в кръговрата на веществата, включвайки въглеводородите, железните оксиди и др. елементи и съединения, достигайки до източници на ядрена енергия.

Господството на човека над околната среда в последните столетия нараства неимоверно. Редица философи одобряват това. Напр. според Френсис Бейкън нашите знания и нашето могъщество трябва да служат за покорение на Природата. Стремещът към покоряване на природата се превръща в доктрина на много цивилизации и в крайна сметка ни довеждат до един преломен момент – границата между хилядолетията очертава опасността от тази доктрина за господство над околния свят. Но постепенно като чели мнозина осъзнават, че това ще доведе до гибелни последици както за самия човек, така и за живата природа на Земята.

В началото на 21 в. действително започваме да разбираме, че много неща около нас имат предели – самата Земя е с определени гранични възможности на много от своите системи, като географско пространство и основни ресурси. Повечето от ресурсите на Земята са не само с пределни запаси, но и са невъзобновяеми. Сляпата представа за неизчерпаемостта на полезните изкопаеми ще ни доведе до катастрофа. Днес сме свидетели на неимоверно покачване на цените на нефта. Изходът не е в увеличаването на неговия добив, а в намаляване на неговата консумация. Да не говорим за безумната идея за производство на биогорива, които да заместят нефта. Колко време трябва да се казва, че биогоривата са новата заплаха за екологията.

Все повече се очертава необходимостта от преустройство на съвременната глобална картина към устойчиво развитие на основата на **нови цивилизационни начала и нова философия**. Това изисква развитие на нова ценностна система, която да постави човека в съответствие с новите условия на околната среда, в унисон с природните закони, с отпадането на представата, че Той е наместник на Бога. Това изисква и ново възпитание на всички – от децата до политиците. С това ще се

сложи нов етап в антропогенезата, подобно на предшестващия етап в началото на неолита (Мойсеев, 1996).

Всичко това не може да стане по насилствен път, тъй като на Земята има огромни количества ядрено оръжие, с което може напълно да се изстреби човечеството и да се нанесат тежки последици на нашата планета, които ще я върнат в състоянието ѝ от преди 3-4 милиарда години. Нова глобална криза, по подобие на раннохолоценовата (раннонеолитната) ще доведе до унищожение на цялото човечество. “Единственото, което може да ни спаси, е старата мечта на човечеството: световен мир и световна организация” (Борн, 1981, с. 111).

Дали е постижим този идеал. Трудно е да се каже, но ако това не може да се постигне, то тогава лекото падане (или падение?) на човека ще се превърне в сгромолясване в небитието.

В дългата история на живота върху Земята има множество примери на борба за съществуване, която често се е ожесточавала до борба за оживяване. Когато даден вид се бори за своето оцеляване, то той губи способността да се усъвършенства; търси пътища за оцеляване чрез специализации, които обикновено са неперспективна стратегия.

Блестящ пример за това са динозаврите – една империя в животинския свят, която господства на Земята около 165 млн. години. Динозаврите са били истински властелини на планетата, така както сега *Homo sapiens* е “господар на всички живи твари”.

В последния етап от своето съществуване динозаврите водят невероятна борба за оцеляване, но остават тромави и неповратливи гиганти, покрити с брони, шипове и всякакви костни израстъци, с малък мозък, остаряла физиология и непроменено поведение. Ако използваме изрази от характеристиката на някой човек, то можем да кажем, че поведението на динозаврите в края на тяхното съществуване се характеризира с безотговорност, арогантност и глупост.

### **Така ли ще завърши и *Homo sapiens*?**

На всички е известна идеята за **ноосферата – сферата, в която господства разума**. Това засега обаче остава само сферата на мечтите на светли умове. Първият учен, който употребява термина носфера е френския математик и философ Едуард Ле-Руа през 1927 г. Той отбелязва, че е дошъл до тази идея съвместно със своя приятел – големият френски палеонтолог и философ Пиер Тейяр де Шарден под влияние на лекциите по геохимия, които В. И. Вернадски е чел в Сорбоната през учебната 1922/23 г. По-нататък най-значителен принос за развитието на

тази идея имат Вернадски и Тейяр де Шарден и техните последователи.

Към края на 20 в. терминът “ноосфера” все по-често се измества от термина “коеволюция на човека и биосферата”. По своя основен смисъл двата термина изглеждат синоними. Руският учен Н.Н. Мойсеев (1996) предложи понятието «эпоха ноосферы» да се отъждестви с етапа, по време на който обществото и природата бъдат способни да осигурят съвместна еволюция (коеволюция). Това всъщност трябва да бъде цел на съвременната цивилизация в най-широк смисъл на тази дума.

За реализация на коеволюцията на природата и обществото са необходими усилия на всички: политици и учени от всички направления на човешкото знание. Трябва да се освободим от много излишни и неясни концепции, като анвайроментализма и да вникнем в същностните проблеми на екологията. Ще си позволя да перифразирам една мисъл на Джон Гришам от неговата книга “Версия Пеликан”: просто ми става лошо, като си помисля, че няколко неандерталци ще разработват нова екологическа политика.

Човечеството трябва да положи усилия за да се включи в естествените биохимични цикли на биосферата, а не да създава сътресения сред живия свят. Защото, когато в съвременния свят се говори за дива природа, това изглежда най-точно съответства на природата на човека по отношение на собствената люлка – планетата Земя.

По природа съм оптимист, а като специалист, познаващ строежа, динамиката и историята на Земята не съм привърженик на катастрофалния тип мислене. Не допускам, че човечеството ще се унищожи чрез ядрени оръжия, макар че те са една реална заплаха. Голямата глобална заплаха за човечеството е нарушаването на равновесието в природата, глобалното затопляне, унищожаване на естествените екосистеми и замърсяването на въздуха, които могат да доведат до реална и гибелна глобална катастрофа, съизмерима с масовата гибел на динозаврите и много други групи животни в края на мезозойската ера. Споменавам изчезването на динозаврите вече няколко пъти, защото тяхната история е сред най-ярките примери за масово измиране в геоложката история.

И кой стих на поета Л. Левчев (“Звездопът”) да вземем:

“Позволете ми да бъда тъжен.

Къде са небесата, пълни с птици?

Къде са гласовете на щурците?

Къде е скъпоценната трева?”

**Или:**

“Аз съм безнадеждно заразен  
От легендата за утрешния ден?”

Съвременната Земя прилича на претоварен Ноев ковчег. Тя може да се оприличи и на космически кораб, който е на старт. Ще излети ли корабът към други светове или ще се разбие на старта? Това зависи от разума на човека.

Всички трябва да осъзнаем, че бъдещето на Земята, върху която е възникнал живота и върху която живеем, трябва дълбоко да ни вълнува, да е близка до нашето сърце и до нашия разум, защото нейната съдба е и наша съдба.

Безпорно знанията за нашата динамична планета, за света около нас и неговата дълга, удивителна и превратна история, както и мъдростта при прилагането на тези знания, могат да осигурят добра основа, стъпили върху която можем **ДА ГЛЕДАМЕ НА МИНАЛОТО КАТО ПОУЧИТЕЛЕН СПОМЕН И ДА СЕ ВГЛЕЖДАМЕ В БЪДЕЩЕТО С НАДЕЖДА.**



# Structural Properties of Functions

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**Abstract.** We will discuss some structural properties of functions of six variables, with respect to their separable pairs of arguments.

**Definition 1** We call graph of the function  $f(x_1, \dots, x_n)$ ,  $n \geq 2$ , the graph with **vertices** the **essential** variables of  $f(x_1, \dots, x_n)$  and with edges the separable pairs of  $f(x_1, \dots, x_n)$ .

The graph of the function  $f(x_1, \dots, x_n)$  will be denoted by  $H(f(x_1, \dots, x_n))$ .

With  $F(n)$  we denote the set of all function, which depend essentially exactly on  $n$  variables.

With  $Sep(f)$  we denote the set of all separable pairs of  $f$ .

With  $P_k$  we denote the set of all function from the  $k$ -valued logic.

**Theorem 1** If the function  $f(x_1, \dots, x_n) \in F(n)$ ,  $n \geq 2$ , then the graph  $H(f(x_1, \dots, x_n))$  is connected and the distance between any two of its vertices is not greater than 2.

With  $D(f, x_i)$  we denote the set of all variables  $x_j$ ,  $j \neq i$ , for which  $(x_i, x_j) \in Sep(f)$ .

By the term "order" of the variable  $x_i$  for the function  $f$ , we will understand the number  $|D(f, x_i)|$ .

**Theorem 2** There does not exist any function  $f$ , with a graph of the type shown on fig. 1.

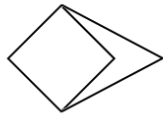


Fig. 1

**Theorem 3** If the function  $f \in F(6)$  possesses a variable of order one, then its graph has the shape of one of the figures 2, ..., 12.

**Theorem 4** If the function  $f \in F(6)$  has not a variable of order one, but it has a variable of order two, then its graph has the shape of one of the figures 13, ..., 27.

**Theorem 5** If the function  $f \in F(6)$  has not variables of order one and two, but it has a variable of order three, then its graph has the shape of one of the figures 28, ..., 38.

**Theorem 6** If the function  $f \in F(6)$  has not variables of order one, two and three, then its graph has the shape of one of the figures 39, ..., 42.

**Theorem 7** For each  $m \in \{2, 3, \dots, 42\}$ , there exists a function with a graph of the shape shown on fig.  $m$ .

We shall note that there does not exist any function of  $P_2$ , with a graph of the shape shown on fig. 2, ..., 42.



Fig. 2

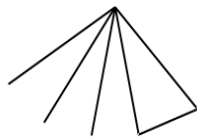


Fig. 3

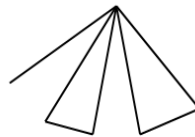


Fig. 4

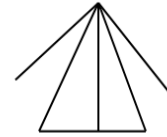


Fig. 5

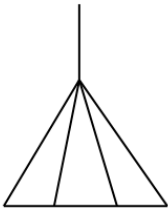


Fig. 6

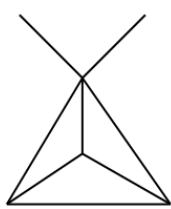


Fig. 7

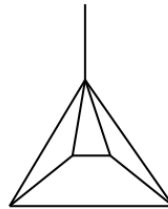


Fig. 8

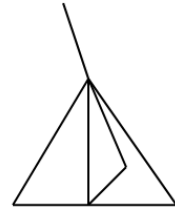


Fig. 9

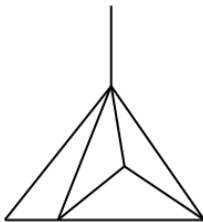


Fig. 10

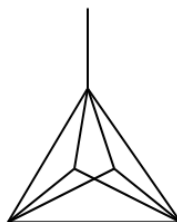


Fig. 11

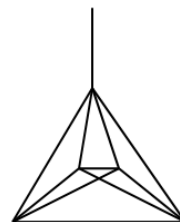


Fig. 12

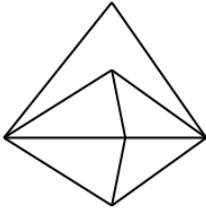


Fig. 13

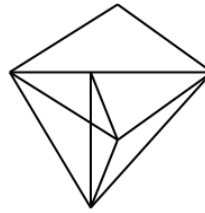


Fig. 14

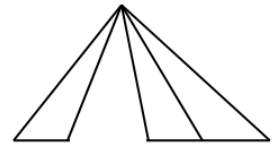


Fig. 15

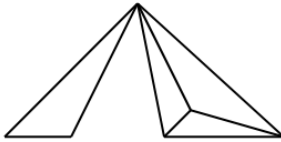


Fig. 16

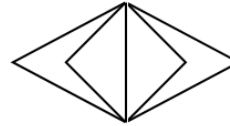


Fig. 17

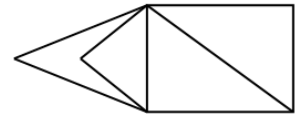


Fig. 18

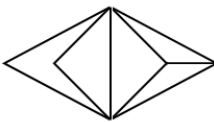


Fig. 19

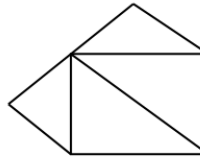


Fig. 20

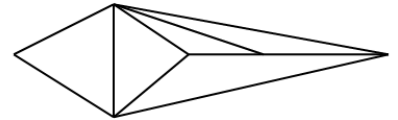


Fig. 21

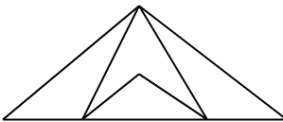


Fig. 22

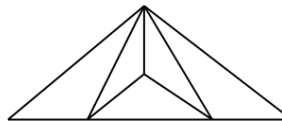


Fig. 23

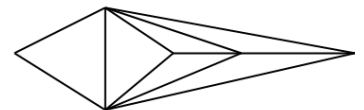


Fig. 24



Fig. 25

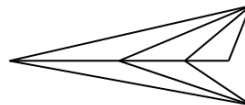


Fig. 26

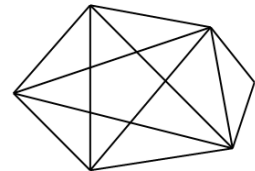


Fig. 27

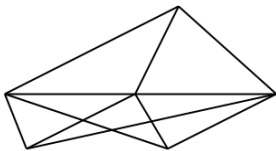


Fig. 28

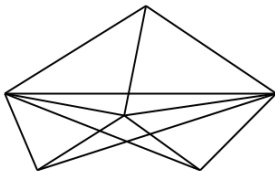


Fig. 29

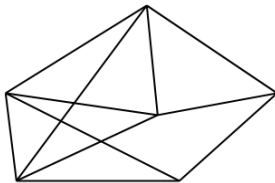


Fig. 30

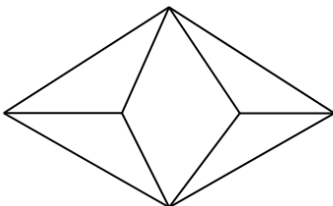


Fig. 31



Fig. 32

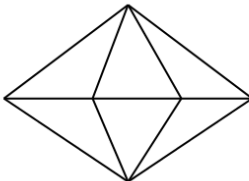


Fig. 33

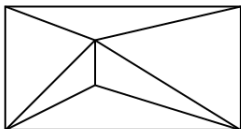


Fig. 34

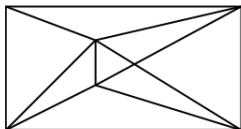


Fig. 35

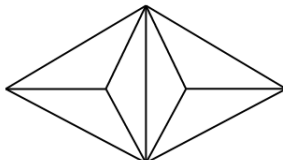


Fig. 36

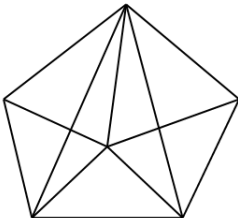


Fig. 37

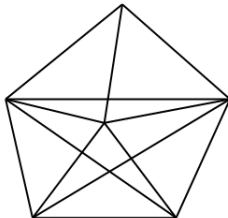


Fig. 38

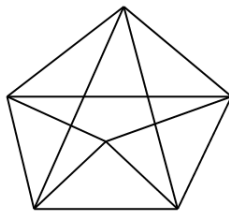


Fig. 39

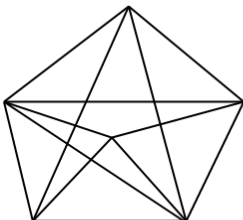


Fig. 40

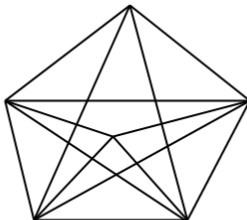


Fig. 41

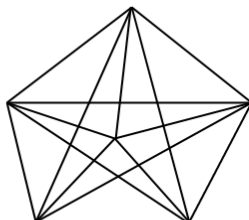


Fig. 42

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# On the number of functions in a class of $k$ -valued logic

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Given an  $n$ -ary  $k$ -valued function  $f$ ,  $\text{gap}(f)$  denotes the essential arity gap of  $f$ . We obtain an explicit determination of  $n$ -ary  $k$ -valued functions  $f$  with  $2 < \text{gap}(f) \leq n \leq k$ . Our methods yield new combinatorial results about the number of  $k$ -valued functions with given gap.

**Key words:** essential variable, identification minor, essential arity gap.

**AMS Subject Classification 2001:** Primary: 03G25; Secondary: 05E05.

## Introduction

Given a function  $f$ , the essential variables in  $f$  are defined as variables which occur in  $f$  and weigh with the values of that function. The number of essential variables is an important measure of complexity for discrete functions.

We shall obtain a few results concerning simplifying of functions by identification of variables.

The essential arity gap ( $\text{gap}$ ) of Boolean functions are deeply investigated in [1, 2, 3].

In [4] R. Willard proved that if  $n > k$  then  $\text{gap}(f) \leq 2$ .

## 1 Preliminaries

Let  $k$  be a natural number with  $k > 2$  and let  $K = \{0, 1, \dots, k-1\}$  be the set (ring) of remainders modulo  $k$ . An  $n$ -ary  $k$ -valued function (operation) on  $K$  is a mapping  $f: K^n \rightarrow K$  for a natural number  $n$ , called the arity of  $f$ . The set of the all such functions is denoted by  $P_K^n$ .

**Definition 1.1** Let  $X_n = \{x_1, \dots, x_n\}$  be the set of  $n$  variables. A variable  $x_i$  is called essential in  $f$ , or  $f$  essentially depends on  $x_i$ , if there exist values  $a_1, \dots, a_n, b \in K$ , such that

$$f(a_1, \dots, a_{i-1}, a_i, a_{i+1}, \dots, a_n) \neq f(a_1, \dots, a_{i-1}, b, a_{i+1}, \dots, a_n).$$

The set of all essential variables in a function  $f$  is denoted by  $Ess(f)$  and the number of its essential variables is denoted by  $ess(f) = |Ess(f)|$ .

Let  $x_i$  and  $x_j$  be two distinct essential variables in  $f$ . We say that the function  $g$  is obtained from  $f \in P_K^n$  by the identification of the variable  $x_i$  with  $x_j$ , if

$$g = f(x_1, \dots, x_{i-1}, x_j, x_{i+1}, \dots, x_n) = f(x_i = x_j).$$

Briefly, when  $g$  is obtained from  $f$ , by identification of the variable  $x_i$  with  $x_j$ , we will write  $g = f_{i \sim j}$  and  $g$  is called the identification minor of  $f$  and  $MIn(f)$  denotes the set of all identification minors of  $f$ .

We shall allow formation of identification minors when  $x_i$  or  $x_j$  are not essential in  $f$ , also. Such minors of  $f$  are called *trivial* and they do not belong to  $MIn(f)$ . So, if  $x_i$  does not occur in  $f$ , then we define  $f_{i \sim j} = f$ .

Clearly,  $ess(f_{i \sim j}) \leq ess(f)$ , because  $x_i \notin Ess(f_{i \sim j})$ , even though it might be essential in  $f$ .

**Definition 1.2** Let  $f \in P_K^n$  be an  $n$ -ary  $k$ -valued function. Then the essential arity gap (shortly arity gap or gap) of  $f$  is defined by

$$gap(f) := ess(f) - \max_{g \in MIn(f)} ess(g).$$

We let  $G_{p,k}^m$  denote the set of all functions in  $P_K^n$  which essentially depend on  $m$  variables whose arity gap is  $p$  i.e.  $G_{p,k}^m = \{f \in P_K^n \mid ess(f) = m \text{ \& } gap(f) = p\}$ , with  $m \leq n$ .

So, we shall consider the case  $2 \leq k$  and  $n \leq k$ , solving a problem of M. Couceiro and E. Lehtonen, namely:

For each  $1 \leq m \leq |A|$ , determine explicitly the functions  $f: A^n \rightarrow B$  whose arity gap is  $m$  ([1], page 6, Problem 1).

We shall assume that  $A = B = K$ . The most of the results obtained in this case might be easily generalized about finite defined and finite valued functions.

Let  $m \in N$ ,  $0 \leq m \leq k^n - 1$  be an integer. It is well known that for every  $k, n \in N$ ,  $k \geq 2$  there is an unique finite sequence  $(\alpha_1, \dots, \alpha_n) \in K^n$  such that

$$m = \alpha_1 k^{n-1} + \alpha_2 k^{n-2} + \dots + \alpha_n.$$

The last equation is known as the representation of  $m$  in  $k$ -ary positional numerical system. One briefly writes  $m = \overline{\alpha_1 \alpha_2 \dots \alpha_n}$ .

Given a variable  $x$  and  $\alpha \in K$ ,  $x^\alpha$  is an important function defined by:

$$x^\alpha = \begin{cases} 1 & \text{if } x = \alpha \\ 0 & \text{if } x \neq \alpha. \end{cases}$$

In this paper we shall use *sums of conjunctions* (SC) for representation of functions in  $P_k^n$ . This is the most natural representation of the functions in finite algebras. It is based on so called operation tables of the functions.

Each function  $f \in P_k^n$  can be uniquely represented in SC-form as follows

$$f = a_0 \cdot x_1^{\alpha_1} \dots x_n^{\alpha_n} \oplus \dots \oplus a_m \cdot x_1^{\alpha_1} \dots x_n^{\alpha_n} \oplus \dots \oplus a_{k^n-1} \cdot x_1^{k-1} \dots x_n^{k-1}$$
 with  $m = \overline{a_1 a_2 \dots a_n}$ , and  $a_p, a_m \in K$ , where " $\oplus$ " and " $\cdot$ " are the operations addition and multiplication modulo  $k$  in the ring  $K$ .

## 2 Essential Arity Gap of Functions

First, we study the  $n$ -ary  $k$ -valued functions whose arity gap is  $n$ .

Given two natural numbers  $k, n \geq 2$ ,  $Eq_k^n$  denotes the set of all strings over  $K = \{0, 1, \dots, k-1\}$  with length  $n$  which have at least two equal letters i.e.

$$Eq_k^n := \{\alpha_1 \dots \alpha_n \in K^n \mid \alpha_i = \alpha_j \text{ for some } i, j \leq n, i \neq j\}.$$

**Theorem 2.1** Let  $f \in P_k^n$ , be a function which depends essentially on all of its  $n$  variables and  $2 \leq n \leq k$ . Then  $f \in G_{n,k}^n$  if and only if it can be represented as follows

$$f = [ \bigoplus_{\beta_1 \dots \beta_n \in Eq_k^n} a_r \cdot x_1^{\beta_1} \dots x_n^{\beta_n} ] \oplus a_0 \cdot [ \bigoplus_{\alpha_1 \dots \alpha_n \in Eq_k^n} x_1^{\alpha_1} \dots x_n^{\alpha_n} ], \quad (1)$$

where  $r = \overline{\beta_1 \dots \beta_n}$  and at least two among the coefficients  $\{a_0\} \cup \{a_r \mid r = \overline{\beta_1 \dots \beta_n}, \& \beta_1 \dots \beta_n \in Eq_k^n\}$ , are distinct.

**Corollary 2.1** If  $f \in G_{n,k}^n$  and  $2 \leq n \leq k$ , then  $f(\alpha_1, \dots, \alpha_n) = f(0, \dots, 0)$  for all  $\alpha_1 \dots \alpha_n \in Eq_k^n$ .

**Theorem 2.2** If  $2 \leq n \leq k$  then

$$|G_{n,k}^n| = k^{\binom{k}{n} \cdot (n+1)} - k.$$

**Lemma 2.1** Let  $f \in P_k^n$  be a  $k$ -valued function. If  $x_i \in \text{Ess}(f_{u-v})$ ,  $i, n, v \leq n$  and  $i \notin \{u, v\}$  then  $f_{u-v} = g_{u-v}$ , where  $g = f_{i-j}$  for any arbitrary  $j, j \in \{1 \dots n\}, j \neq i$ .

**Lemma 2.2** Let  $f \in P_k^n$  be a  $k$ -valued function. If  $x_v \in \text{Ess}(f_{u-v})$  for some  $u, v \leq n$ , then  $f_{u-v} = g_{u-j}$ , where  $g = f_{v-j}$  for any arbitrary  $j$ ,  $j \in \{1 \dots n\}$ ,  $j \neq v$ .

**Lemma 2.3** Let  $f \in P_k^n$  be a function depending essentially on all of its  $n$  variables and  $1 \leq j < l \leq n$ . If for each pair  $(\alpha_i, \alpha_j) \in K^2$  with  $\alpha_i \neq \alpha_j$  there exists  $\gamma \in K$  such that  $f(x_1, \dots, x_{j-1}, \alpha_j, x_{j+1}, \dots, x_{l-1}, \alpha_l, x_{l+1}, \dots, x_n) = \gamma$  then  $X_n \setminus \{x_l, x_j\} \subseteq \text{Ess}(f_{l-j})$ .

**Theorem 2.3** Let  $f$  be a  $k$ -valued function which depends essentially on the all of its  $n$  variables and  $2 < p < n \leq k$ . Then  $f \in G_{p,k}^n$  if and only if there exist  $n - p$  variables  $y_{i_1}, \dots, y_{i_{n-p}} \in X_n$  such that

$$f(x_1, \dots, x_n) = h(y_{i_1}, \dots, y_{i_{n-p}}) \oplus g(x_1, \dots, x_{n-p}, x_{n-p+1}, \dots, x_n), \quad (2)$$

where  $h$  depends essentially on all of its  $n - p$  variables and  $g \in G_{n,k}^n$ .

**Theorem 2.4** If  $2 < p < n \leq k$ , then

$$|G_{p,k}^n| = [k^{\binom{n}{n-p+1}} - k] \cdot \sum_{j=p}^n (-1)^{j-p} j_p n_j \cdot k^{i^{n-j}}.$$

The functions depending essentially on three variables which have essential arity gap 2 are special in sense that almost all of the results proved for  $p > 2$  or  $n > 3$  are not satisfied here. In [4] it is shown that all functions with non-trivial (distinct from 1) arity gap belong to the class of functions  $G_{2,k}^n$  when  $n > k$ . This class is deeply investigated and it is proved that it consists of totally symmetric functions.

The class  $G_{2,k}^n$  when  $n \leq k$  is quite interesting, also. We shall pay attention to this case, starting with description of the class  $G_{2,3}^3$ .

### Example 2.1

To describe the functions from  $G_{2,3}^3$  we need the following auxiliary functions.

$$s(x_1, x_2) := \bigoplus_{\beta=\alpha}^{\beta} x_1^{\beta} x_2^{\alpha}, \quad u^{(\alpha)}(x_1, x_2) := \bigoplus_{\beta=\alpha}^{\beta} x_1^{\beta} x_2^{\beta}, \quad v^{\alpha}(x_1, x_2) := \bigoplus_{\beta=\alpha}^{\beta} x_1^{\alpha} x_2^{\beta}$$

Now, we might prove that  $f \in G_{2,3}^3$ , if and only if  $f$  can be represented in one of the following special forms:

$$f = \bigoplus_{i=0}^2 \alpha_0^{(i)} [x_2^i \cdot s(x_1, x_2) \oplus x_2^i \cdot u^{(i)}(x_1, x_2) \oplus x_1^i \cdot u^{(i)}(x_2, x_3)] \oplus p_3(x_1, x_2, x_3),$$

$$f = \bigoplus_{i=0}^2 \alpha_0^{(i)} [x_1^i \cdot x_2^i \oplus x_1^i \cdot u^{(i)}(x_2, x_3) \oplus x_2^i \cdot u^{(i)}(x_1, x_3)] \oplus p_3(x_1, x_2, x_3),$$

$$f = \bigoplus_{i=0}^2 \alpha_0^{(i)} [x_1^i \cdot x_2^i \oplus x_2^i \cdot v^{(i)}(x_2, x_1) \oplus x_2^i \cdot u^{(i)}(x_1, x_3)] \oplus p_3(x_1, x_2, x_3),$$

$$f = \bigoplus_{i=0}^2 \alpha_0^{(i)} [x_1^i \cdot x_2^i \oplus x_1^i \cdot v^{(i)}(x_2, x_2) \oplus x_2^i \cdot v^{(i)}(x_2, x_1)] \oplus p_3(x_1, x_2, x_3),$$

such that at least two among the coefficients  $\alpha_0^{(0)}, \alpha_0^{(1)}, \alpha_0^{(2)}$  are different and  $p_3$  are arbitrary functions defined by

$$p_3(x_1, x_2, x_3) = \bigoplus_{\alpha_1, \alpha_2, \alpha_3 \in \mathbb{B}_{q_2}^2} u_m \cdot x_1^{\alpha_1} x_2^{\alpha_2} x_3^{\alpha_3}.$$

**Proposition 2.1**  $|G_{2,3}^3| = 192.729 = 139968.$

Without any difficulties, excluding the more complex calculations, we might generalize these results from  $G_{2,3}^3$  to  $G_{2,k}^3$  for arbitrary  $k, k \geq 3$ .

**Proposition 2.2**

$$|G_{2,k}^3| = 8.729 \cdot k_3 \cdot (k^k - k) = 5832 \cdot k_3 \cdot (k^k - k).$$

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# Dual Methods for Solving Variational Inequalities

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**Abstract.** *In this paper, we consider a variational inequality problem (VIP) defined by a maximal monotone operator and a feasible region defined by convex inequality constraints and bounds on the variables. A Lagrangian primal-dual method for solving this problem is presented and its convergence is proved.*

**Key words:** variational inequalities, complementarity problems, dual methods.

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## 1 Introduction

Variational inequalities arise in different mathematical problems, for example, in nonlinear optimization; they are connected with operator theory, especially monotone operators, etc.

Given an operator  $T$ , point to set in general, and a closed convex subset  $X$  of  $R^n$ . The *variational inequality problem*  $VIP(T, X)$  consists in finding a pair  $x^* \in X$  and  $g^* \in T(x^*)$  such that

$$(g^*, x - x^*) \geq 0 \quad \forall x \in X, (1)$$

where  $(\cdot, \cdot)$  denotes the usual inner product of  $R^n$ .

When  $T$  is single-valued,  $VIP(T, X)$  consists in finding  $x \in X$  such that

$$(T(x^*), x - x^*) \geq 0 \quad \forall x \in X, (2)$$

where  $T: R^n \rightarrow R^n$  and  $X$  is a nonempty, closed and convex set in  $R^n$ .

If the constraint set  $X$  is the nonnegative orthant  $R_+^n \equiv \{x \in R^n: x \geq 0\}$  of  $R^n$ , then the VIP reduces to the complementarity problem (CP).

Recall that the *nonlinear complementarity problem* NCP ( $F$ ) is to find a point  $x \in R^n$  such that

$$x \geq 0, \quad F(x) \geq 0, \quad (x, F(x)) = 0,$$

where  $F: R^n \rightarrow R^n$ .

Variational inequalities have been studied in many works.

The monograph of Kinderlehrer and Stampacchia [11] is a complete introduction in this topic.

Equivalence of variational inequality problems to unconstrained optimization problems is studied in [Peng 16].

Unconstrained optimization reformulations of variational inequality problems are proposed in [Yamashita, Taji, and Fukushima 27]. Reformulations of variational inequalities are also considered in [Andreani and Martnez 1].

Newton-type methods for solving variational inequalities are suggested, e.g., in [Marcotte and Dussault 14], [Qi 17], [Qi and Sun 18], [Taji, Fukushima, and Ibaraki 26], etc.

A hybrid projection-proximal point algorithm is proposed in [Solodov and Svaiter 20].

Nesterov and Vial ([15]) introduced a homogeneous analytic center cutting plane method (HACCPM) which solves monotone VIPs in a conic setting and pseudopolynomial-time complexity. ACCPM is considered, for example, in [Sonnevend 22]. An ACCPM for pseudomonotone variational inequalities and a complexity bound was derived in [Goffin, Marcotte, and Zhu 10].

An analytic center quadratic cut method for strongly monotone variational inequality problems is suggested in [Lüthi and Büeler 12].

Conditions ensuring applicability of cutting plane methods for solving variational inequalities are derived in [Crouzeix, Marcotte, and Zhu 5]. Solution of variational inequality problems by using cutting plane methods is considered in [Stefanov 25].

Descent methods for asymmetric variational inequality problems are suggested in [Fukushima 8].

Characterization of strong regularity for variational inequalities over polyhedral sets is considered in [Dontchev and Rockafellar 6].

Complementarity problems are considered, e.g., in [Facchinei and Kanzow 7], [Gabriel and Moré 9], [Mangasarian and Solodov 13], [Solodov and Svaiter 21], etc.

The VIP and the CP can be reformulated as equivalent unconstrained optimization problems by using the  $D$ -gap function (for the VIP) and the implicit Lagrangian (for the CP). The implicit Lagrangian was proposed by Mangasarian and Solodov ([13]) for the CP, and Peng ([16]) extended the implicit Lagrangian approach to the VIP and showed that the implicit Lagrangian can be expressed as the difference of two regularized gap functions proposed by Fukushima ([8]). Yamashita, Taji and Fukushima ([26]) extended the results of Peng and studied properties of the  $D$ -gap

function  $g_{\alpha\beta}(x) \stackrel{\text{def}}{=} f_{\alpha}(x) - f_{\beta}(x)$ , where  $\alpha$  and  $\beta$  are arbitrary parameters with  $\beta > \alpha > 0$  and  $f_{\alpha}$  is the following regularized gap function  $f_{\alpha}(x) \stackrel{\text{def}}{=} \max_{y \in X} (F(x), x - y) - (\alpha/2) \|y - x\|^2 = (F(x), x - y_{\alpha}(x)) - (\alpha/2) \|y_{\alpha}(x) - x\|^2$ ,  $y_{\alpha}(x) \stackrel{\text{def}}{=} \Pi_X(x - (1/\alpha)F(x))$  and  $\Pi_X(\cdot)$  is the projection operator onto the constraint set  $X$ .

The implicit Lagrangian is a particular case of the  $D$ -gap function with  $\beta = 1/\alpha$ .

Consider the box constrained variational inequality problem: find  $x^* \in X$  such that  $\langle F(x^*), x - x^* \rangle \geq 0 \quad \forall x \in X$ , with  $F: R^n \rightarrow R^n$  a continuously differentiable function and  $X \stackrel{\text{def}}{=} \{x \in R^n: a \leq x \leq b\}$ ,  $a \in \{R \cup \{-\infty\}\}^n$ ,  $b \in \{R \cup \{\infty\}\}^n$ ,  $a < b$ . If  $a = 0, b = \infty$ , then VIP becomes the well-known nonlinear complementarity problem (NCP). This VIP is also called the *mixed complementarity problem*.

As mentioned at the beginning, variational inequality problems are connected with the nonlinear/convex programming (complementary slackness conditions in the Theorem of John, in Karush - Kuhn - Tucker (KKT) theorem), complementarity problems, etc.

For example, the differential version of *KKT theorem* for problem

$$\min f(x)$$

subject to

$$g_i(x) \leq 0, i \in I_1; \quad l_i(x) \leq 0, i \in I_2; \quad l_i(x) = 0, i \in I_3; \quad x_j \geq 0, j \in J_1,$$

where  $I_1 \cup I_2 \cup I_3 = I \equiv \{1, \dots, m\}; J_1 \subseteq J \equiv \{1, \dots, n\}$  can be formulated as follows.

Let  $f$  and  $g_i$  be differentiable convex functions,  $l_i$  be affine functions and Slater's constraint qualification be satisfied. A necessary and sufficient condition for  $x^*$  to be an optimal solution to the convex program is that there exists  $\lambda^* \in A = \{\lambda = (\lambda_1, \dots, \lambda_m): \lambda_i \geq 0, i \in I_1 \cup I_2\}$  such that

$\partial L / \partial x_j(x^*, \lambda^*) \geq 0, j \in J_1$	$\partial L / \partial \lambda_i(x^*, \lambda^*) \leq 0, i \in I_1 \cup I_2$
$\partial L / \partial x_j(x^*, \lambda^*) = 0, j \in J \setminus J_1$	$\partial L / \partial \lambda_i(x^*, \lambda^*) = 0, i \in I_3$
$\lambda_i^* \cdot \partial L / \partial x_j(x^*, \lambda^*) = 0, j \in J_1$	$\lambda_i^* \cdot \partial L / \partial \lambda_i(x^*, \lambda^*) = 0, i \in I_1 \cup I_2$
$x_j^* \geq 0, j \in J_1$	$\lambda_i^* \geq 0, i \in I_1 \cup I_2$

where  $L$  is the Lagrangian associated with the convex program.

Third type conditions in the above system are the complementary slackness conditions.

Convex separable minimization problems subject to bounded variables are studied, for example, in [23], [24], etc. As mentioned above, complementary slackness conditions for these problems, which are among the KKT optimality conditions, are connected with complementarity problems and variational inequalities.

In this section we also give some notation used in the paper.

### Notation.

0	zero or zero vector of appropriate dimension
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$\ x\ $	the Euclidean norm of $x \in \mathbb{R}^n$
$y^T x = \langle x, y \rangle$	the inner (scalar) product of $x, y \in \mathbb{R}^n$
$\overline{\mathbb{R}} = \mathbb{R} \cup \{\pm\infty\}$	the extended real numbers
$\mathbb{R}_+^n$	the nonnegative orthant $\{x \in \mathbb{R}^n : x \geq 0\}$ of $\mathbb{R}^n$
$\mathbb{R}_{++}^n$	the positive orthant $\{x \in \mathbb{R}^n : x > 0\}$ of $\mathbb{R}^n$
$I$	the unit matrix of appropriate dimension, the identity mapping
$\nabla F(x) = (\partial F / \partial x_1, \dots, \partial F / \partial x_n)^T$	the gradient of $F: \mathbb{R}^n \rightarrow \mathbb{R}$ at $x \in \mathbb{R}^n$
$F'(x)$	the Jacobian of $F: \mathbb{R}^m \rightarrow \mathbb{R}^n$ at $x \in \mathbb{R}^m$
$\nabla F(x) = (F'(x))^T$	the transposed Jacobian of $F: \mathbb{R}^m \rightarrow \mathbb{R}^n$ at $x \in \mathbb{R}^m$

where  $F(x) = (F_1(x), \dots, F_m(x))$  and  $\nabla F(x) = \begin{pmatrix} \nabla F_1(x)^T \\ \vdots \\ \nabla F_m(x)^T \end{pmatrix}_{m \times n}$ .

## 2 Preliminaries on Monotone Operators and Normal Cones

Recall that a *point to set valued map* (or *multifunction*)  $A: \mathbb{R}^n \rightrightarrows \mathbb{R}^n$  is an operator which associates with each point  $x \in \mathbb{R}^n$  a set (possibly empty)  $A(x) \subseteq \mathbb{R}^n$ . The inverse operator is denoted by  $A^{-1}(y) = \{x \in \mathbb{R}^n : y \in A(x)\}$  and we have  $(A^{-1})^{-1} = A$ . The domain and range of  $A$  are defined by

$$\begin{aligned} \text{dom } A &= \{x : A(x) \neq \emptyset\}, \\ \text{rg } A &= \text{dom } A^{-1} = \{y : \exists x, y \in A(x)\}. \end{aligned}$$

When  $A$  is a single-valued map (that is, a function) we can write  $A(x) = \{y\}$  or  $A(x) = y$ .

**Definition 1** The multivalued mapping  $F: X \rightrightarrows \mathbb{R}^n$ , where  $X$  is a nonempty convex subset of  $\mathbb{R}^n$ , is said to be:

- *monotone on  $X$*  if for all  $x_1, x_2 \in X$   
 $\langle v_1 - v_2, x_1 - x_2 \rangle \geq 0$  whenever  $v_1 \in F(x_1), v_2 \in F(x_2)$ ;
- *strictly monotone on  $X$*  if for all  $x_1, x_2 \in X, x_1 \neq x_2$   
 $\langle v_1 - v_2, x_1 - x_2 \rangle > 0$  whenever  $v_1 \in F(x_1), v_2 \in F(x_2)$ ;
- *strongly monotone with modulus  $m > 0$  on  $X$*  if for all  $x_1, x_2 \in X$   
 $\langle v_1 - v_2, x_1 - x_2 \rangle \geq m \|x_1 - x_2\|^2$  whenever  $v_1 \in F(x_1), v_2 \in F(x_2)$ .

When  $F$  is single-valued, the monotonicity property takes the form

$$\langle F(x_1) - F(x_2), x_1 - x_2 \rangle \geq 0 \quad \forall x_1, x_2 \in X;$$

the strict and strong monotonicity cases are modified similarly.

Recall that a matrix  $A$  is called

- *positive semidefinite* if  $\langle y, Ay \rangle \geq 0$  for all  $y \in \mathbb{R}^n$ ;
- *positive definite* if  $\langle y, Ay \rangle > 0$  for all  $y \in \mathbb{R}^n, y \neq 0$ ; and
- *uniformly positive definite with constant  $m$*  if

$$(x - y, A(x - y)) \geq m \|x - y\|^2 \quad \forall x, y \in \mathbb{R}^n.$$

When the mapping  $F$  is differentiable,  $F$  is

- *monotone on  $X$*  if and only if  $\nabla F(x)$  is positive semidefinite for all  $x \in X$ ;
- *strictly monotone on  $X$*  if  $\nabla F(x)$  is positive definite for all  $x \in X$ ;
- *strongly monotone with modulus  $m$  on  $X$*  if and only if  $\nabla F(x)$  is uniformly positive definite with constant  $m$ .

When the mapping  $F$  is affine such that  $F(x) = Ax + b$  with  $A$  being an  $n \times n$  matrix and  $b$  being an  $n$ -vector, there is no difference between the strict monotonicity and the strong monotonicity of  $F$ . More specifically, matrix  $A$  is positive definite if and only if  $F$  is strongly monotone as well as strictly monotone. Moreover,  $A$  is positive semidefinite if and only if  $F$  is monotone. In particular, the identity mapping  $I$  is strictly monotone.

**Definition 2** A monotone mapping  $F$  is said to be *maximal* if its graph is not properly contained in the graph of any other monotone mapping, that is, if

$$(y - y', x - x') \geq 0 \quad \forall x' \in \text{dom} F, \forall y' \in F(x') \text{ implies } y \in F(x).$$

The following properties of maximal monotone operators hold (for details see, e.g., [Rockafellar and Wets 19, Chapter 12]).

**Proposition 1** i)  $A^{-1}$  is maximal monotone if and only if  $A$  is maximal monotone.

ii) Let  $A_1, A_2$  be maximal monotone. Then  $A_1 + A_2$  is also maximal monotone if either one of the following conditions is satisfied:

- a)  $\text{int dom } A_1 \cap \text{dom } A_2 \neq \emptyset$ ,
- b)  $\text{ri}(\text{dom } A_1) \cap \text{ri}(\text{dom } A_2) \neq \emptyset$ , where  $\text{ri } A$  denotes the relative interior of  $A$ .

For a nonempty closed convex set  $X \in \mathbb{R}^n$  denote by  $X_\infty$  the recession cone of  $X$ . For a closed and proper convex function  $f: \mathbb{R}^n \rightarrow \mathbb{R} \cup \{+\infty\}$ , the *recession function*  $f_\infty$  of  $f$  is defined by  $\text{epi } (f_\infty) = (\text{epi } f)_\infty$ , where  $\text{epi } f = \{(x, r) \in \mathbb{R}^n \times \mathbb{R} : f(x) \leq r\}$  is the epigraph of  $f$ .

Recall that a vector  $\hat{f}(x_0)$  is said to be a *subgradient* of (a convex function)  $f$  at  $x_0$  if the inequality

$$f(x) - f(x_0) \geq \hat{f}(x_0)(x - x_0)$$

holds for each  $x \in \mathbb{R}^n$ .

The set containing all subgradients of  $f$  at the point  $x_0$  is called the *subdifferential* of  $f$  at  $x_0$  and is denoted by  $\partial f(x_0)$ . If  $\partial f(x_0) \neq \emptyset$ , then  $f$  is said to be *subdifferentiable* at  $x_0$ . The subdifferential of  $f$  is defined as the multivalued mapping  $\partial f: x \mapsto \partial f(x)$ .

**Definition 3** The *normal cone operator* associated with a closed convex set  $X$  is defined by

$$N_X(x) = \begin{cases} \{y: \langle y, v - x \rangle \leq 0 \forall v \in X\}, & \text{if } x \in X \\ \emptyset, & \text{otherwise.} \end{cases}$$

We have  $\text{dom } N_X = X$ , and  $N_X(x) = \{0\}$  when  $X = \mathbb{R}^n$  or  $x \in \text{int } X$ .

$N_X$  is a maximal monotone operator on  $\mathbb{R}^n$ . Moreover,  $N_X = \partial \delta(\cdot | X)$  where  $\delta(\cdot | X)$  is a closed proper convex function (indicator function) defined as follows

$$\delta(x | X) = \begin{cases} 0, & \text{if } x \in X \\ +\infty, & \text{otherwise.} \end{cases}$$

In terms of  $N_X$ , we can rewrite the VIP (1) as the one of finding the zero of the generalized equation

$$0 \in T(x) + N_X(x). \quad (3)$$

Problem (3) can be considered as another equivalent *primal* formulation of the VIP (1). Problem (3) is also called *variational condition* for any set  $X \subset \mathbb{R}^n$  and any mapping  $T: X \rightarrow \mathbb{R}^n$ . When  $X$  is convex, (3) can be written equivalently in the form (1) or (2).

The multivalued mapping  $F: \mathbb{R}^n \rightrightarrows \mathbb{R}^n$  defined by  $F(x) \stackrel{\text{def}}{=} T(x) + N_X(x)$  and  $F(x) = \emptyset$  when  $x \notin X$ , is strictly monotone when  $T$  is strictly monotone relative to  $X$ . Then the solution set has at most one element.

### 3 Lagrangian Duality for Box Constrained VIPs

#### 3.1 Introduction. Main Results

It is known that  $x^*$  is a solution of the VIP (1) if and only if

$$x^* \in \arg \min \{ \langle g^*, x - x^* \rangle : x \in X \}, \quad (4)$$

where  $g^* \in T(x^*)$ . Consider the case where  $T$  is a maximal monotone mapping from  $\mathbb{R}^n$  into itself, the constraint set  $X$  is explicitly defined by  $X = \{x: f_i(x) \leq 0, i = 1, \dots, m, \alpha_j \leq x_j \leq b_j, j = 1, \dots, n\}$  and  $f_i: \mathbb{R}^n \rightarrow \mathbb{R} \cup \{+\infty\}$  are closed proper convex functions. Without loss of generality suppose that at least one  $f_i$  is continuous. Denote  $F(x) = (f_1(x), \dots, f_m(x))^T$ .

Let  $\Phi \stackrel{\text{def}}{=} \bigcap_{i=1}^m \text{dom } f_i$  be an open set.

With the convex optimization problem

$$\min \{ \langle g^*, x - x^* \rangle : f_i(x) \leq 0, i = 1, \dots, m, \alpha_j \leq x_j \leq b_j, j = 1, \dots, n \} \quad (5)$$

we can associate a Lagrangian defined by  $L: \mathbb{R}^n \times \mathbb{R}^{m+2n} \rightarrow \overline{\mathbb{R}}$ ,

$$L(x, \mu; x^*) =$$

$$\begin{cases} (g^*, x - x^*) + \sum_{i=1}^m \lambda_i f_i(x) + \sum_{j=1}^n [u_j(a_j - x_j) + v_j(x_j - b_j)], & \text{if } x \in \Phi \cap C, \mu \in R_+^{m+2n} \\ -\infty, & \text{if } \mu \notin R_+^{m+2n} \\ +\infty, & \text{otherwise,} \end{cases} \quad (6)$$

where  $\mu = (\lambda, u, v) \in R_+^{m+2n}$  is the dual variables vector and  $C = \{x_j \leq x_j \leq b_j, j = 1, \dots, n\}$ .

The dual problem is then

$$\sup_{\mu \geq 0} \inf_{x \in \Phi \cap C} [L(x, \mu; x^*)]. \quad (7)$$

It is known that  $(x^*, \mu^*) \in (\Phi \cap C) \times R_+^{m+2n}$  is a saddle point of  $L$  if and only if  $x^* \in \Phi \cap C$  and  $\mu^* \geq 0$  are optimal solutions to the primal and dual problem, respectively, with no duality gap, that is, with equal optimal values of the primal and dual problems.

**Theorem 1** Let Slater's constraint qualification be satisfied for the constraint set  $X$ .  $x^* \in R^n$  solves (3) if and only if there exists  $\mu^* \in R_+^{m+2n}$  such that  $(x^*, \mu^*)$  solves the problem

$$(0, 0) \in W(x^*, \mu^*), \quad (8)$$

where

$$\begin{aligned} W(x, \mu) &\equiv \{(y, w) \in R^n \times R_+^{m+2n}, \\ y &\in T(x) + \sum_{i=1}^m \lambda_i \partial f_i(x) - u + v, w \in (-F(x) + N_{R_+^m}(\mu), x - a, b - x)\}, \quad (9) \\ \text{if } (x, \mu) &\in \text{dom} W = (\text{dom} T \cap \Phi \cap C) \times R_+^{m+2n} \neq \emptyset, \text{ and } W(x, \mu) = \emptyset, \\ &\text{otherwise.} \end{aligned}$$

**Proof.** We have

$$\begin{aligned} \partial((g^*, x - x^*) + \partial(x|\Phi \cap C))|_{x=x^*} &= \partial((g^*, x - x^*) + \partial(x|\Phi)|_{x=x^*} + \partial(x|C))|_{x=x^*} = \\ &= g^* + N_{\Phi}(x^*) + N_C(x^*), \end{aligned}$$

and since  $\Phi$  is open then  $N_{\Phi}(x^*) = \{0\}$ . Therefore for the primal and dual problem we get

$$0 \in g^* + \sum_{i=1}^m \lambda_i^* \partial f_i(x^*) - u^* + v^* \quad (10)$$

and

$$0 \in (-F(x^*) + N_{R_+^m}(\lambda^*), x^* - a, b - x^*), \quad (11)$$

respectively, where  $g^* \in T(x^*)$ . Since  $(g^*, x - x^*) \geq 0 \forall x \in X$  then the optimal value of problem (5) is 0.

Since Slater's constraint qualification is satisfied, that is, there exists  $x \in X$   $f_i(x) < 0, i = 1, \dots, m$  then there exists a KKT vector  $\mu$ . The relations (10) and (11) are the KKT necessary and sufficient optimality conditions for problem (5).

Thus  $\mu^*$  can be interpreted as the solution of the Lagrangian dual VIP: Find

$$\mu^* \in R_+^{m+2n}, d^* \in G(\mu^*) \times A(x^*) \times B(x^*): (d^*, \mu - \mu^*) \geq 0 \quad \forall \mu \in R_+^{m+2n}, \quad (12)$$

where

$$G(\mu) \equiv \{-F(x) : x \in M(\mu)\}, \quad (13)$$

$$M(\mu) = \{x \in \mathbb{R}^n : 0 \in T(x) + \sum_{i=1}^m \lambda_i \partial f_i(x) - u + v\}, \quad (14)$$

$$A(x) = \{x - a\}, B(x) = \{b - x\}. \quad (15)$$

The dual problem (12) can also be written as

$$0 \in T_D(\mu^*)$$

where

$$T_D(\mu) \equiv \{G(\mu) + N_{\mathbb{R}_+^m}(\lambda)\} \times A(x) \times B(x).$$

Using (10) and (11), we obtain the primal-dual formulation (8) of VIP where  $W(x, \mu)$  is defined through (9).

Thus, (3), (8) and (12) are equivalent primal, primal-dual and dual formulation of VIP (1), respectively.

The following operators

$$T_P := T + N_X \quad (\text{primal})$$

$$T_{PD} := W \quad (\text{primal-dual})$$

$$T_D := G + N_{\mathbb{R}_+^m} \quad (\text{dual})$$

are associated with these three formulations, respectively.

Denote by  $X^* = (T + N_X)^{-1}(0)$ ,  $Z^* = W^{-1}(0, 0)$ ,  $M^*$  the set of solutions to problems (3), (8) and (12), respectively.

From Proposition 1, ii) a) it follows that  $T_D$  is maximal monotone when  $\text{dom } T \cap \text{int } X \neq \emptyset$ .

**Theorem 2** Let  $T: \mathbb{R}^n \rightrightarrows \mathbb{R}^n$  be maximal monotone such that  $\text{dom } T \cap \Phi \cap C \neq \emptyset$ . Then the primal-dual operator  $W$  (9) is also maximal monotone.

**Proof.** Let

$$D(x, \mu) = \begin{cases} T(x) \times \{0\} \times \{0\} \times \{0\}, & \text{if } x \in \text{dom } T \\ \emptyset, & \text{otherwise,} \end{cases}$$

$$E(x, \mu) = \begin{cases} [\sum_{i=1}^m \lambda_i \partial f_i(x)] \times [-F(x) + N_{\mathbb{R}_+^m}(\lambda)] \times (x - a) \times (b - x), & \text{if } x \in \Phi \cap C, \lambda \in \mathbb{R}_+^m \\ \emptyset, & \text{otherwise.} \end{cases}$$

Then the operator  $W$  can be decomposed as  $W = D \dot{+} E$ . Since  $T$  is maximal monotone,  $D$  is also maximal monotone. If we define

$h: (\Phi \cap C) \times \mathbb{R}_+^m \rightarrow \mathbb{R}$  by  $h(x, \lambda) = \sum_{i=1}^m \lambda_i f_i(x)$ , then

$E(x, \mu) = \partial_x h(x, \lambda) \times (-\partial_\lambda h(x, \lambda)) \times (x - a) \times (b - x)$ , where  $\partial$  is the upper subdifferential. (Recall that the upper subdifferential  $\partial f(x)$  is defined by  $\partial f(\bar{x}) = \{\zeta \in \mathbb{R}^n : f(x) - f(\bar{x}) \leq \langle \zeta, x - \bar{x} \rangle \forall x \in \mathbb{R}^n\}$ .)

Therefore  $E$  is maximal monotone, whence applying Proposition 1, ii) a) to operators  $D$  and  $E$  yields  $W$  is maximal monotone.

### 3.2 Auxiliary Consideration

Let function  $\varphi$  be defined as follows

$$\varphi(t) = \begin{cases} (v/2)(t-1)^2 + \rho(t - \log t - 1), & \text{if } t > 0 \\ +\infty, & \text{otherwise,} \end{cases} \quad (16)$$

where  $v > \rho > 0$  are given fixed parameters.

Define for any  $v \in \mathbb{R}_{++}^p$  the function  $d(u, v)$  associated with  $\varphi$

$$d(u, v) = \begin{cases} \sum_{i=1}^p (v/2)(u_i - v_i)^2 + \rho(v_i^2 \log(v_i/u_i) + u_i v_i - v_i^2), & \text{if } v \in \mathbb{R}_{++}^p \\ +\infty, & \text{otherwise.} \end{cases} \quad (17)$$

The following properties of  $\varphi$  hold true, see [Auslender, Teboulle, and Ben-Tiba 3, 4].

**Proposition 2** Let  $\varphi$  be defined by (16). Then

1.  $\varphi$  is a differentiable strongly convex function on  $\mathbb{R}_{++}$  with modulus  $v > 0$ .

2.  $\lim_{t \rightarrow 0} \varphi'(t) = -\infty$ .

3. The conjugate of  $\varphi$  is

$$\varphi^*(s) = (v/2)t^2(s) + \rho \log t(s) - v/2,$$

where

$$t(s) = (1/2v)[v - \rho + s + \sqrt{(v - \rho + s)^2 + 4\rho v}] = (\varphi^*)'(s).$$

4.  $\text{dom } \varphi^* = \mathbb{R}$ ,  $\varphi^* \in C^\infty(\mathbb{R})$ .

5.  $(\varphi^*)''(s) = (\varphi')^{-1}(s)$  is Lipschitz for all  $s \in \mathbb{R}$  with Lipschitz constant  $1/v$ .

6.  $\varphi^*$  is a strictly convex and increasing function on  $\mathbb{R}$ .

7.  $(\varphi^*)'''(s) \leq 1/v$  for all  $s \in \mathbb{R}$ .

8.  $(\varphi^*)_\infty(-1) = 0$  and  $(\varphi^*)_\infty(1) = +\infty$  where  $(\varphi^*)_\infty$  is the recession function of  $\varphi^*$ .

Suppose that following assumptions are satisfied.

**Assumptions.**

1.  $T$  is a maximal monotone operator with  $\Phi = \bigcap_{i=1}^m \text{dom } f_i$  an open subset of  $\text{int dom } T$ .

2. The solution set of VIP (1) is nonempty and compact.

3. Slater's constraint qualification is satisfied for some  $x \in \text{dom } T$ .

For  $\gamma > 0, \mu > 0$  and  $\varphi$  (16) consider the multifunction

$$H(x, \mu, \gamma) = \begin{cases} T(x) + \sum_{i=1}^m \lambda_i (\varphi_i')'(\gamma f_i(x)/\lambda_i) \partial f_i(x) - u + v, & \text{if } x \in \Phi \cap C \\ \emptyset, & \text{otherwise.} \end{cases}$$

**Theorem 3** Let  $\varphi$  be defined by (16) and Assumptions 1 - 3 be satisfied. Then for every  $\gamma > 0$ , for every  $\mu \in \mathbb{R}_{++}^p$ , the operator  $H(\cdot, \mu, \gamma)$  is maximal monotone on  $\mathbb{R}^n$ .

**Proof.** From Proposition 2, 8. it follows that  $(\varphi^*)_\infty(-1) = 0, (\varphi^*)_\infty(1) = +\infty$ . Let  $\gamma > 0$  and  $\mu > 0$  be fixed. From Proposition 2.1 [2] it follows that the function

$$g(x) \stackrel{\text{def}}{=} (1/\gamma) \sum_{i=1}^m \lambda_i \varphi^*(\gamma f_i(x)/\lambda_i)$$
 is closed, proper and convex with  $\text{dom } g = \bigcap_{i=1}^m \text{dom } f_i \neq \emptyset$ . Moreover,
 
$$g_\infty(d) = \begin{cases} 0, & \text{if } (f_i)_\infty(d) \leq 0 \forall i \\ +\infty, & \text{otherwise.} \end{cases}$$

Since  $\Phi = \bigcap_{i=1}^m \text{dom } f_i$  is open, then  $H = T + \partial g - u + v$ . Applying Assumption 1 ( $\Phi \subset \text{int dom } T$ ) and Proposition 1, ii) a) yields  $H$  is maximal monotone.

It can be proved that the solution set  $H^{-1}(0, \mu, \gamma)$  of the generalized equation  $0 \in H(x, \mu, \gamma)$  is nonempty.

### 3.3 The Primal-dual Method (PDM)

The primal-dual method is based on solving VIP (1) by solving the equivalent primal-dual problem (8):

$$0 \in W(x, \mu), \quad (8')$$

where  $W$  is defined by (9), assuming that  $W$  is maximal monotone (for example, under assumptions of Theorem 2) and Slater's constraint qualification holds true for  $x \in \text{dom } T$ .

Consider the following distance-like functional

$$D((x, \mu), (y, w)) \stackrel{\text{def}}{=} (1/2) \|x - y\|^2 + d(\mu, w),$$

where  $d(u, v)$  is defined by (17).

Beginning with an initial guess  $(x^0, \mu^0) \in R^n \times R_+^{m+2n}$ , generate a sequence  $\{(x^k, \mu^k)\} \subset R^n \times R_+^{m+2n}$  satisfying

$$0 \in W(x^k, \mu^k) + (1/\gamma_k) \nabla_{(x, \mu)} D((x^k, \mu^k), (x^{k-1}, \mu^{k-1})), \quad (18)$$

where  $\gamma_k \geq \gamma > 0, \mu^k = (\lambda^k, u^k, v^k)$ .

**Theorem 4** Let  $W$  be the maximal monotone operator defined by (9).

Then

(i) There exists a unique  $(x^k, \mu^k) \in R^n \times R_+^{m+2n}$  satisfying (18) for all  $\gamma_k > 0, \mu^{k-1} > 0$ .

(ii) If the solution set of problem (8) is nonempty, then the sequence  $\{(x^k, \mu^k)\}$  generated by (18) converges to a solution  $(x^*, \mu^*) \in X^* \times M^*$ .

The proof of Theorem 4 is similar to that of a theorem from [3].

The iterative process (18) can be written as follows

$$0 \in T(x^k) + \sum_{i=1}^m \lambda_i^k \partial f_i(x^k) - u^k + v^k + (x^k - x^{k-1})/\gamma_k, \quad (19)$$

$$0 \in F(x^k) + \gamma_k [\lambda_1^k \varphi'(\lambda_1^{k-1}/\lambda_1^k), \dots, \lambda_m^k \varphi'(\lambda_m^{k-1}/\lambda_m^k)] + N_{R_+^m}(\lambda^k). \quad (20)$$

This consideration leads to the so-called *primal-dual method*.

Let  $\varphi$  be defined by (16),  $(x^0, \mu^0) \in R^n \times R_+^{m+2n}$  and  $\gamma_k \geq \gamma > 0 \forall k \geq 1$ .

Generate the sequence  $\{(x^k, \mu^k)\}$  through

$$0 \in H(x^k, \mu^{k-1}, \gamma_k) + (x^k - x^{k-1})/\gamma_k, \quad (21)$$

$$\mu_t^k = \mu_t^{k-1} (\varphi^*)'(\gamma_k f_t(x^k)/\mu_t^{k-1}), \quad t = 1, \dots, m+2n. \quad (22)$$

For fixed  $\mu^{k-1} > 0, \gamma_k > 0$  define the multifunction

$$H_k(x) \stackrel{\text{def}}{=} H(x, \mu^{k-1}, \gamma_k) + (x - x^{k-1})/\gamma_k.$$

Using this notation, (21) can be written as

$$0 \in H_k(x^k). \quad (21')$$

**Theorem 5** Let  $\varphi$  be defined by (16),  $T$  be a maximal monotone mapping and Slater's constraint qualification be satisfied for some  $x \in \text{dom } T$ . Then operator  $H_k$  is maximal monotone and strongly monotone with modulus  $1/\gamma_k$ , that is,

$$\langle y - y', x - x' \rangle \geq (1/\gamma_k) \|x - x'\|^2 \quad \forall y \in H_k(x), y' \in H_k(x').$$

**Proof.** Using definition of  $H$  and that Slater's constraint qualification is satisfied for some  $x \in \text{dom } T$ , we get  $H = T + \partial g - u + v$  and  $H$  is maximal monotone.

Define  $R_k(x) = \left(\frac{1}{2\gamma_k}\right) \|x - x^{k-1}\|^2$ . By definition of  $H_k$ ,  $H_k = H + \nabla R_k$ , and since  $\nabla R_k$  is strongly monotone then  $H_k$  is also strongly monotone.

Since the multifunction  $H_k(x)$  in (21') is maximal monotone and strongly monotone then the existence and uniqueness of the sequence  $\{x^k\}$  in (21) is guaranteed.

**Theorem 6** Let  $T$  be a maximal monotone operator on  $\mathbb{R}^n$ ,  $W$  be also maximal monotone, Slater's constraint qualification hold for  $x \in \text{dom } T$ , and the solution set of (8) be nonempty. Then the primal-dual sequence  $\{(x^k, \mu^k)\}$ , generated by PDM, converges to a primal-dual solution  $(x^*, \mu^*) \in X^* \times M^*$  of (8), that is, to a solution of VIP (1) and dual problem (12), respectively.

**Proof.** Since the sequence  $\{(x^k, \mu^k)\}$ , generated by PDM, is given by (18), then Theorem 4 implies that  $\{(x^k, \mu^k)\}$  converges to a solution of problem (8).

#### 4 Extensions and Concluding Remarks

PDM can be modified to solve the standard nonlinear complementarity problem with

$$T: \mathbb{R}^n \rightarrow \mathbb{R}^n, \text{ single-valued and continuous,}$$

$$T(x) = (T_1(x), \dots, T_n(x))^T, X = \mathbb{R}_+^n$$

as follows

$$T_i(x^k) - \lambda_i^k (\varphi^*)'(-\gamma_k x^k / \lambda_i^{k-1}) - u_i^k + v_i^k + (x_i^k - x_i^{k-1})/\gamma_k = 0, \quad i = 1, \dots, n \quad (23)$$

$$\mu_t^k = \mu_t^{k-1} (\varphi^*)'(-\gamma_k x^k / \mu_t^{k-1}), \quad t = 1, \dots, m+2n. \quad (24)$$

Since (24) is a system of equations, it can be solved via a Newton-type method.

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# On the Cardinality of Some Classes of Discrete Functions

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**Abstract:** *The subject of this paper is discrete functions of  $n$  variables of the  $k$ -valued logic. The number of some special classes of functions is found. Emphasis is on finding the number of functions that depend essentially or the subfunctions of which depend essentially on a given number of variables.*

**Keywords:** *Key words:  $k$ -valued logic, subfunctions, principle of inclusion and exclusion, range, essential or fictitious set of variables.*

## 1. INTRODUCTION

Let  $P_n^k = \{ f : E_k^n \rightarrow E_k \mid E_k = \{0, 1, \dots, k-1\}, k \geq 2 \}$  be the set of all functions of  $n$  variables of the  $k$ -valued logic..

The number  $Rng(f)$  of different values which the function  $f$  assumes when its variables are replaced with constants, is called range of  $f$  [3].

Obviously, for each function  $f$  from  $P_n^k$ , the following holds

$$1 \leq Rng(f) = \left| \bigcup_{\alpha \in E_k^n} \{f(\alpha)\} \right| \leq k.$$

If  $P_n^{k,q}$  is the set of all functions in  $P_n^k$ , whose range is equal to  $q$ ,  $1 \leq q \leq k$ , then regarding the cardinality of  $P_n^{k,q}$ , the following holds [4],

$$(1) \quad |P_n^{k,q}| = C_k^q \cdot \sum_{\substack{r_1+r_2+\dots+r_q=k^n \\ r_i \geq 1, i=1,2,\dots,q}} \frac{k^n!}{r_1!r_2!\dots r_q!} = C_k^q \cdot \sum_{s=0}^q (-1)^{q-s} C_q^s s^{k^n}.$$

We will call the functions of range equal to 1 constants [2].

The set of all variables of the function  $f(x_1, x_2, \dots, x_n)$  will be denoted by  $X_f = \{x_1, x_2, \dots, x_n\}$ .

Every function obtained from  $f$  by replacing the variables from  $N$ ,  $N \subseteq X_f$ ,  $0 \leq |N| \leq n$ , with constants is called a subfunction of  $f(x_1, \dots, x_n)$  with respect to

$N$ . The notation  $g \xrightarrow{N} f$  ( $g \xrightarrow{N} f$ ) means that  $g$  is a subfunction of  $f$  (with respect to  $N$ ) [1].

[5] We say that the function  $f(x_1, x_2, \dots, x_n)$  depends essentially on  $M$ ,  $M \subseteq X_f$ ,  $1 \leq |M| = m \leq n$  or that  $M$  is an essential set of variables for the function  $f$ , if there exists a subfunction of  $f$  with respect to  $\bar{M} = X_f \setminus M$ , which is not a constant.

The variables and sets of variables, which are not essential, are called fictitious.

Let  $R$  be a finite set and let  $P = \{p_1, p_2, \dots, p_n\}$  be a set of properties which the elements from  $R$  can satisfy. Let us denote by  $N(p_{i_1}, p_{i_2}, \dots, p_{i_s})$  the number of elements from  $R$  that have the properties  $p_{i_1}, p_{i_2}, \dots, p_{i_s}$ .

According to the principle of inclusion and exclusion [6], the number  $N(r)$  of the elements in  $R$ , which satisfy exactly  $r$  properties of  $P$ , is given by the formula:

$$(2) \quad N(r) = \sum_{j=r}^n (-1)^{j-r} C_j^r S_j, \quad r = 0, 1, \dots, n,$$

$$\text{where } S_0 = |R|, \quad S_j = \sum_{1 \leq i_1 < \dots < i_j \leq n} N(p_{i_1}, \dots, p_{i_j}), \quad j = 1, \dots, n.$$

## 2. MAIN RESULTS

Let us denote by  $Q_n^k$  the set of the functions from  $P_n^k$ , which satisfy the characteristic property  $Q$ .

**Lemma 2.1.** The number of functions  $f \in P_n^k$ , for which each subfunction  $g$ ,

$g \xrightarrow{\bar{M}} f$ ,  $M \subseteq X_f$ ,  $1 \leq |M| = m \leq n$ ,  $\bar{M} = X_f \setminus M$  satisfies the property  $Q$ , is equal to

$$(3) \quad [|Q_m^k|]^{k^{n-m}}.$$

Proof: Let  $\bar{M} = X_f \setminus M = \{x_{j_1}, x_{j_2}, \dots, x_{j_{n-m}}\}$  and  $(c_1^i, c_2^i, \dots, c_{n-m}^i)$ ,  $i = 1, 2, \dots, k^{n-m}$ , be all the possible sets of constants for the variables of  $\bar{M}$ , for

which we get subfunctions  $g_i = f(x_{j_1} = c_1^i, x_{j_2} = c_2^i, \dots, x_{j_{n-m}} = c_{n-m}^i)$ ,  $g_i \in P_m^k$ ,  $i=1, 2, \dots, k^{n-m}$ , that satisfy a property Q. In the tabular form of the function  $f$ , it is represented by  $k^{n-m}$  parts, where the separate parts are the subfunctions  $g_i$ ,  $g_i \in P_m^k$ ,  $i=1, 2, \dots, k^{n-m}$ . Since each subfunction  $g_i$ ,  $i=1, 2, \dots, k^{n-m}$ , satisfies the property Q and can be picked among  $|Q_m^k|$  in number functions, then the number of the different functions  $f$ , whose subfunctions  $g, g \xrightarrow{\bar{M}} f$  satisfy the property Q is equal to  $[|Q_m^k|]^{k^{n-m}}$ .



The number of functions from  $P_n^k$ , which have a range equal to  $q$ ,  $1 \leq q \leq k$ , (property Q), according to formula (1), is equal to  $|P_n^{k,q}| = |Q_n^k|$ .

**Corollary 2.1.** The number of functions  $f \in P_n^k$ , for which each subfunction

$$g, g \xrightarrow{\bar{M}} f, M \subseteq X_f, 1 \leq |M|=m \leq n, \bar{M} = X_f \setminus M, \text{ has a range equal to } q, 1 \leq q \leq k, \text{ is}$$

$$[|P_m^{k,q}|]^{k^{n-m}} = [C_k^q \sum_{\substack{r_1+r_2+\dots+r_q=k^m \\ r_i \geq 1, i=1, 2, \dots, q}} \frac{k^m!}{r_1! r_2! \dots r_q!}]^{k^{n-m}} = [C_k^q \sum_{s=0}^q (-1)^{q-s} C_q^s s^{k^m}]^{k^{n-m}}$$

For  $q=1$ , from Corollary 2.1. it follows that:

**Corollary 2.2.** The number of functions  $f \in P_n^k$ , for which each subfunction

$g, g \xrightarrow{\bar{M}} f, M \subseteq X_f, 1 \leq |M|=m \leq n, \bar{M} = X_f \setminus M$  is a constant, i.e. has a range equal to 1, is

$$((4) \quad k^{k^{n-m}}.$$

Therefore, if  $M \subseteq X_f, 1 \leq |M|=m \leq n$ , then the number of functions  $f \in P_n^k$ , for which each of the  $m$  variables of  $M$  is fictitious, is equal to  $k^{k^{n-m}}$ .

We say that a function from  $P_n^k$  satisfies the property  $p_i$ ,  $i=1, 2, \dots, n$ , if its  $i^{th}$  variable is fictitious.

**Theorem 2.1.** The number of functions from  $P_n^k$ , which have exactly  $r$  in number fictitious variables,  $r=0, 1, 2, \dots, n$ , is equal to

$$(5) \quad N_n^k(r) = \sum_{j=r}^n (-1)^{j-r} C_j^r C_n^j k^{k^{n-j}}, \quad r=0, 1, \dots, n.$$

Proof: We apply the principle of inclusion and exclusion and formula (2), and in this particular case we have  $S_0 = |P_n^k| = k^{k^n} = C_n^0 k^{k^{n-0}}$ . Taking into account that  $j$  properties out of  $n$  possible properties can be chosen in  $C_n^j$  different ways, as well as the fact that the number of functions from  $P_n^k$ , for which  $j$  fixed variables are fictitious (formula 4), is

$$k^{k^{n-j}}, \text{ we get } S_j = \sum_{1 \leq i_1 < \dots < i_j \leq n} N(p_{i_1}, \dots, p_{i_j}) = C_n^j k^{k^{n-j}}, \quad j=1, \dots, n. \text{ Adding } S_0$$

and  $S_j$ ,  $j=1, \dots, n$ , in  $S_j = C_n^j k^{k^{n-j}}$ ,  $j=0, 1, \dots, n$  and applying formula (2), we get that the number  $N_n^k(r)$  of the functions from  $P_n^k$ , which have exactly  $r$  fictitious variables  $r=0, 1, 2, \dots, n$ , is equal to  $\sum_{j=r}^n (-1)^{j-r} C_j^r C_n^j k^{k^{n-j}}$ ,  $r=0, 1, \dots, n$ .



From *Theorem 2.1.*, for  $r=0$ , i.e. when all variables are essential, we get:

**Corollary 2.3.** The number of functions from  $P_n^k$ , whose all variable are essential, is equal to:

$$\sum_{j=0}^n (-1)^j C_n^j k^{k^{n-j}}.$$

Since for each function from  $P_n^k$ , the sum of its essential and fictitious variables is equal to  $n$ , we have:

**Corollary 2.4.** The number of the functions from  $P_n^k$ , which have exactly  $t$ ,  $0 \leq t \leq n$  essential variables, i.e.  $n-t$  fictitious variables, is equal to:

$$\tilde{N}_n^k(t) = N_n^k(n-t) = \sum_{j=n-t}^n (-1)^{j-n+t} C_j^{n-t} C_n^j k^{n-j}$$

Applying *Lemma 2.1.* and *Corollary 2.4.*, we get:

**Corollary 2.5.** If  $M \subseteq X_f$ ,  $1 \leq |M| = m \leq n$ ,  $\bar{M} = X_f \setminus M$ , then the number of functions from  $P_n^k$ , for which each subfunction of  $f$  with respect to  $\bar{M}$ , has exactly  $t$ ,  $0 \leq t \leq m$ , essential variables, is equal to:

$$\left[ \sum_{j=m-t}^m (-1)^{j-m+t} C_j^{m-t} C_m^j k^{m-j} \right] k^{n-m}.$$

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# The maximal subsemigroups of the ideals of the semigroup of all isotone partial injections

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**Abstract.** We study the structure of the ideals of the semigroup  $IO_n$  of all isotone (order-preserving) partial injections on an  $n$ -element set. The main result is the characterization of the maximal subsemigroups of the ideals of  $IO_n$ . Each of the considered ideals has exactly  $2^{\binom{n}{2}} - 2$  maximal subsemigroups.

**Keywords:** finite transformation semigroup, isotone partial transformations, maximal subsemigroups.

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## 1 Introduction

Let  $X_n = \{1, 2, \dots, n\}$  be an  $n$ -element set ordered in the usual way. The monoid  $PT_n$  of all partial transformations of  $X_n$  is a very interesting object. In this paper we will multiply transformations from the right to the left and use the corresponding notation for the right to the left composition of transformations:  $x(\alpha\beta) = (x\alpha)\beta$ , for  $x \in X_n$ . We say that a transformation  $\alpha \in PT_n$  is *isotone* (order-preserving) if  $x \leq y \Rightarrow x\alpha \leq y\alpha$  for all  $x, y$  from the domain of  $\alpha$ .

In the present paper, we study the structure of the semigroup  $PO_n$  of all isotone partial transformations, in particular of the semigroup  $IO_n$  of all isotone partial injections of  $X_n$  (excluding the identity permutation).

Some semigroups of transformations have been studied since the sixties. In fact, presentations of the semigroup  $O_n$  of all isotone transformations and of the semigroup  $PO_n$  of all isotone partial transformations (excluding the permutation in both cases) were established by Aîzenštat ([1]) in 1962 and by Popova ([11]), respectively, in the same year. Some years later (1971), Howie ([10]) studied some combinatorial and

algebraic properties of  $O_n$  and, in 1992, Gomes and Howie ([9]) established some more properties of  $O_n$ , namely its rank and idempotent rank. In recent years it has been studied in different aspects by several authors (for example [3], [12], [13]). The monoid  $IO_n$  of all isotone partial injections of  $X_n$  has been the object of study since 1997 by Fernandes in various papers ([5], [6], [7]). Some basic properties of  $IO_n$ , in particular, a description of Green's relations, congruences and a presentation, were obtained in [2]. Ganyushkin and Mazorchuk ([8]) studied some properties of  $IO_n$  as describe ideals, systems of generators, maximal subsemigroups and maximal inverse subsemigroups of  $IO_n$ .

In this paper we consider the semigroup  $IO_n$  and its ideals. In Section 2 we recall the structure of the ideals and Green's relations on  $IO_n$ . In Section 3 we characterize the maximal subsemigroups of the ideals of  $IO_n$ . It happens that each of the considered ideals has exactly  $2^{\binom{n}{r}} - 2$  maximal subsemigroups.

We will try to keep the standard notation. For every partial transformation  $\alpha$  by  $\text{dom } \alpha$  and  $\text{im } \alpha$  we denote the domain and the image of  $\alpha$ , respectively. If  $\alpha$  is injective, the number  $\text{rank } \alpha = |\text{dom } \alpha| = |\text{im } \alpha|$  is called the rank of  $\alpha$ . Clearly,  $\text{rank } \alpha\beta \leq \min\{\text{rank } \alpha, \text{rank } \beta\}$  and  $\text{im } \beta = \text{im } \alpha\beta$  as well as  $\text{dom } \alpha = \text{dom } \alpha\beta$  if  $\text{im } \alpha = \text{dom } \beta$ . From the definition of isotone transformation, it follows that every element  $\alpha \in IO_n$  is uniquely determined by  $\text{dom } \alpha$  and  $\text{im } \alpha$  satisfying  $|\text{dom } \alpha| = |\text{im } \alpha|$ . Moreover, for every  $A, B \subseteq X_n$  of the same cardinality there exists exactly one isotone transformation  $\alpha \in IO_n$  such that  $\text{dom } \alpha = A$  and  $\text{im } \alpha = B$ , denoted by  $\alpha_{AB}$ . The elements  $\alpha_{AA}$ ,  $A \in X_n$ , exhaust all idempotents in  $IO_n$ .

## 2 Ideals and Green's relations

The first proposition characterize the principal ideals on  $IO_n$ .

**Proposition 1** [8] *Let  $\alpha \in IO_n$ . Then*

1.  $IO_n \cdot \alpha = \langle \alpha \rangle = \{\beta \in IO_n : \text{im } \beta \subseteq \text{im } \alpha\}$ .
2.  $\alpha \cdot IO_n = \langle \alpha \rangle = \{\beta \in IO_n : \text{dom } \beta \subseteq \text{dom } \alpha\}$ .
3.  $IO_n \cdot \alpha \cdot IO_n = \langle \alpha \rangle = \{\beta \in IO_n : \text{rank } \beta \leq \text{rank } \alpha\}$ .

For every  $r$ ,  $1 \leq r \leq n-1$ , we put  $I_r := \{\alpha \in IO_n : \text{rank } \alpha \leq r\}$ .

**Corollary 1** *All two-sided ideals of  $IO_n$  are principal and form the following chain:*

$$I_1 \subset I_2 \subset \dots \subset I_{n-1} = IO_n.$$

The Green's relations  $\mathcal{L}$ ,  $\mathcal{R}$ ,  $\mathcal{J}$  and  $\mathcal{H}$  on  $IO_n$  are characterized as follows:

$$\alpha \mathcal{L} \beta \Leftrightarrow \text{im } \alpha = \text{im } \beta$$

$$\alpha \mathcal{R} \beta \Leftrightarrow \text{dom } \alpha = \text{dom } \beta$$

$$\alpha \mathcal{D} \beta \Leftrightarrow \text{rank } \alpha = \text{rank } \beta$$

$$\mathcal{H} = \mathcal{L} \cap \mathcal{R},$$

The semigroup  $IO_n$  is the union of the  $J$ -classes  $J_1, J_2, \dots, J_{n-1}$ , where

$$J_r := \{\alpha \in IO_n : \text{rank } \alpha = r\} \text{ for } r = 1, \dots, n-1.$$

It is well known that the ideal  $I_r$  ( $r = 1, \dots, n-1$ ) of the semigroup  $IO_n$  is the union of  $J$ -classes  $J_1, J_2, \dots, J_r$ .

Every principal factor on  $IO_n$  is a Rees quotient  $I_r/I_{r-1}$  ( $2 \leq r \leq n-1$ ) of which we think as  $J_r \cup \{0\}$  (as it is usually convenient), where the product of two elements of  $J_r$  is taken to be zero if it falls into  $I_{r-1}$ .

Let us denote by  $\Lambda_r$  the collection of all subsets of  $X_n$  of cardinality  $r$ .

The  $\mathcal{R}$ -,  $\mathcal{L}$ - and  $\mathcal{H}$ -classes in  $J_r$  have the following form:

$$R_A := \{\alpha \in I_r : \text{dom } \alpha = A\}, \quad A \in \Lambda_r;$$

$$L_B := \{\alpha \in I_r : \text{im } \alpha = B\}, \quad B \in \Lambda_r;$$

$$H_{AB} := \{\alpha_{AB}\} = R_A \cap L_B, \quad A, B \in \Lambda_r.$$

The  $\mathcal{L}$ -class,  $\mathcal{R}$ -class and  $\mathcal{H}$ -class, respectively, containing the element  $\alpha \in IO_n$  will be denoted by  $L_\alpha$ ,  $R_\alpha$ , and  $H_\alpha$ , respectively.

Clearly, each  $R_A$ -class ( $L_B$ -class),  $A \in \Lambda_r$ , contains exactly one idempotent  $\alpha_{AA}$ . Thus if  $E_r$  is the set of all idempotents in the class  $J_r$ , then  $|E_r| = \binom{n}{r}$ .

Since the product  $\alpha\beta$  for all  $\alpha, \beta \in J_r$  belongs to the class  $J_r$  iff  $\text{im } \alpha = \text{dom } \beta$ , it is obvious that

#### Lemma 1

1.  $L_B R_A = \begin{cases} J_r, & \text{if } A = B, \\ 0, & \text{if } A \neq B. \end{cases}$
2.  $\alpha_{AB} \alpha_{CD} = \begin{cases} \alpha_{AD}, & \text{if } B = C, \\ 0, & \text{if } B \neq C. \end{cases}$

**Proposition 2** [5]  $\langle J_r \rangle = I_r$ , for  $1 \leq r \leq n-1$ .

### 3 Maximal subsemigroups of the ideals of $IO_n$

In this section we describe all maximal subsemigroups of the ideals of the semigroup  $IO_n$ . We begin with the following lemma.

**Lemma 2** Every maximal subsemigroup in  $I_r$  contains the ideal  $I_{r-1}$ .

**Proof:** Let  $S$  be a maximal subsemigroup of  $I_r$ . Assume that  $I_r \subseteq S$ , then according to Proposition 2 it follows that  $I_r = \langle J_r \rangle \subseteq S$ , i.e.  $S = I_r$ , a contradiction. Thus  $I_r \not\subseteq S$ . Then  $S \cup I_{r-1}$  is a proper subsemigroup of  $I_r$ , since  $I_{r-1}$  is an ideal, and hence  $S \cup I_{r-1} = S$  by maximality of  $S$ . This implies  $I_{r-1} \subseteq S$ . ■

Let us denote by  $Dec(\Lambda_r)$  the set of all decompositions  $(N_1, N_2)$  of  $\Lambda_r$ , i.e.  $N_1 \cup N_2 = \Lambda_r$  and  $N_1 \cap N_2 = \emptyset$  where  $N_1, N_2 \neq \emptyset$ .

**Definition 1** Let  $(N_1, N_2) \in Dec(\Lambda_r)$  ( $r = 1, \dots, n-1$ ). Then we put

$$S_{(N_1, N_2)} = I_{r-1} \cup \{\alpha_{A,B} : A \in N_1 \text{ or } B \in N_2\}$$

Now in our main theorem, we will characterize the maximal subsemigroups of the ideals of the semigroup  $IQ_n$ .

**Theorem 1** A subsemigroup  $S$  of  $I_r$  is maximal iff there is an element  $(N_1, N_2) \in Dec(\Lambda_r)$  with  $S = S_{(N_1, N_2)}$ .

**Proof:** Let  $S = S_{(N_1, N_2)}$  for some  $(N_1, N_2) \in Dec(\Lambda_r)$ . Then

$$S = I_{r-1} \cup \{\alpha_{A,B} : A \in N_1 \text{ or } B \in N_2\}.$$

Therefore, if  $\alpha_{A,B} \in S$  then  $A \in N_1$  and  $B \in N_2$ , and thus  $\alpha_{B,A} \in S$ .

From Lemma 1 it follows that  $S$  is a semigroup. Really, let  $\alpha_{A,B}, \alpha_{C,D} \in S$ , i.e.  $A, C \in N_1$  or  $B, D \in N_2$  or  $A \in N_1, D \in N_2$ . Then we have  $\alpha_{A,B}\alpha_{C,D} = \alpha_{A,D} \in S$  for  $B = C$  and  $\alpha_{A,B}\alpha_{C,D} = 0 \in I_{r-1} \subseteq S$  for  $B \neq C$ .

Now we will show that  $S$  is maximal. Let  $\alpha_{C,D} \in I_r \setminus S$ , i.e.  $C \in N_1$  and  $D \in N_2$ . Then  $D \in N_1$ , since  $N_1 \cup N_2 = \Lambda_r$  and so  $\alpha_{D,B} \in S$  for all  $B \in \Lambda_r$  and thus  $R_D = \{\alpha_{D,B} : B \in \Lambda_r\} \subseteq S$ . Moreover, we have  $\alpha_{C,B} = \alpha_{C,D}\alpha_{D,B}$ , for all  $B \in \Lambda_r$ , by Lemma 1. Thus we obtain the  $\mathcal{R}$ -class  $R_C = \{\alpha_{C,B} : B \in \Lambda_r\} \subseteq \langle S \cup \{\alpha_{C,D}\} \rangle$ . Moreover,  $C \in N_2$  and so  $L_C = \{\alpha_{P,C} : P \in \Lambda_r\} \subseteq S$ . Using Lemma 1, we have  $L_C R_C = J_r \subseteq \langle S \cup \{\alpha_{C,D}\} \rangle$ . Thus, we obtain that  $\langle S \cup \{\alpha_{C,D}\} \rangle = I_r$ . Therefore,  $S$  is a maximal subsemigroup of the ideal  $I_r$ .

For the converse part let  $S$  be a maximal subsemigroup of the ideal  $I_r$ . From Lemma 2, we have that  $I_{r-1} \subseteq S$ . Then  $S = I_{r-1} \cup T$ , where  $T \subseteq J_r$ .

Let  $\alpha_{A,B} \in S$ . Then  $\langle S \cup \{\alpha_{A,B}\} \rangle = I_r$ . Let now  $P, Q \in \Lambda_r$ . Suppose that  $\alpha_{P,Q} \in S$ . Then  $\alpha_{P,Q} \in \langle S \cup \{\alpha_{A,B}\} \rangle$  and  $\alpha_{P,Q} = \alpha_{P,A}\alpha_{A,B}\alpha_{B,Q}$ . Moreover,  $\alpha_{P,A} = \alpha_{P,A}\alpha_{A,B}\alpha_{B,A}$  and  $\alpha_{B,Q} = \alpha_{B,A}\alpha_{A,B}\alpha_{B,Q}$ . This shows that we need  $\alpha_{P,A}$  and  $\alpha_{B,Q}$  to generate  $\alpha_{P,A}$  and  $\alpha_{B,Q}$ , respectively, with elements of  $S \cup \{\alpha_{A,B}\}$ . Hence  $\alpha_{P,A}, \alpha_{B,Q} \in S$ .

Assume that  $\alpha_{Q,P} \in S$ . Then  $\alpha_{Q,P} = \alpha_{Q,A}\alpha_{A,B}\alpha_{B,P}$  and by the same arguments, we obtain that  $\alpha_{Q,A}, \alpha_{B,P} \in S$ .

Further, from  $\alpha_{Q,P} = \alpha_{Q,A}\alpha_{A,B}$  it follows that  $\alpha_{A,P} \in S$ . But  $\alpha_{P,Q} \in \langle S \cup \{\alpha_{A,P}\} \rangle$  since  $\alpha_{P,Q} = \alpha_{P,A}\alpha_{A,B}\alpha_{B,Q}$ . This contradicts the maximality of  $S$  and thus  $\alpha_{Q,P} \in S$ . Hence if  $\alpha_{P,Q} \in S$  then  $\alpha_{Q,P} \in S$  for any  $P, Q \in \Lambda_r$ .

Therefore, for  $N_1 = \{B: \alpha_{A,B} \in S\}$  and  $N_2 = \{A: \alpha_{A,B} \in S\}$  we have that  $S = S_{(N_1, N_2)}$ . ■

There are exactly  $2^{\binom{n}{r}} - 2$  maximal subsemigroups of the ideal  $I_r$ , for  $r = 1, \dots, n-1$ .

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# On Finding a Particular Class of Combinatorial Identities

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**Abstract:** *In this paper, a class of combinatorial identities is proved. A method is used which is based on the following rule: counting elements of a given set in two ways and making equal the obtained results. This rule is known as "counting in two ways". The principle of inclusion and exclusion is used for obtaining a class of (0,1)-matrices.*

**Keywords:** *"counting in two ways", (0,1)-matrix, Boolean matrix, principle of inclusion and exclusion, set*

A modification of the method of "counting in two ways" ([1], p.2) is to obtain a general formula for the number of elements of a set, after that to consider some of the subsets of this set, and to find elements of these subsets, on the one hand, by using the general formula, and on the other hand, by using specific properties of the subsets.

We will demonstrate this method by considering and proving the following identities:

$$(1) \quad \sum_{s=0}^{n-1} (-1)^s \binom{n}{s} (n-s)^n = n!$$

$$(2) \quad \sum_{s=0}^p (-1)^s \binom{2p}{s} \binom{2p-s}{p}^2 = \frac{(2p)!}{(p!)^2}$$

$$(3) \quad \sum_{s=0}^{n-p} (-1)^s \binom{n}{s} \binom{n-s}{p}^k = 0, \text{ where } n > pk$$

$$(4) \quad \sum_{s=0}^{p(k-1)} (-1)^s \binom{kp}{s} \binom{kp-s}{p}^k = \frac{(kp)!}{(p!)^k}$$

$$(5) \quad \sum_{s=0}^{n-1} (-1)^s \binom{n}{s} (n-s)^k = \sum_{\substack{t_1+t_2+\dots+t_n=k \\ t_j \geq 1, \quad j=1,2,\dots,n}} \frac{k!}{t_1! t_2! \dots t_n!}, \text{ if } n \leq k$$

What these identities have in common is the left-hand side that can be written by the expression:

$$(6) \quad \mathfrak{R}(n \times k, p) = \sum_{s=0}^{n-p} (-1)^s \binom{n}{s} \binom{n-s}{p}^k$$

and (1) is obtained with  $n=k$  and  $p=1$ ; (2) with  $n=2p$  and  $k=2$ ; (3) with  $n>pk$ ; (4) with  $n=kp$ ; (5) with  $p=1$ .

It remains to give some of the possible combinatorial interpretations of the expression (6). Boolean (binary, or (0,1)-matrix) is a matrix whose entries are equal to 0 or 1. We will show that  $\mathfrak{R}(n \times k, p)$  gives the number of all  $n \times k$  (composed of  $n$  rows and  $k$  columns) Boolean matrices, such that in each column they have exactly  $p$  ones, and in each row these matrices have at least 1 one [2, Lemma 1]. Necessary and sufficient condition for existence of such matrices is  $1 \leq p \leq n \leq kp$  as in the special case when  $n=kp$ , in each row we have exactly 1 one, and when  $n>kp$ , such matrices do not exist, that is, their number is equal to zero (see Proposition 3). Indeed, it is easy to see that the number  $r(n \times k, p)$  of all  $n \times k$  Boolean matrices, that have exactly  $p$  ones in each column, is equal to

$$(7) \quad r(n \times k, p) = \binom{n}{p}^k.$$

From the set of all  $n \times k$  Boolean matrices, that have exactly  $p$  ones in each column, we have to remove matrices that have at least one row of zeroes, and to determine the number of the remaining matrices. We will do this by using the principle of inclusion and exclusion. Recall this known principle in the following form:

**Inclusion and exclusion principle:** Let  $M$  be a finite set and let  $P = \{p_1, p_2, \dots, p_m\}$  be the set of properties that can be possessed by the elements of  $M$ . Denote by  $N(p_{i_1}, p_{i_2}, \dots, p_{i_s})$  the number of elements of  $M$  that possess the properties  $p_{i_1}, p_{i_2}, \dots, p_{i_s}$ . Then the number  $N(0)$  of elements of  $M$  that do not possess any of the properties of  $P$  is given by the formula:

$$N(0) = |M| + \sum_{s=1}^m (-1)^s \sum_{1 \leq i_1 < \dots < i_s \leq m} N(p_{i_1}, p_{i_2}, \dots, p_{i_s}) = |M| - \sum_{j=1}^m N(p_j) +$$

$$\sum_{1 \leq i_1 < i_2 \leq m} N(p_{i_1}, p_{i_2}) - \sum_{1 \leq i_1 < i_2 < i_3 \leq m} N(p_{i_1}, p_{i_2}, p_{i_3}) + \dots + (-1)^s \sum_{1 \leq i_1 < \dots < i_s \leq m} N(p_{i_1}, p_{i_2}, \dots, p_{i_s}) + \dots + (-1)^m N(p_1, p_2, \dots, p_m).$$

In particular, in our problem let  $M$  be the set of all  $n \times k$  Boolean matrices that have in each column exactly  $p$ ,  $1 \leq p \leq n$  ones, and the property  $p_i$  is possessed by these matrices belonging to the set  $M$  whose  $i$ -th row,  $1 \leq i \leq n$ , consists of zeroes. Since  $M$  cannot contain matrices with more than  $n-p$  rows of zeroes, then  $N(p_{i_1}, p_{i_2}, \dots, p_{i_s}) = 0$  when  $s > n-p$ . Then obviously  $|M| = r(n \times k, p)$ , and for each set of properties  $\{p_{i_1}, p_{i_2}, \dots, p_{i_s}\}$  we have  $N(p_{i_1}, p_{i_2}, \dots, p_{i_s}) = r((n-s) \times k, p)$ ,  $s = 1, 2, \dots, n-p$ .

Since  $s$  of  $n$  properties  $p_1, p_2, \dots, p_n$  can be chosen in  $\binom{n}{s}$  ways, then

$$\sum_{1 \leq i_1 < \dots < i_s \leq n} N(p_{i_1}, p_{i_2}, \dots, p_{i_s}) = \binom{n}{s} r((n-s) \times k, p).$$

From (7), applying the inclusion and exclusion principle, we get:

$$\mathfrak{R}(n \times k, p) = |M| + \sum_{s=1}^{n-p} (-1)^s \binom{n}{s} \binom{n-s}{p}^k = \binom{n}{p}^k + \sum_{s=1}^{n-p} (-1)^s \binom{n}{s} \binom{n-s}{p}^k = \sum_{s=0}^{n-p} (-1)^s \binom{n}{s} \binom{n-s}{p}^k,$$

quod erat demonstrandum [2, Lemma 1].



In order to prove the identities (1) ÷ (5), it remains to prove following propositions:

**Proposition 1.** Prove that the number of all quadratic Boolean matrices with  $n$  rows and  $n$  columns, having in each row and in each column exactly 1 one, is equal to  $n!$ .

**Proposition 2.** Prove that the number of all Boolean matrices with  $2p$  rows and two columns, having in each row 1 one and 1 zero and the same number of ones in each column, is equal to  $\frac{(2p)!}{(p!)^2}$ .

**Proposition 3.** Prove that in a Boolean matrix with  $n$  rows and  $k$  columns, such that in each column there is exactly  $p$  ones and  $n > kp$ , there exists at least one row of zeroes.

**Proposition 4.** If  $\mathfrak{S}_1$  is the set of all Boolean matrices with  $n$  rows and  $k$  columns, such that in each column there is exactly  $p$  ones,  $n=kp$  and there are no rows of zeroes, prove that  $|\mathfrak{S}_1| = \frac{(kp)!}{(p!)^k}$ .

**Proposition 5.** If  $\mathfrak{S}_2$  is the set of all Boolean matrices with  $n$  rows and  $k$  columns,  $n \leq k$ , that have in each column exactly 1 one and there are no rows of zeroes, prove that

$$|\mathfrak{S}_2| = \sum_{\substack{t_1+t_2+\dots+t_n=k \\ t_i \geq 1, i=1,2,\dots,n}} \frac{k!}{t_1!t_2!\dots t_n!}.$$

Proofs of Proposition 4 and identity (4):

**Proof.** From  $n=kp$  it follows that in each row of a matrix of the set  $\mathfrak{S}_1$  there is exactly 1 one and  $|\mathfrak{S}_1| = \mathfrak{R}(n \times k, p) = \mathfrak{R}(kp \times k, p)$ . Let  $C, C \in \mathfrak{S}_1$  be an arbitrary matrix and the ordered  $n$ -tuple  $(c_{1t_1}, c_{2t_2}, \dots, c_{nt_n})$  consists of the nonzero elements of this matrix. With these elements, we associate numbers of their columns, respectively, namely the ordered  $n$ -tuple  $(t_1, t_2, \dots, t_n)$ . Conversely, with the  $s$ -th element  $t_s$ , we can associate the nonzero element of row  $s$  of matrix  $C$ , namely  $c_{st_s}$ . If  $(d_{11}, d_{23}, d_{31}, d_{43}, d_{52}, d_{62})$  are the nonzero elements of matrix  $D, D \in \mathfrak{S}_1, k=3, p=2$ , we associate the ordered 6-tuple  $(1, 3, 1, 3, 2, 2)$  with them. Since Boolean matrices are uniquely determined by their nonzero entries, then the number of matrices of the set  $\mathfrak{S}_1$  is equal to the number of different permutations of  $(t_1, t_2, \dots, t_n)$ , that is, equal to  $(1, \dots, 1, 2, \dots, 2, \dots, k, \dots, k)$ , where each number of a column (columns are  $k$  in number) is repeated exactly  $p$  times, where  $p$  is the number of ones in a column. The number of these permutations with repetitions ([1] - the number of permutations of length  $n$ , composed by  $s$  different elements, repeated  $q_1, q_2, \dots, q_s$  times, respectively, is given by the expression

$\frac{n!}{q_1! q_2! \dots q_n!}$ , where  $n = q_1 + q_2 + \dots + q_s$  is equal to

$$\frac{(n)!}{(p!)^k} = \frac{(kp)!}{(p!)^k} = |\mathfrak{S}_1| = \mathfrak{R}(kp \times k, p).$$

The proof is completed. ◆

From *Proposition 4*, with the special case when  $p=1$ , ( $k=2$ ), we obtain *Proposition 1 (Proposition 2)*.

Proofs of *Proposition 5* and identity (5):

**Proof.** Each Boolean matrix of the set  $\mathfrak{S}_2$  contains  $k$  ones - exactly 1 one in the column and at least 1 one in each row. Therefore  $|\mathfrak{S}_2| = \mathfrak{R}(n \times k, 1)$ . If  $C \in \mathfrak{S}_2$  is an arbitrary matrix, the ordered  $k$ -tuple  $(c_{r_1 1}, c_{r_2 2}, \dots, c_{r_k k})$  consists of its nonzero elements, then let  $t_i$  be the number of ones in the  $i$ -th row, where  $t_i \geq 1$ ,  $i=1, 2, \dots, n$  and  $t_1 + t_2 + \dots + t_n = k$ . With matrix  $C$ , we can uniquely associate the ordered  $k$ -tuple  $(c_{r_1 1}, c_{r_2 2}, \dots, c_{r_k k})$  or the ordered  $k$ -tuple  $(r_1, r_2, \dots, r_k)$ . The number of Boolean matrices of  $\mathfrak{S}_2$ , that have  $t_i$  ones in the  $i$ -th row, is equal to the permutations  $(r_1, r_2, \dots, r_k)$ , that is, to the number of permutations of the  $k$ -tuple  $(1, \dots, 1, 2, \dots, 2, \dots, n, \dots, n)$ , where the number  $i$ ,  $i=1, 2, \dots, n$  is repeated  $t_i$  times. This number is equal to  $\frac{k!}{t_1! t_2! \dots t_n!}$ , and concerning the number of matrices of the set  $\mathfrak{S}_2$  we get

$$|\mathfrak{S}_2| = \sum_{\substack{t_1+t_2+\dots+t_n=k \\ t_i \geq 1, i=1, 2, \dots, n}} \frac{k!}{t_1! t_2! \dots t_n!},$$

where the sums are taken over all possible expansions of number  $k$  into  $n$  nonzero terms.

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# Numerical Modelling of Humoral Immune Response to Virus

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**Abstract:** We present a mathematical model of humoral immune response to viral infection. The model is a bilinear system of integro-differential equations of Boltzmann type. Results of numerical experiments are presented.

**Keywords:** Numerical modelling, kinetic model, integro-differential equations, nonlinear dynamics, virus, humoral immunity.

## 1. INTRODUCTION

The present paper is devoted to numerical analysis of a recently proposed model related to humoral immune response to viral infection [2]. The model is a system of partial integro-differential equations. The interacting individuals (cells and particles) belonging to several interacting populations are characterized by an internal state variable  $u$  that describes their biological activity or ability to express their main functions.

The kinetic models describe the dynamics of the statistical distributions over the microscopic inner state of the populations of interacting individuals. The distribution density of the population labelled by the index  $i$  at time  $t$  is denoted by:

$$f_i(t, u), f_i : [0, \infty) \times [0, 1] \rightarrow R^+.$$

The concentrations of the populations are denoted by:

$$(1) \quad n_i(t) = \int_0^1 f_i(t, u) du, \quad n_i : [0, \infty) \rightarrow R^+.$$

After the proper choice of the most important populations involved in the interactions, one usually tries to describe the time dynamics of their distribution densities, by including in mathematical equations respective gain, loss and conservative terms describing possible production and destruction of individuals as well as change of their activation states.

The humoral immunity is one of the most important acquired mechanisms of the immune system used to fight the foreign pathogens like viruses, microbes, cancers etc. The humoral response is performed mainly by antibodies (ABs) which are produced by B lymphocytes. They are able to destroy free virus particles that invade the organism. The viruses can enter

the susceptible cells, which produce new virus particles that may leave the infected cells. The viral particles can destroy some of the host cells [4].

## 2. DESCRIPTION OF THE MATHEMATICAL MODEL

The interactions between immune system and invading pathogens are very complicated. In vivo experiments have been of central importance for understanding the dynamics of pathogens' populations and of different species of immune cells. In addition, since the beginning of the 1990s mathematical models have started to be used in order to describe and predict the dynamics of an infection and of immune responses, for example in the context of human immunodeficiency virus (HIV) infection [4].

We present a model that is a simplification of a kinetic model describing the humoral response to virus proposed in [2]. The model is the following bilinear system of Boltzmann type integro-differential equations:

$$\begin{aligned}
 (2) \quad & \frac{d}{dt} n_1(t) = S_1(t) - d_{11}n_1(t) - d_{13}n_1(t) \int_0^1 v f_3(t, v) dv, \\
 (3) \quad & \frac{\partial f_2}{\partial t}(t, u) = p_{13}^{(2)}(1-u)n_1(t) \int_0^1 v f_3(t, v) dv - d_{22}u f_2(t, u) \\
 & \quad + c_{22}(2 \int_0^u (u-v) f_2(t, v) dv - (1-u)^2 f_2(t, u)), \\
 (4) \quad & \frac{\partial f_3}{\partial t}(t, u) = p_{22}^{(3)} \int_0^1 v f_2(t, v) dv - d_{34}f_3(t, u) \int_0^1 v f_4(t, v) dv - d_{33}f_3(t, u), \\
 (5) \quad & \frac{\partial f_4}{\partial t}(t, u) = p_{34}^{(4)}(1-u) \int_0^1 f_3(t, v) dv \int_0^1 f_4(t, v) dv - d_{44}f_4(t, u),
 \end{aligned}$$

where all parameters are assumed to be nonnegative and  $p_{13}^{(2)} = 2d_{13}$ . The model describes the interactions between the following four populations:

Tab. 1: Virus-humoral immune system dynamics variables.

Variable $i$	Population	Activation state $u \in [0,1]$
1	Susceptible uninfected cells	Not considered
2	Infected cells	Virus replication, destruction of inf. cells
3	Free virus particles	Rate of infectivity of susceptible cells
4	Antibodies	Destruction of virus, lowering viral activity

The activation state of populations denoted by  $i \in \{2, 3, 4\}$  is assumed to be a variable  $u \in [0, 1]$ .

The state of activity of the population of infected cells denotes the rate of destruction of the infected cell by virus as well as the rate of replication of virus particles inside the infected cells. The cells that are infected by cytopathic virus possess higher activation states (i.e. values of  $u$  close to 1). More active infected cells are assumed to produce higher amount of virus particles.

The state of activity of population  $i = 3$  expresses the ability of the virus to infect susceptible cells. The higher the ability of a virus particle to enter a cell is, the higher its activation state is.

Additionally, we suppose that the state of activity of antibodies denotes their ability to destroy virus particles and to lower their activation states.

In the presented model, it is assumed for simplicity that the distribution function of the population of uninfected cells is independent of their activation states, i.e.

$$f_1(t, u) = n_1(t), \quad \forall u \in [0, 1], \quad t \geq 0.$$

The first equation (2) of the model describes the evolution of the concentration  $n_1(t)$  of the uninfected cells. The gain term corresponds to the rate of their generation, while the loss terms describe the rate of their natural death as well as the rate of their infection by virus particles. The meaning of the parameters participating in equation (2) is the following:

- The function  $S_1(t)$  characterizes the production of uninfected cells;
- $d_{11}$  - characterizes the natural death of the uninfected cells;
- $d_{13}$  - characterizes the rate of infection of uninfected cells by virus particles.

Equation (3) describes the evolution of the distribution density  $f_2(t, u)$  of the infected cells. We assume that the state of activity of the newly infected cells is low. This is the meaning of the factor  $(1 - u)$  in the gain term. The rate of destruction of infected cells by virus particles is assumed to be proportional to the state of activity of the infected cells. Therefore, the activation state of the infected cells is a measure of the cytopathicity of the virus particles, i.e. of their ability to shorten the life-span of the infected cells. The replication of the virus inside the host cells leads to raising of the activation state of the infected cells. This is described by the corresponding conservative term. The meaning of the parameters included in equation (3) is as follows:

- $p_{13}^{(2)}$  - characterizes the rate of infection of uninfected cells by virus particles;
- $d_{22}$  - characterizes the destruction of infected cells by virus particles;

- $c_{22}$  - characterizes the steady progress of infected cells towards increasing activation state due to the replication of virus inside the infected cells.

Equation (4) describes the evolution of the distribution density  $f_3(t, u)$  of the free virus particles. The rate of their reproduction is assumed to be proportional to the activity of the infected cells. Two causes of destruction of viruses are taken into account in our model: the natural death as well as killing of viruses by active antibodies. Moreover, the possible raising of the activity of the virus particles due to their development as well as possible lowering of their activation due to the activity of ABs are described in equation (4) by conservative terms. The meaning of the parameters participating in equation (4) is the following:

- $p_{22}^{(3)}$  - characterizes the replication of virus particles;
- $d_{33}$  - characterizes the natural death of virus particles;
- $d_{34}$  - characterizes the destruction of virus particles by ABs.

Equation (5) describes the dynamics of the distribution density  $f_4(t, u)$  of the population of antibodies. It is assumed that the activity of the newly produced ABs is low, which is described by the factor  $(1 - u)$  in the gain term. The rate of generation of ABs is assumed to be proportional to the concentrations of the viruses and of ABs. The natural death of ABs is taken into account. Moreover, equation (5) describes the possibility of raising as well as of lowering of their activity. The meaning of the respective parameters is the following:

- $p_{34}^{(4)}$  - characterizes the production of ABs;
- $d_{44}$  - characterizes the natural death of ABs.

### 3. NUMERICAL RESULTS AND DISCUSSIONS

Quantitative results for the model (2)-(5) have been obtained by classical discretization schemes, see, e.g., [1]. The activation state  $u$  was discretized over a suitable set of uniform grid-points. The values of integrals were approximated by the composite Simpson formula. The resulting system of ordinary differential equations was solved by the code *ode15s* from the Matlab ODE suite [3]. The concentrations  $n_i(t)$  of populations  $i \in \{2, 3\}$  presented in Figs. (1)-(2) were computed from the obtained approximate solutions for  $f_i(t, u)$  by using Eq. (1).

System (2)-(5) has to be supplemented by initial conditions. We have performed numerical experiments with the following initial values and values of parameters:

$$n_1(0) = 1, f_2(0, u) = 0, f_3(0, u) = 0.1, f_4(0, u) = 0.1, \forall u \in [0, 1], S_1(t) = 1,$$

$$d_{11} = d_{33} = d_{34} = d_{44} = p_{22}^{(3)} = p_{34}^{(4)} = 1, c_{22} = 0.15, d_{22} = 0.55.$$

The choice of the parameters allows us to investigate the ability of the presented model to describe the essential types of humoral response to virus. In our future work we plan to address the problem of finding precise parameter values for system (2)-(5), through comparison of the numerical solution with experimental data.

Here, we have analyzed the role of parameter  $d_{13}$  describing the rate of infection of uninfected cells. The numerical experiments show, that when the value of parameter  $d_{13}$  is not very high, the humoral immune response can be successful in the fight against the infection. This is illustrated by graphs corresponding to  $d_{13} = 1.0$  on Figs. (1) and (2) where the dynamics of the concentrations  $n_2(t)$  of the infected cells and  $n_3(t)$  of the virus particles is shown. In the initial period of the infection the number of infected cells increases but later the activity of antibodies fight off the virus.

When the value of  $d_{13}$  is high, the humoral immune response is not able to clean the infection. More susceptible cells become infected. This results in a higher replication of the virus, which infect new cells. This situation is observed for example for value  $d_{13} = 1.15$ .

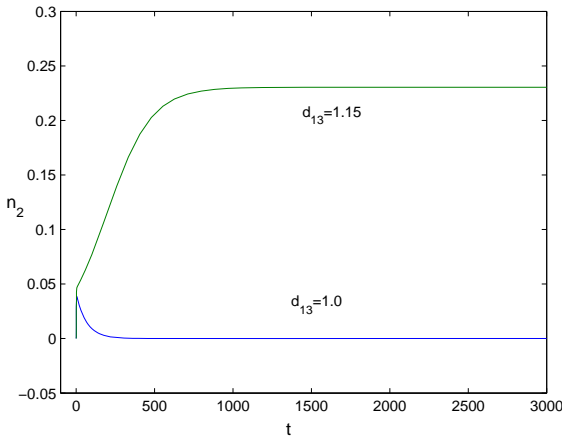


Fig. 1: Dynamics of the infected cells for values  $d_{13} = 1.0$  and  $d_{13} = 1.15$

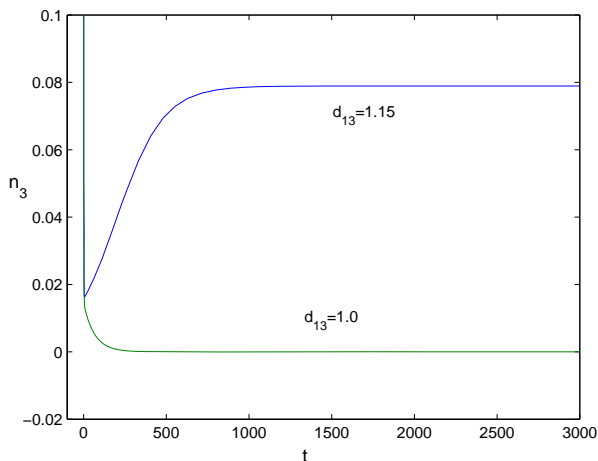


Fig. 2: Dynamics of the free viruses for values  $d_{13} = 1.0$  and  $d_{13} = 1.15$

#### 4. CONCLUSIONS

The presented model has illustrated two typical results of competition between virus infection and humoral immunity: (i) an successful, sustained immune response leading to very low levels of viral load and (ii) an ineffective response of humoral immunity resulting in high levels of viral load.

In our future work we plan to analyze the role of other parameters of the model, in particular the coefficients describing the change of activity of virus particles and of antibodies. Moreover, the problem of finding precise parameter values for system (2)-(5) will be addressed. For this aim the approximate solution will be compared with experimental data.

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# Models for measurement of Bulgarian speech rhythm

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**Abstract.** *The present research is devoted to finding and analyzing measurable and significant linguistic, phonologic and phonetic correlations of different emotional statuses in the Bulgarian language with the help of applied statistics.*

*The aim of this work is to present the possibilities provided by different methods for measurement and classification of certain speech rhythms in the Bulgarian language.*

## 1. INTRODUCTION

Speech rhythm is a part of the language prosody and fluency and is significant for pattern recognition and language intelligibility.

The recent language-rhythm studies [6] focus on language classification, as they are based on the traditional rhythm types, namely syllable-, stress- and mora-timed.

Several studies have failed to classify the Bulgarian language in this traditional language-rhythm typology. [3] In articulation and acoustic point of view the stress in the Bulgarian language is not centralized, free and mobile and reveals a clear difference between stressed and unstressed syllable types. Additionally, Bulgarian shows vowel reduction in unstressed syllables and increases with the positional distance from the stress. [8] The phoneme variants of unstressed syllables have their own acoustic properties. Two main types of syllables have been described in the Bulgarian vocal system – open and closed. Tilkov has shown syllable positioning in relation to the stress syllable (SS) – first forestressed (FVSS), second forestressed (SVSS), first post-stressed (FASS), second post-stressed (SASS) syllable etc. [10, 11, 12] The variants of FVSS were similar to the phonemes, while the other unstressed syllables became closed [a] toward [ə], [e] – [i] and [o] – [u]. [5]

Since the syllable is a main carrier of the speech tempo and rhythm, determination of the nature of the variations of duration of different syllable types (around 15 types in Bulgarian), as well as other acoustic properties like amplitude (intensity), frequency (pitch), formant structure

etc. could lighten how emotions and other psycho-physiological states are encoded in the speech rhythm itself.

Tilkov (1990) has claimed that systematic analyzes of the language and speech emotiveness is not possible. [10]

To enrich our knowledge in this direction more suitable rhythm measurements should be developed.

Although researchers have measured many speech signal properties they have failed to identify reliable acoustic characteristics even for language classes. [6] Ramus et al. (1999) have presented instrumental measurements based on consonant/vowel segmentation. The model has suggested that intuitive rhythm types might reflect specific phonological properties, which in turn were signaled by the acoustic/phonetic properties of speech. [6]

Ramus et al. (1999) uses three measures: %V,  $\Delta V$  (standard deviation of the vowel interval) and  $\Delta C$  (standard deviation of the consonant interval). With the exception of %V, which is simply the proportion to which an utterance is vocalic, the measures all address the variability of the vocalic and consonantal interval durations within a stretch of speech. Barry et al. (2009) has shown that all known measures differ in the type of variability they capture. [1] Barry et al. (2009) have analyzed the PVI measure, introduced by Grabe and Low (not published). PVI is a Pair-wise Variability Index that has taken into consideration the sequential variability by averaging the durational difference between consecutive vowel or consonantal intervals. [1]

The described above measures have failed to classify clearly the Bulgarian language. [1] The factors affecting those measures such as syntactico-lexical structure, speaker selection, style of speech, speech tempo and so far emotiveness, have not been taken into consideration and are not suitable for our research.

In the proposed in this article models are suggested other rhythmic properties as measures – syllable types, variability of intensity, pitch and formant structure of the syllables. The main aim of the study is to find, analyze and put in use intuitive rhythm correlates of speech emotiveness signaled by the acoustic/phonetic properties of syllable structure of the Bulgarian language.

A Tilkov's typology of the syllables in the Bulgarian language is used [10, 11, 12]. The development of powerful tools in applied statistics allows us to search further possibilities for systematic analysis of acoustic/phonetic rhythmic properties of the emotional correlates in the Bulgarian speech.

## 2. METHOD

The object of observation and analysis is the acoustic signal of grammatically simple and meaningful sentences, pronounced without pauses. The speech was recorded with microphone, visualized by the LocuTour Speech Visualization 1.0 (SpeechLocuTour Multimedia, Inc., 2004-2007) and Praat 5.0.23 (Boersma&Weenink, 1992-2008). In order to determine precisely the time course of the syllable structure and the other acoustic characteristics of the syllables, such as intensity, pitch and formant structure was used the mentioned above software.

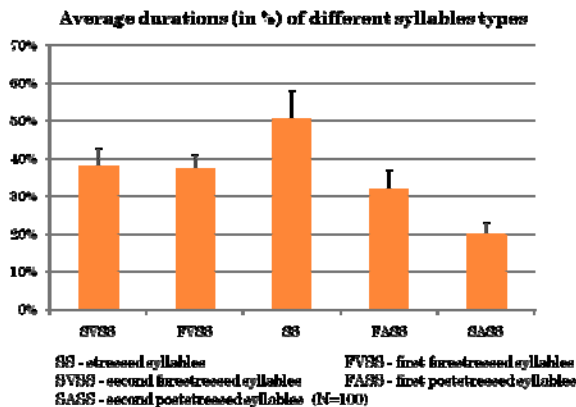
The syllable duration was measured in time-scale with precision of 0,01sec and the intensity (in 0,01 dB) were exported as digital data to spreadsheets in Excel (MS Excel, 2003) and were further analyzed. In an observed phrase or sentence the longest syllable duration was taken as 100% and all other syllable durations were presented as a proportion (in %). [5, 9]. The same was done with the other acoustic properties of the syllables – intensity, pitch etc. Proclitics and enclitics were observed as unstressed syllables in the relevant position. The relative frequency of the amplitudes in a given syllable were calculated and put into further statistical analysis in Excel (MS Excel, 2003). The results were shown as graphics made in Excel (MS Excel, 2003).

## 3. MODELS

In each suggested model the Tilkov's syllable typology was used as rhythm measures: stressed syllables (SS), fore-stressed syllables (VSS) and post-stressed syllables (ASS) in a relevant position (first, second etc.) shown in the following table (example: in English "maths"; in Bulgarian "ма-те-ма-ти-ка"):

Ma	Te	ma	ти	Ka
SVSS <i>second fore- stresses syllable</i>	FVSS <i>First fore- stressed syllable</i>	SS <i>Stressed syllable</i>	FASS <i>First post- stressed syllable</i>	SASS <i>Second post- stressed syllable</i>

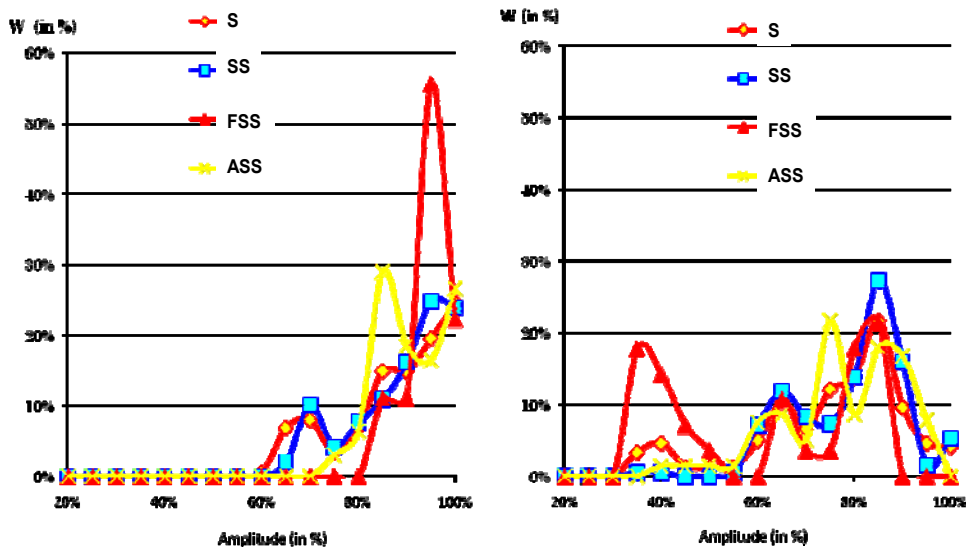
In Fig. 1 are shown own empirical data for the durations of different syllable types.



**Fig. 1** Durations of different syllable types in Bulgarian

Vowel reduction in positions after the stressed syllable and a significant difference between the durations of stressed and unstressed syllables were empirically proved.

In the suggested model, we use the dependence between the relative frequency of the amplitude and the amplitude proportion in every given syllable type (Fig. 2).



**Fig. 2** Distribution of the relative amplitude frequencies of every given syllable type in fluent (to left) and dysfluent speech (to right).

The preliminary results show difference between the distributions of the relative amplitude frequencies of the chosen syllable types in fluent and dysfluent speech (cluttering).

Additionally, differences between the relative amplitude frequencies of different types of speech manner in the same language phrase or sentence were calculated. Intuitively, this variability of the rhythmic properties could be a measure of speech emotiveness.

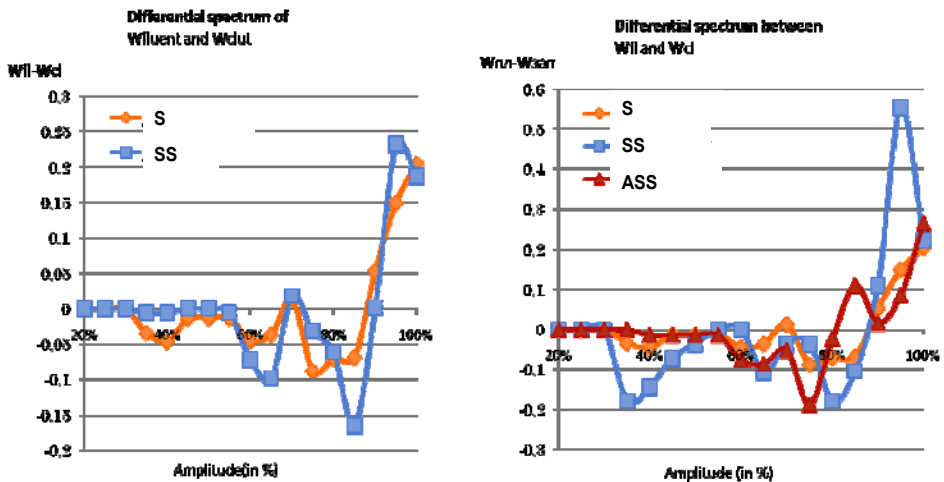


Fig. 3 Differences between relative amplitude frequencies of different speech manner in the same syllable sequence. S – syllable; SS – stressed syllables; ASS – post-stressed syllables.

Additionally, we use confidence interval for the average values and the dispersion of the peaks in differential spectra.

The second model uses the intuitive relationship between the respiratory cycle and the rhythmic properties of the syllable structure according to their position in the cycle.

Since the respiratory cycle (neurophysiological factor) is affected by the emotional state of the speaker, on one hand, and directly influences the speech onset, on the other, it is important to study and analyze this dependency.

We suggest the following model for analysis of variations of the described above measures of each syllable type in a given respiratory cycle. For this purpose we range the syllables of the spoken fragment in the observed cycle.

“Relative” syllable positions in a given respiratory cycle were calculated as the division of the real syllable position ( $P_i$ ) to the total number of syllables in the specific cycle ( $N_j$ ) ( $P_i = P_i / N_j$ ). Thus, we adjust the scale for further comparative analysis.

In order to calculate the average values of all functions (Syllable durations vs. Relative syllable positions in a given Resp cycle), we use the method of the moving averages.

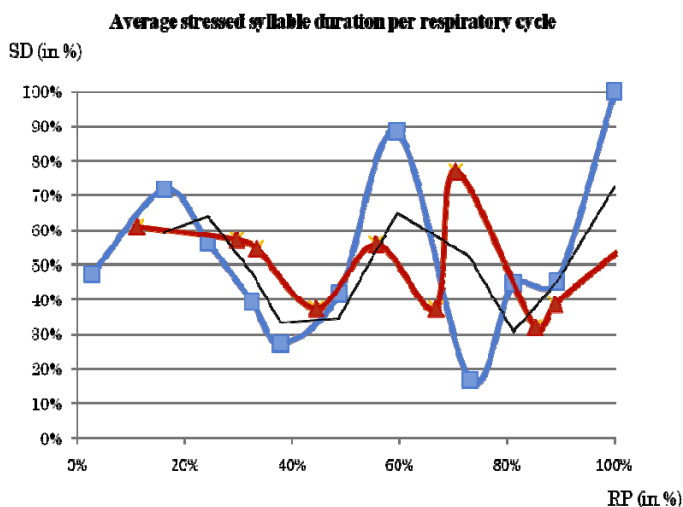


Fig. 4 Duration of stressed syllables in given respiratory cycles. SD – syllable duration; RP – respiratory cycle;

In the second model we use ANOVA to analyze the dependences between the measures and the positions (range) of the syllables in a given respiratory cycle.

Additional information for the observed linguistic, phonological and phonetic correlates of the emotiveness in the Bulgarian language could be obtained by a novel approach of analyzing the dependence measures between random events, suggested by Dimitrov (2008, not published).

**Definition 1.** The number

$$\delta(A, B) = P(A \cap B) - P(A)P(B)$$

is called a correlation between the two random events A and B.

**Definition 2.** Regression coefficient:

$$r_B(A) = P(A | B) - P(A | \bar{B})$$

#### 4. EMPIRICAL ESTIMATION OF THE DEPENDENCE MEASURES BETWEEN TWO RANDOM EVENTS

The fact that the dependence measures between random events are based on their probabilities makes them very attractive, and in the same time convenient and easy for statistical estimation and practical use. It is well known that the statistical definition of probability is

$P(A) = k_A / N$ , where within  $N$  independent repetitions of the experiment the event  $A$  has happened  $k_A$  times.

So all the probabilities included in the definitions of the mentioned above dependence measures can be statistically estimated.

Estimation of the correlation between the two random events  $A$  and  $B$ :

$$\hat{\delta}(A, B) = \frac{k_{A \cap B}}{N} - \frac{k_A}{N} \cdot \frac{k_B}{N}$$

Estimations of the two regression coefficients:

$$\hat{r}_A(B) = \frac{\frac{k_{A \cap B}}{N} - \frac{k_A}{N} \cdot \frac{k_B}{N}}{\frac{k_A}{N} (1 - \frac{k_A}{N})}; \quad \hat{r}_B(A) = \frac{\frac{k_{A \cap B}}{N} - \frac{k_A}{N} \cdot \frac{k_B}{N}}{\frac{k_B}{N} (1 - \frac{k_B}{N})},$$

Usually, a lot of complicated procedures for multidimensional statistical analysis are used in this area. It would be interesting to compare the results of this new empirical estimation of the dependence measures between two random events with those estimated with the traditional approach.

## 5. CONCLUSIONS

The preliminary results showed that a systematic approach for observation of the emotiveness and other psycho-physiological factors affecting the speech rhythm is possible. These models might be used for different diagnostic and therapeutic purposes in the fields of psychology, speech and language pathology etc.

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# A Relational Model of Personality Psychological Tests

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**Abstract:** A mathematical description of psychological assessment with the aid of personality tests is discussed in this article. A relational model of data, needed to design a computer system for automation of certain psychological assessments is suggested. The described model could be used to develop real software – generator of personal psychological tests.

## 1. GENERAL CONCEPTS AND DEFINITIONS

This piece of writing continues and adds the article [9], accepted for publishing in the present volume.

*Personality tests* are those psychological tests, which are purposed for description and evaluation of the characteristics of conative (behavioral), emotional and motivation sphere, the interpersonal relations and attitudes of an individual [14]. It's typical for the Personality questionnaires (in contrast to Achievement tests or Intelligence tests) where the items are questions or statements, for which answers the respondent has to independently report certain information concerning himself, his experience and relations. The format of the answers to items is also specific – most often they are described with the help of a finite set of preliminary known answers or statements. For more details concerning the general concepts in the field of personal computer testing see [9, 14, 15].

There are different ways to structure, process and store data in a software product. Data and data links are abstraction of facts and relations from the real world. Very often this abstraction is rather complex and requires a special mathematical model for its description – a *data model*. The use of one or other model means that in certain information system are chosen different principles for data structuring or data operation. The most wide-spread data model nowadays is the relational model [6, 10, 11], suggested for the first time by E. F. Codd at the beginning of the 1970s of the last century and described in a set of articles, the first of which is [2].

Let the family of sets  $D = \{D_1, D_2, \dots, D_m\}$  be given, which we will call *domains*. Let's examine the Cartesian product:

$$W = D_{i_1} \times D_{i_2} \times \dots \times D_{i_n} = \{ \langle x_1, x_2, \dots, x_n \rangle \mid x_k \in D_{i_k}, D_{i_k} \in D, k = 1, 2, \dots, n \}.$$

(It is possible for some  $s$  and  $t$ ,  $D_{i_s} = D_{i_t}$ .) Each subset

$$\rho \subseteq W$$

is called *n-ary relation* in  $D$ . From a practical point of view the finite relations are of interest, i.e. all possible finite subsets of  $W$  and therefore in the present piece of writing „relation” will mean „finite relation” (besides the opposite is explicitly emphasized), no matter it is supposed that the sets  $D_i$ ,  $i=1,2,\dots,m$  could possibly be infinite (for example infinite sets of real numbers).

Let's mark with  $R$  the set of all  $n$ -ary relations formed by  $n$ ,  $n=1,2,\dots$  (not definitely different) sets (domains) from the family  $D$ .

Let  $\rho \in R$  and let  $r^i = \langle r_1^i, r_2^i, \dots, r_n^i \rangle$  be the  $i$ -th element of  $\rho$ .  $r^i$  is called the  $i$ -th *record* of the relation  $\rho$ . In this case  $i$  is an element index, not an exponent. The component  $r_j^i$  of  $r^i$  is called *value of the  $j$ -th attribute in the  $i$ -th record of  $\rho$* . The values of the  $j$ -th attributes of all records of  $\rho$  make the  $j$ -th *field* of  $\rho$ . From the definition of the term field follows that the elements of  $j$ -th field can receive values from one sole domain  $D_{i_j} \in D$ .

In the set  $R$  of all relations in  $D$  in certain circumstances it is possible to define various operations – union, intersection, subtraction, complement, projection, composition, indexing, sorting, etc. Relationships responding to certain conditions are possible between the separate attributes. Thus  $R$  together with the introduced operations and relationships between attributes turns into algebra, called *relational algebra*. Relational algebra is in the base of relational data model. The systems for managing databases, which have the relational model in their bases, are also called *relational databases*. Basic knowledge in the field of the theory of relational algebras can be obtained in [3], and for more details see for example [7].

Each relation  $\rho \in R$  could be visually presented like a rectangular table in which the  $i$ -th row is the  $i$ -th record, and the  $j$ -th column is the  $j$ -th field of  $\rho$ . This correspondence is one-to-one, i.e. the so built table completely determines the relation presented by it. Due to that reason and to help each user easily understand the main notions of relational algebra, in the most of software manuals for relational database [5, 6, 12] they talk about and operate mostly with the notion *table* as a synonym of the notion relation in the family of domains, never mind that from a practical point of view there could be a greater number of table types and not every table could present concrete relation, i.e. not every type of table could be used in a software for relational database.

At this moment there is a great number of softwares, by the means of which is possible to make a relational database management. In that piece of writing we have decided to make use of the possibilities for programming

given by C++ algorithmic language in an environment of Borland Development Studio [1, 5, 12]. Our purpose is to develop software for automation of psychological assessments and to be more precise – software for computer administering of personal psychological testing. The software that we are developing must automatically generate a relational database, fitted to the specific needs of the research psychologist, which will be in a great use in his further personal psychological assessments through computer testing. That software together with some additional program products (if needed) we will call system – *generator of personal psychological tests*.

## **2. SETS OF VALUES OF PERSONALITY PSYCHOLOGICAL TEST**

To create a Personality psychological test the following sets have to be defined:

**2.1.** The set  $Qst$  is compound of questions or statements, presented for answer or opinion to the tested individual or group of people from the research psychologist. The elements of  $Qst$  are called *items*.

The presenting order of the items has a significant meaning for the psychologist, as the sequence of the discussed items has influence to answers and therefore is important for drawing the final conclusion and test results interpretation. In this relation arises the need of next set:

**2.2.** Set  $Z_m = \{1, 2, \dots, m\}$ , where  $m = |Qst|$  is the cardinal number of the elements of set  $Qst$ . Between set  $Z_m$  and set  $Qst$  exists one-to-one (bijective) mapping  $\varphi \subset Qst \times Z_m$ , and the author of the psychological test for each  $q \in Qst$  has to very carefully define the image  $k = \varphi(q)$  of the element  $q$  in the mapping  $\varphi$ . In this case  $k$  is a number of the item  $q$  and determines the order of items presentation to the tested individual. As it was above emphasized, determining the number of each item is important for the final conclusion and all that is in the competence of the psychologist – author of the test. In addition the number must be in the interval  $[1, m]$  of natural numbers. In this sense in a database management system, needed for computer Personality psychological test (Tests generator) development when deleting an item or inserting a new one between two existing items, an automatic items renumbering has to be provided. In this sense the field  $Z_m$  is quite different from the auto increment field envisaged in a number of database management systems, which serves a primary key. For fields of that type the above mentioned operations division and item insertion are not

followed by renumbering, even more it's not allowed to make changes in the primary key value. [5, 12].

**2.3.** Finite set  $Ans$  of possible answers to the items. The most wide-spread concrete implementations of the set  $Ans$  are  $Ans=\{\text{"Yes"}, \text{"No"}\}$ ,  $Ans=\{\text{"Yes"}, \text{"I can't say."}, \text{"No"}\}$ ,  $Ans=\{\text{"Definitely Yes"}, \text{"Somewhat Yes"}, \text{"Undecided"}, \text{"Somewhat No"}, \text{"Definitely No"}\}$ ,  $Ans=\{\text{"Always"}, \text{"Often"}, \text{"Sometimes"}, \text{"Never"}\}$  etc.

**2.4.** A set  $Ctg$  of *psychological categories (Personality characteristics)*, which are subject of analysis and evaluation concerning the assessed individual or group of people with the aid of the items from the set  $Qst$  and the concrete answer that is chosen. It is not obligatory for each item to be related to given psychological category.

We are examining the finite family of subsets of  $Qst$

$$T = \{T_c \subseteq Qst \mid c \in Ctg\},$$

with the element  $q \in Qst$  which belongs to the subset  $T_c$ , if and only if the item  $q$  has a relation to the category  $c \in Ctg$  in the correspondent psychological assessment. Obviously  $\bigcup_{c \in Ctg} T_c \subseteq Qst$  and if  $q \in Qst$

and  $q \notin \bigcup_{c \in Ctg} T_c$ , then the item  $q$  will not effect the entire test and will drop out.

**2.5.** We are examining the following family of numeric sets:

$$\{S_a \mid a \in Ans\}.$$

We are constructing the set:

$$Scl = \prod_{a \in Ans} S_a = \{ \langle s_1, s_2, \dots, s_k \rangle \mid s_i \in S_i, i=1,2,\dots,k, k=|Ans| \}.$$

Obviously the number of all sets of the type  $S_a$  is equal to the cardinal number of the set  $Ans$ . Each element  $s \in S_a$  of the set  $S_a$ ,  $a \in Ans$  from a practical point of view represents an assessment numerical value of the psychological categories from the set  $Ctg$  on condition that the assessed person could possibly respond to a random item with an answer or a

statement  $a \in Ans$ . Quite often these assessment values are 1 or 0. For example, if  $|Ans| = 2$  and we assume that the assessment value for each positive answer is equal to 1 and for each negative answer is 0, then we can easily calculate the total number of positive answers.

Let's remind that a binary relation  $f \subset A \times B$  is called *function*, if for each  $x \in A$  there is no more than one  $y \in B$ , so that  $\langle x, y \rangle \in f$  [3, 4]. The fact that  $f \subset A \times B$  is a function is presented also like that  $f: A \rightarrow B$  and instead of  $\langle x, y \rangle \in f$ , we write  $y = f(x)$ .

For each psychological category  $c \in Ctg$  is defined one function  $f_c: Qst \rightarrow Scl$  with the aid of which the psychologist evaluates the assessed person regarding the category  $c \in Ctg$ . Such function is called a *scale for the psychological category*  $c \in Ctg$ . It's a common practice the name of the scale to be exactly the same as the name of the psychological category. The set of functions  $\{f_c | c \in Ctg\}$ , composed by all scales for the examined psychological categories is called a *scale for the Personality psychological test*.

What is the assessment of the different items, regarding the correspondent answers, i.e. how the functions are defined  $f_c: Qst \rightarrow Scl$ ,  $c \in Ctg$  and what is the influence of this to the summary assessment of the test implementation can be estimated after wide psychological and statistical investigations [8, 13, 14, 15].

**2.6.** Let  $c \in Ctg$  and let

$$m_c = \min \sum_{q \in Qst} \mu(f_c(q)),$$

where

$$\mu(\langle x_1, x_2, \dots, x_k \rangle) = \min(x_1, x_2, \dots, x_k).$$

In other words  $m_c$  is the minimum assessment value (minimum score), which could possibly be obtained in a random testing, related to the category  $c \in Ctg$  and depending on the correspondent scale  $f_c: Qst \rightarrow Scl$ . Analogously we specify the maximum assessment value

$$M_c = \max \sum_{q \in Qst} \nu(f_c(q)),$$

where

$$\nu(\langle x_1, x_2, \dots, x_k \rangle) = \max(x_1, x_2, \dots, x_k).$$

Obviously,  $m_c < M_c$ . We are examining the finite sequence of numbers  $m_c = b_0 < b_1 < \dots < b_{k-1} < b_k = M_c$ . We are separating the interval  $[b_0, b_k]$  to the subintervals  $[b_0, b_1]$ ,  $(b_1, b_2]$ ,  $(b_2, b_3]$ ,  $\dots$ ,  $(b_{k-1}, b_k]$ . Let's mark with  $D_c$  the set of all intervals of that type  $\Delta_1 = [b_0, b_1]$  and  $\Delta_i = (b_{i-1}, b_i]$ ,  $i = 2, 3, \dots, k$ , corresponding to the category  $c \in Ctg$ . For each  $\Delta_i \in D_c$  we create text  $t_i$ ,  $i = 1, 2, \dots, k$ , corresponding to the text given by a professional psychologist about the psychological condition of the assessed person regarding the psychological category  $c \in Ctg$ , in case that the *total summary* (the sum of the values for each item according to the scale  $f_c$ ) belongs to the interval  $\Delta_i$ .

The number  $k$  and each of the intervals  $\Delta_i$ ,  $i = 1, 2, \dots, k$  should be a result of profound psychological investigations.

Let  $N_c = \bigcup_{i=1}^k t_i$ . For each  $c \in Ctg$  we have functional dependency  $g_c : D_c \rightarrow N_c$  and let

$$G_c = \{ \langle \Delta_i, t_i \rangle \mid g_c(\Delta_i) = t_i, i = 1, 2, \dots, k \}$$

be the corresponding binary relation, in conformity with this dependency (graph of the function  $g_c$ ). The function  $g_c : D_c \rightarrow N_c$  is called *interpretation* of the test, regarding the psychological category  $c \in Ctg$ .

Thus we come to construction of the relation

$$Ntp = \bigcup_{c \in Ctg} G_c \subset \bigcup_{c \in Ctg} D_c \times N_c.$$

### 3. RELATIONS, RELATIONSHIPS AND FILES IN A SOFTWARE - GENERATOR OF PERSONALITY PSHYCHOLOGICAL TESTS

To create a certain computer Personality test the system-tests generator makes a lot of files - the database which is needed for the test implementation and for analysis of the test results. Let's mark with *DBName* the name of that set (database) which actually will also be the name of the test. That name is given in the beginning by the author (the operator) of computer test. For convenience all files, created by the system-test generator must have the same name (which was conditionally named *DBName*) with a *suffix* (ending, end) added. We must note that this

suffix is a part of the name and has not be confused with the file extension, which most often gives information about the file type.

**3.1.** The file *DBName.Ans* is a text file, a linear list containing the set *Ans* of all possible answers to various items. For convenience it is good to write down the number of those answers at the beginning.

**3.2.** The file *DBName\_Qst.Db*, which contains all information about the relation  $\varphi \subset Qst \times Z_m$  described in section 2.2. It's convenient to index this file in ascending order concerning the field  $Z_m$ , i.e. in ascending order of the item numbers and this field to be set out visually before the field *Ans*.

**3.3.** The contents of the file *DBName\_Ctg.Db* is set out visually like one-column table (a one field relation, here we skip the needed working fields) and contains the names of all psychological categories, used in the test. As we will later use the elements of this relation for operands in relational operations, it is not expedient to use the more simple structure linear list (as the one in the file *DBName.Ans*), and this will be a file with special structure according to the concrete system used for database management (for example Paradox type Data file).

**3.4.** In file *DBName\_Scl.Db* is recorded the data of table (relation) with  $k$  fields, where  $k = |Ans|$  is the number of the possible answers of each item. Each record (row) in this table represents the possible assessment values according to the scales  $f_c : Qst \rightarrow Scl, c \in Ctg$ . The number  $k$  is taken from the beginning of the file *DBName.Ans*, and the remaining elements of the linear list, represented by this file, are used for a heading (title) of each column at table visualization. The difficulties for the creation of this file come from the fact that the number of the fields of this table are not preliminary specified, which is not typical and it is not a common practice while working with the relational database management systems [11]. The unspecified number of the fields involves a work with dynamic data structures and dynamic creation of each field.

**3.5.** It is convenient the tables *DBName\_Qst*, *DBName\_Ctg* and *DBName\_Scl* to be set out visually on the same screen, as we will connect a part of the records in a new relation  $DBName\_Bnd \subseteq Ctg \times Qst \times Scl$ . This will be realized by the use of a

button „Connect” by which we will generate new records in  $DBName\_Bnd$ , in accordance with the current records respectively in  $DBName\_Qst$ ,  $DBName\_Ctg$  и  $DBName\_Scl$ . The content of this new relation is recorded in the file  $DBName\_Bnd.Db$ . Here the use of dynamic data structures for dynamic creation of some of the fields is needed again. The meaning of each record in  $DBName\_Bnd$  is for the category  $c \in Ctg$  and for the item  $q \in Qst$  which assessment (score) is given, if the assessed person gives the correspondent answer  $a \in Ans$  according to the scale  $f_c(q)$ . In this sense for a more clear visualization of  $DBName\_Bnd$  between the tables  $DBName\_Ctg$  and  $DBName\_Bnd$  is convenient to implement a relationship of the type Master – Detail, where Master Source is the table  $DBName\_Ctg$ , and Master Field is the field  $Ctg$ .

Since for each  $c \in Ctg$  the scale  $f_c \subset Qst \times Scl$  is a function, then the system has to watch and produce appropriate messages if in  $DBName\_Bnd$  we have two records with equal couple of values in  $Ctg \times Qst$ . From a psychological point of view that means that it is impermissible for a given psychological category, a certain item to be assessed by two different ways.

**3.6.** The implementation of analogical relationship of the type Master – Detail and between tables  $DBName\_Ctg$  and the next table  $DBName\_Ntp$ , created by the system – Generator of personality psychological tests and recorded in file  $DBName\_Ntp.Db$  is expedient. The contents of  $DBName\_Ntp$  represents the relation  $Ntp$  described in section 2.6, which is union of the test interpretations of the examined psychological categories. Each of the interpretations actually represents the subset of the Cartesian product  $D_c \times N_c$ ,  $c \in Ctg$ , where  $D_c$  and  $N_c$  are the sets examined in section 2.6 (and there is a functional dependence between them).

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# Signaling Delay in Wireless Networks with Session Initiation Protocol over User Datagram Protocol

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**Abstract.** *An important aspect of VoIP services over the wireless systems is signaling. Before a user can start a VoIP session, the end-user terminal has to establish the session using signaling protocols, e.g. Session Initiation Protocol in order to negotiate media parameters. The time interval to perform the signaling is called the session initiation delay. It can be affected by the quality of the wireless link, measured in terms of frame error rate, which can result in retransmissions of packets lost and can lengthen the session initiation delay. The present paper aims at to give a more complete and accurate evaluation of the Session Initiation Protocol session initiation delay.*

## 1. INTRODUCTION

An important aspect of Voice over Internet Protocol (VoIP) services over the wireless systems is signaling. Two different signaling schemes evolved for VoIP services. The first one is H.323, specified by International Telecommunication Union standardization group (ITU-T), for the implementation of multimedia services over packet-based networks. The other one, developed by the Internet Engineering Task Force (IETF), is the Session Initiation Protocol (SIP). SIP is an application-layer control protocol that can establish, modify and terminate multimedia sessions or calls. Unlike H.323, SIP is specifically defined for the Internet.

While VoIP quality has been extensively studied in [7], session setup time for VoIP has received relatively less attention. The session initiation delay has a direct impact on the users' satisfaction. The user is satisfied if waiting for session setup a maximum of 11seconds and expects to experience the same even if the technology is new [2].

The wireless networks are highly erroneous due to fading, shadowing, and even intermittent disconnections, which can result in a frame error rate (FER) as high as 10 percent [4]. Therefore, the session initiation delay should be evaluated for wireless networks with experiencing high error rates. The design of optimal robustness mechanisms in signaling protocols is an important issue. In [1], the session initiation delay over public Internet is evaluated for SIP through cascaded queueing nodes and P-K formulas. Using simulations authors of [3] investigate the SIP session initiation delay

in the 3GPP context. The session initiation delay is defined [3] as the period of time between the instant the originator of a session triggers the "initiate session" command and the instant the initiator receives a message stating that the other party has been alerted. In an important study [6], the performance of H.323 is evaluated in terms of average call setup delay, considering the RLP and the H.323/TCP/RLP stack. In [2], to reduce the session initiation delay, the implementation of an adaptive retransmission timer that is adjustable to the SIP transaction as well as appropriate choice of the protocol stack have been proposed. The mean queuing delays of the SIP servers and source and destination terminals are investigated using M/M/1 and M/G/1 queues. The authors also assume the Internet delay for transmitting the SIP messages that is constant, and equal to 100 ms[2]. However, these assumptions are not realistic in common case. Thus, in the literature there is no (to the knowledge of the author) study on the SIP session setup time giving the realistic delay due to high error rates in the wireless networks. This is the motivation behind this paper.

The present paper aims at to give a more complete and accurate evaluation of SIP over User Datagram Protocol (UDP) signaling delay in wireless networks.

## **2. SIP OVER UDP**

SIP is a client-server protocol and defines two basic classes of network entities: client and server. A client is any network element, such as a PC with a headset attachment or a SIP phone, which sends SIP requests, and receives SIP responses. A server is a network element that receives requests and sends back responses, which accept, reject or redirect the request. Note that client and server are logical entities. Their roles last only for the duration of a certain transaction, which means a client might also be found within the same platform as a server. For example, SIP enables the use of proxies, which act as both client and servers for the purpose of making requests on behalf of other clients.

Four different types of servers exist: proxy, user agent server (UAS), redirect server and registrar. Proxy servers are application-layer routers that are responsible for receiving a request, determining where to send it based on knowledge of the location of the user, and then sending it there. To those other entities, it appears as if the message is coming from the proxy rather than from some entity hidden behind the proxy. A proxy must implement both the client and server requirement of one specification. It is also useful for enforcing policy and for firewall traversal. A UAS is a logical entity that generates a response to a SIP request and contacts the user. In reality, a SIP device (such as a SIP-enabled telephone) will function as both a user agent client (UAC) and as a UAS, which enables SIP to be used for peer-to-peer communication. A redirect server is a server that accepts SIP requests,

maps the destination address to a set of one or more addresses, and returns the new routing information to the originator of the request. Thereafter, the originator of the request can send a new request to the address(es) returned by the redirect server. A redirect server does not issue any SIP requests of its own. A registrar acts as a front end to the location service for a domain, reading and writing mappings based on the contents of the REGISTER messages. Then SIP proxy servers, which are responsible for sending a request to the current host that the callee is reachable at, will consult this location service. If the user being called doesn't exist in the registrar, then the proxy will return a 404 Not Found.

Upon reception of the INVITE, the UAS sends its media parameters (e.g. the endpoint can request certain codecs, sampling rates, or even a packaging protocol other than RTP, which is very rare) to the UAC using Session Description Protocol (SDP). Then, the UAC decides on the proposed media parameters and returns its answer back to the UAS. The UAC sends a 200OK for reserving resources along the path and receives a ringing tone together with the 180 response. When the called party decides to accept the call (i.e., picks up), a 200OK response is sent. The final step is to confirm the media session with an acknowledgment request ACK. Then, the media session is established.

The session initiation delay depends on a number of factors. The most obvious factors are the transmission delay over the wireless network, which may experience losses, and the queuing and Internet delays. This transmission delay can be affected by the transport protocols used and their error recovery strategies. SIP messages can be carried by User Datagram Protocol (UDP) or Transmission Control Protocol (TCP). UDP is the widespread SIP transport protocol [5]. When SIP is carried by UDP, the reliable delivery procedures are ensured by SIP (application layer) and each end has to acknowledge the data it receives from the other end. But, these data and acknowledgments can get lost through the wireless network. Each end handles this by setting a timer when it sends data and, if the data is not acknowledged when the timer expires, it retransmits the data (stop and wait mechanism). The SIP timer is an estimate of the Round-Trip Time (RTT) and its default value is 500ms, but it is recommended to be larger in case of high latency access links[2]. The queuing delay depends on the load of the different servers involved in the communication path. The Internet delay depends on the number and utilization of routers and the type of used communication channels (links).

Therefore, the average session initiation delay is the cumulative delay due to the transmission, and the queuing. The session initiation delay is as follows:

$$(1) \quad T_{\text{session}} = T_q + T_{t_{\text{UDP}}}$$

where  $T_q$  is queuing delay in the different servers used to serve SIP messages,  $T_{t_{UDP}}$  varies, reflecting the transport, network and data link protocols used to convey SIP messages through the network/s. Note that number of the necessary SIP messages to set up a VoIP session using SIP over UDP is  $M=5$  (tabl. 1).

The present paper discusses only the transmissions delay of SIP over UDP in wireless networks.

### 3. TRANSMISSION DELAY FOR SIP OVER UDP

User Datagram Protocol (UDP) is unreliable transport protocol. In order to ensure the reliable delivery of the SIP requests and responses (involved in the various transactions), retransmission mechanism is needed at the user agent client and the user agent server.

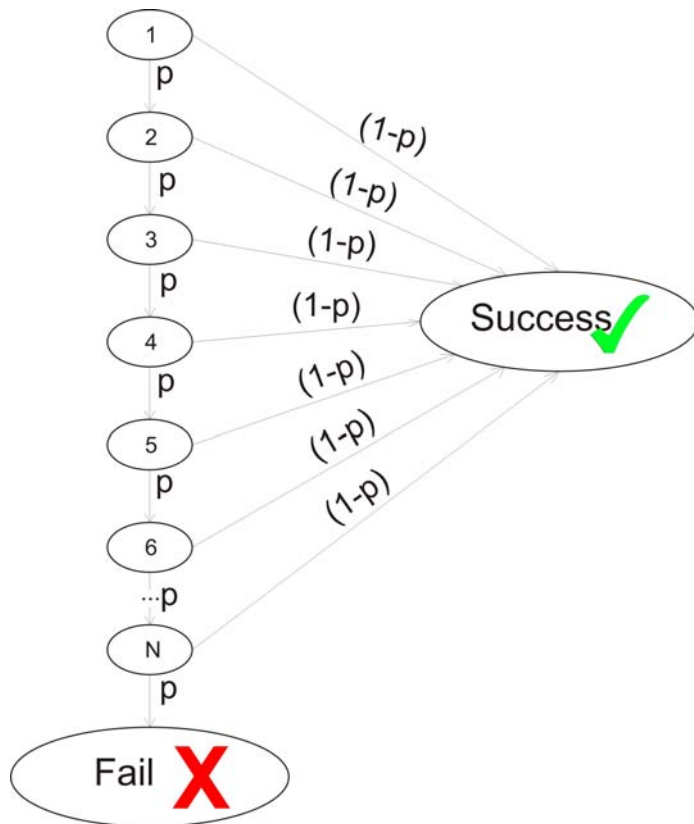


Fig. 1

As mentioned above the both UAC and UAS send a datagramme containing a SIP message and wait for receiving the corresponding

acknowledgment. If retransmission timer expired, UAC or UAS sends again the same datagram. Let N be the maximum number of retransmissions (for SIP, it is fixed to N= 7) before to fail. It is interesting to investigate can implementation of the simplest “stop and wait” retransmission mechanism satisfy users of SIP- based VoIP wireless networks.

Let p be the probability of a frame being erroneous in the air link. Therefore, (1- p) is the probability of a datagram not being in error in the radio link (fig. 1) and:

$$(2) \quad P\{\text{success}\}=1-p^N$$

$$(3) \quad P\{\text{fail}\}=p^N$$

$$(4) \quad P\{k^{\text{th}} \text{ attempt of retransmission}\} = (1-p).p^{k-1}$$

Note,  $k^{\text{th}}$  attempt of retransmission is preceded by (k-1) times of retransmission timer expired or (k-1) realized timeouts. Therefore, the average delay due to timeouts-  $T_{\text{out}_{\text{Delay}}}$  (preceded successful transmission of an UDP datagram) is as follows:

$$(5) \quad T_{\text{out}_{\text{Delay}}} = \frac{1-p}{1-p^N} T \sum_{k=0}^{N-1} k p^k ; 0 < p < 1$$

The formula (5) can be expressed as follows. From mathematics the power sum when  $|p|<1$  is:

$$(6) \quad \sum_{K=0}^n p^K = \frac{1-p^{n+1}}{1-p}$$

The following equation is received by differentiation of this well-known formula (6). It is differentiable when  $|p|<1$ .

$$(7) \quad \sum_{k=0}^n k.p^{k-1} = \left( \frac{1-p^{n+1}}{1-p} \right)'$$

The following equations are received by multiplying with p both sides of (7):

$$(8) \quad \sum_{k=0}^n k.p^k = \left( \frac{1-p^{n+1}}{1-p} \right)' \times p$$

$$(9) \quad \sum_{k=1}^n k.p^k = p \frac{(1-p^{n+1})'(1-p) - (1-p^{n+1})(1-p)'}{(1-p)^2} = \frac{n.p^{n+2} - (n+1).p^{n+1} + p}{(1-p)^2}$$

Therefore, the average delay  $T_{UDPi}$  for the successful transmission of the  $i^{th}$  UDP datagram is as follows:

$$(10) \quad T_{UDPi} = D_{e2e} + T_{out\_Delay} = D_{e2e} + \frac{(N-1) \cdot p^{N+1} - N \cdot p^N + p}{(1-p)(1-p^N)} T$$

This equation (11) is a result of substitute (5) and (6) for  $T_{out\_Delay}$ . The maximum number of retransmissions for SIP is  $N=7$ .

As mentioned above the retransmission timer-  $T$  should not be too short, otherwise the packet is transmitted while a response is on the way to be received, and it should not be too long to avoid increasing the session setup unnecessarily if a loss occurs, i. e:

$$(11) \quad T \approx RTT = 2 \cdot D_{e2e} + Delay_{Queueing},$$

where  $D_{e2e}$  - the end-to-end network delay.

The delay for a successful transaction is the average delay for successfully transmitting an UDP datagram containing a SIP message and successfully receiving the corresponding acknowledgment. This is because the sender knows that its sent packet has successfully been received when it receives an acknowledgment. For instance, UAC knows that its sent packet- INVITE has successfully been received when it receives 183 response. The session setup consists of the successful completion of the client-side and server-side transactions.

Therefore, the total delay for setting up the session is the addition of the delays for queueing and transmitting all the  $M=5$  messages necessary to set up a VoIP session using SIP over UDP. The average session initiation delay  $T_{session}$  is given as:

$$(12) \quad T_{session} = T_{qi} + T_{t\_UDP} = \sum T_{qi} + T_{UDPi} =$$

$$= M \cdot (T_{qi} + D_{e2e} + \frac{(N-1) \cdot p^{N+1} - N \cdot p^N + p}{(1-p)(1-p^N)} T)$$

#### 4. NUMERICAL RESULTS

This section presents the results of the average session initiation delay for SIP over UDP as transport protocol. The model introduced in the previous section implies that the average SIP session initiation delay increases with the FER ( $p$  in the model).

Messages Size for SIP over UDP Session Setup is shown in tabl.1. From these values ( $M=5$ ) average SIP messages size can be obtained as follows:

$$(13) \quad L_{SIP} = \frac{1}{M} \sum_{k=1}^M L_k = 625 \text{ bytes}$$

Tab. 1:

Messages	Payload size, bytes	Message size, bytes
SIP INVITE	700	728
SIP 183	835	863
SIP PRACK	558	586
SIP 200 OK	545	573
SIP 180	349	377

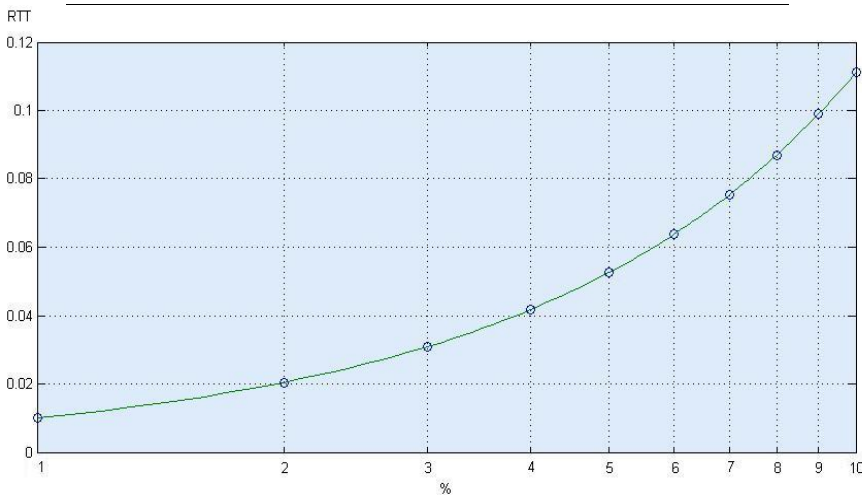


Fig. 2

Fig. 2 shows the results for SIP over UDP transmission delay in RTT, not in seconds. It is assumed that the retransmission mechanism is with a fixed timer and retransmission timer is equal in RTT ( $T=RTT$ ). As can see from fig. 2, for SIP over UDP with the fixed timer, the FER influence the session initiation delay, as increasing FER lead to increasing delay transmission.

The average signaling delay is depicted on fig.3 with assumptions that  $De2e= Tqi= 100 \text{ ms}$  and  $T=RTT=1s$ . These values are chosen same as values used in [2]. As can see the average SIP session initiation delay increases with the FER, but it is not exceed the maximum of 11s which meets the requirements of users, even if FER is 10% (the target FER for VoIP sessions is expected to be between 1-3%).

In order to optimize the SIP session initiation delay, some error correction mechanisms or hybrid ARQ schemes could be employed in order to avoid retransmissions on the wireless link.

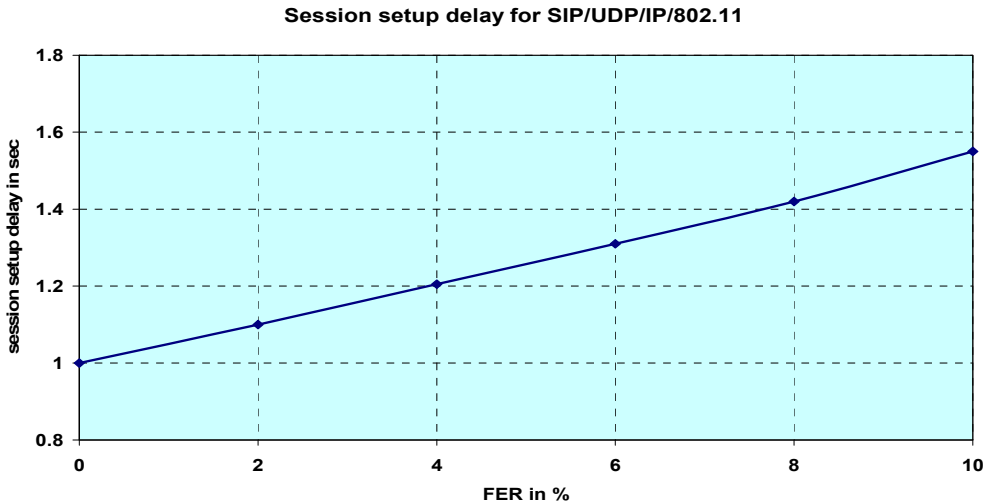


Fig. 3

## 5. CONCLUSIONS

This article provides an analysis on SIP by describing the SIP protocol stack, summarizing the main protocol features over UDP. The article also proposes formulae (12) for signaling delay for SIP over UDP in Wireless Networks.

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# Experiences with the Facebook API: a Case Study

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**Abstract:** *This paper describes the experiences gained with developing an alternative Windows-based Facebook client application by extensively using the published Facebook API. Combined with Microsoft's WPF and .NET Framework 3.5, this new application provides the user with a more intuitive and friendlier Facebook interface. Some of the functionalities that the application provides include a graph representation of the user's social network; the management and organization of photo galleries; and the viewing of video clips in a custom-made media player.*

**Keywords:** *Facebook, API, Windows, interface, social network, case study*

## 1. INTRODUCTION

The concept of a social network is not new phenomenon. Networking between people is as old as humanity. Typically, networking has been, and is still used, for business contacts and friendship circles. However, the availability of an online social network via specialized websites is a relatively modern innovation and has now become firmly entrenched as part of everyday web life. Social networking websites function like an online community of Internet users. Depending on the website in question, many of these online community members share a common interest such as hobbies, occupation, or politics via their own personal web pages which contain information about them. Some of the most popular social network websites are *Facebook* [1], *MySpace* [2] and *LinkedIn* [3]. This paper deals with the *Facebook* website, and, in particular, its user interface.

Wikipedia [4] describes *Facebook* as "a free-access social networking website that is operated and privately owned by Facebook, Inc. Users can join social networks organized by city, workplace, school, and region to connect and interact with other people. People can also add friends and send them messages, and update their personal profiles to notify friends about themselves".

Facebook Inc. announced in May 2007 its plans to open up its *Facebook* API to third-party developers, thus allowing anyone to create extendable widgets for use on *Facebook* pages. Essentially, the *Facebook* API allows web developers to create *Facebook* applications and access *Facebook* data from other applications.

## 2. LIMITATIONS OF THE CURRENT *FACEBOOK* INTERFACE

Specifically, the work described in this paper is an investigation of the *Facebook* API via the development of a different *Facebook* interface. Some users of the *Facebook* website have expressed dissatisfaction with the current *Facebook* interface. In order to study, and get some practical experience of, the *Facebook* API, a new, more intuitive and friendlier interface, called *FaceLift*, has been designed and implemented. This paper describes the results of this work.

*FaceLift* is a Windows-based *Facebook* client application. It is built upon the Microsoft .NET Framework 3.5, using its sub-framework Windows Presentation Foundation (WPF).

The stated aim of the new interface is to improve the overall user experience when interacting with the *Facebook* website by

- Providing a more advanced and user-friendly chat. The current *Facebook* chat lacks some basic instant messaging (IM) features like file transfer, history, grouping etc.
- Improving the way that photos are displayed. Due to browser limitations, the *Facebook* platform provides a basic way of browsing through a user's photos. *FaceLift* is able to provide a 3D image gallery by taking full advantage of the operating system and the .NET framework.
- Allowing the user to see his/her friends in an undirected graph form.
- Permitting the user to apply various groupings to his/her friends.

## 3. THE *FACEBOOK* API

The *Facebook* API uses a REST-like interface for interacting with client applications over Internet [5]. This means that *Facebook* method calls are made over the Internet by sending HTTP GET or POST requests to the *Facebook* API REST server. Nearly any computer language can be used to communicate over HTTP with the REST server. This work used C#.

The *Facebook* API provides remotely a rich and powerful set of methods that may be called in this way. As an illustration, Tab. 1 lists a selection of these methods.

The *Facebook* API also supports the *Facebook* Query Language, or FQL, allowing developers to use an SQL-style syntax to query *Facebook* social data tables stored at the *Facebook* site.

Tab. 1: A selection of available Facebook API methods

events.cancel	Cancels an event. The application must be an admin of the event.
events.create	Creates an event on behalf of the user if the application has an active session; otherwise it creates an event on behalf of the application.
events.edit	Edits an existing event. The application must be an admin of the event.
events.get	Returns all visible events according to the filters specified.
events.getMembers	Returns membership list data associated with an event.
events.rsvp	Sets the attendance option for the current user.
fql.query	Evaluates an FQL (Facebook Query Language) query.
friends.areFriends	Returns whether or not each pair of specified users is friends with each other.
friends.get	Returns the identifiers for the current user's Facebook friends.
notifications.get	Returns information on outstanding Facebook notifications for current session user.
photos.upload	Uploads a photo owned by the current session user and returns the new photo.
status.get	Returns the user's current and most recent statuses. This is a streamlined version of users.setStatus.
status.set	Updates a user's Facebook status through your application.
video.upload	Uploads a video owned by the current session user and returns the video.

#### 4. FACELIFT DESIGN AND IMPLEMENTATION

*FaceLift*'s architecture is composed of four main components:

- API Communicator – this is the *Facebook* API communication component that handles all the communication between *Facebook*'s API and the *FaceLift* client – viewing user profiles, uploading photos, sending messages, sending chat messages, poking, etc.
- Graph library component - this is used to provide an alternative way of representing the friends list of the user. Besides the classical list view of friends, *FaceLift* has the functionality to show the list of friends

as an undirected graph, using a force-based algorithm for drawing the graph [6]. This is illustrated in Fig. 1 and Fig. 2.

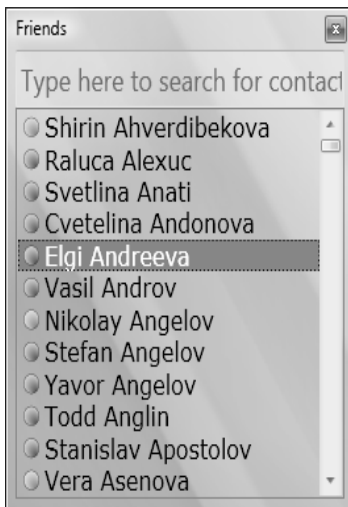


Fig. 1: List of friends



Fig. 2: Corresponding graph of friends

- Glassy Window component - this is used to apply a “glassy” effect to the windows used in *FaceLift*. Fig. 3 and Fig. 4 below show a simple comparison between a classical window and a glassy-effect window.

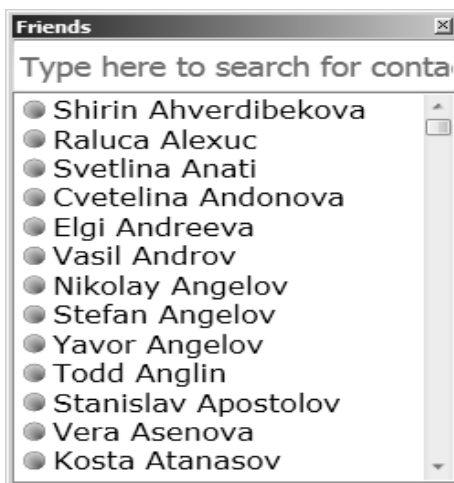


Fig. 3: Classical Window

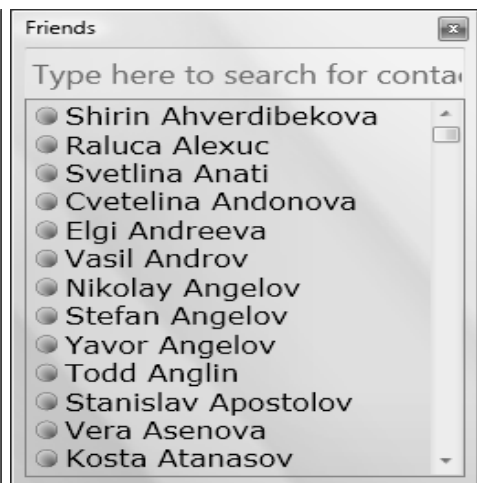


Fig. 4: Glassy Window

- *FaceLift* component that is used to manage all the other frameworks. It contains all the windows that are used to display data, retrieved by the API Communicator component. All the windows are with glassy effect that comes from the Glassy Window Component. Some of the win-

dows used in this component are illustrated In Fig. 5, Fig. 6, Fig. 7 and Fig. 8.

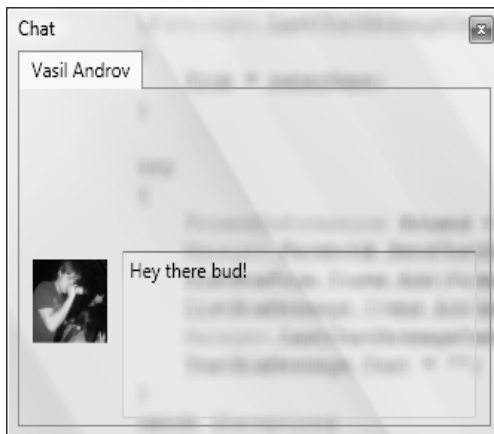


Fig. 5: Chat Window

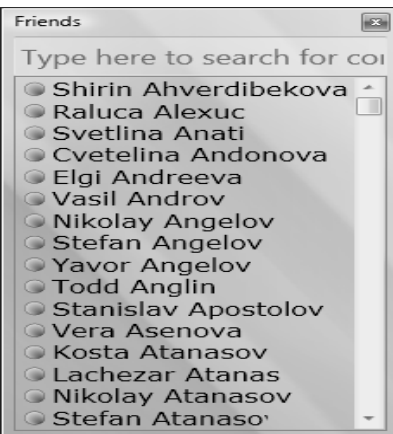


Fig. 6: Friends List Window



Fig. 7: Graph Window

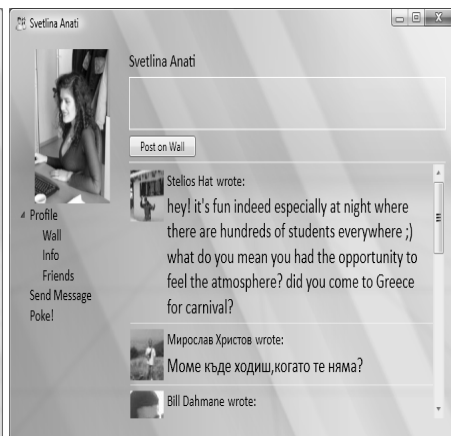


Fig. 8: User Profile Window

## 5. CONCLUSIONS AND FUTURE WORK

This paper has described the successful development of *FaceLift*, an alternative Windows-based *Facebook* client application created by the extensive use of the published *Facebook* API.

The experience we gained has given us the confidence to schedule future work for *FaceLift*, concentrating on improving each and every aspect of the *Facebook* interface. Most attention will be paid to the chat feature. Our research has show that many users do not use the *Facebook* chat because it lacks basic functionality. Additionally, a custom-made media player interface for displaying video clips will be developed.

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# Stimulus-response relations of deep tissue pain obtained with computer-controlled pressure algometry

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**Abstract:** The aim of this study was to test the newly designed computerized pressure algometer. The study included healthy male subjects. The experimental set-up consisted of a tourniquet cuff, a computer controlled air compressor and an electronic visual analogue scale. In case of 1 kPa/s and with biofeedback, the values for the pain threshold (PT) and pain threshold tolerance (PTT) were: 206  $\pm$  10 kPa and 243,7  $\pm$  13 kPa respectively. An increase ( $p < 0.05$ ) of PT was established following the changes of compression rates. The values without biofeedback were similar concerning PTT, while the values for PT were without changes. The optimal approximation of the pressure-pain data was obtained with exponential growth function ( $y = y_0 + A \exp(x/t)$ ). The presented study allow: (i) to obtain and analyze experimental stimulus-response data with computerized cuff pressure algometer; (ii) to established that in healthy volunteers the pressure-pain data could by approximated with exponential growth function; (iii) to precise the range of PT and PTT without and with biofeedback.

**Keywords:** pressure algometry, deep tissue pain

## 1. INTRODUCTION

The most important in any modern scientific studies is the level of automation of the process of measurement and storage of experimental data (data acquisition). How has presented an automated measurement and processing of experimental data sets the representatives of the final results. Manually is impossible considering the testimony in most modern measurement systems of any such instrument more now - present special requirements for equipment such as registering resolution, simple rates and others on the other hand our previous efforts was measure the experimental pain in humans [1] and the recent studies of Polanskis [2] and Jespersen etc. [3] argue the necessity of such kind of devices .

## 2. METHODS

### 2.1. Experimental set-up for computer-controlled pressure algometry

The device consists of a computer-controlled electro-pneumatic regulator (ITV2051-31F2N-Q) set in a cuff, driven by a microcontroller based data acquisition system and air source (compressor).

The working principles of electro-pneumatic regulator are shown on fig 1. When the input signal rises, the air supply solenoid valve 1) turns ON, and the exhaust solenoid valve 2) turns OFF. Therefore, supply pressure passes through the air supply solenoid valve 1) and is applied to the pilot chamber 3). The pressure in the pilot chamber 3) increases and operates on the upper surface of the diaphragm 4). As a result, the air supply valve 5) linked to the diaphragm 4) opens, and a portion of the supply pressure becomes output pressure. This output pressure feeds back to the control circuit 8) via the pressure sensor 7). Here, a correct operation functions until the output pressure is proportional to the input signal, making it possible to always obtain output pressure proportional to the input signal. The regulating pressure range of ITV2051-31F2N-Q is 0.005 to 0.9 MPa, power supply voltage – 12 V, input signal is voltage 0 to 10V DC, analogue monitor output signal 1 to 5V DC [4].

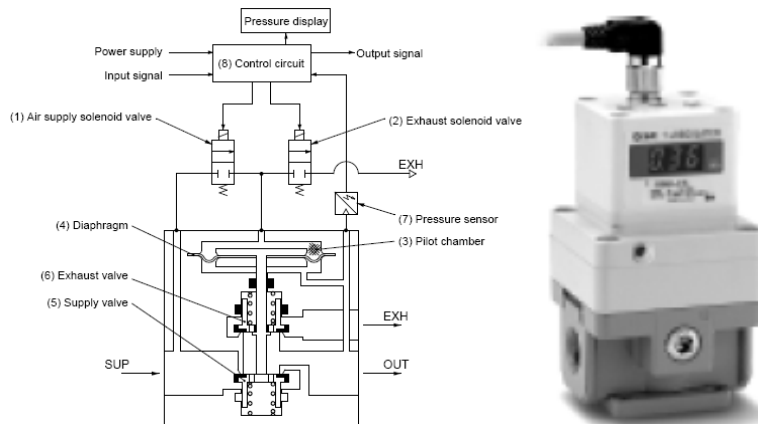


Fig.1. Schema and photo of electro-pneumatic regulator ITV2051-31F2N-Q

Pressure-resistant PVC tubes connect the electro-pneumatic regulator to the air compressor and to the tourniquet (VBM Tourniquet Systems Pressure Infusion Medizintechnik GmbH).

The computer drives and monitoring the electro-pneumatic regulator via USB microcontroller based data acquisition system.

## **2.2. Subject and experimental protocol**

Healthy, untrained male subjects (kinesitherapy students from South West University;  $n = 6$ ) performed pain testing. Informed written consent was obtained from all participants after a complete description of the risks associated with the study. The study was conducted according to the Helsinki Declaration.

The average age, height, weight and body mass index of the male subjects are presented in the Table 1.

Tab. 1. Anthropometric data (means  $\pm$  SD) for male adult subjects ( $n=6$ )

Parameters	Values
Age (years)	$26.5 \pm 3.2$
Height (m)	$1.82 \pm 0.04$
Weight (kg)	$96.5 \pm 4.2$
Body mass index ( $\text{kg} \cdot \text{m}^{-2}$ )	$29.0 \pm 0.8$

The pneumatic tourniquet cuff (7.5 cm wide) was wrapped around the middle of a dominant arm at the level of the innervations zone of biceps brachii muscle and connected to the air compressor. The maximal pressure limit was 300 kPa. The pressure could be released and controlled by the software program. This program served the quantitative sensory testing and allows the volunteers to stop the stimulation.

The study consisted of two separated sessions of measurements for the volunteers: with biofeedback, i.e. the possibility for observation of the values of the pressure and pain, scales and graphics on the monitor of the device or without biofeedback. Interval of 10-15 min between the sessions with relaxation message was sufficient for a full restoration of pain sensitivity of the arm. The following compression rates were used during every session: 1 kPa/s, 2 kPa/s, 3 kPa/s and 4 kPa/s.

## **2.3. Data fitting**

The experimental data obtained by fitting by software package Origin.

## **2.4. Statistics**

The values for anthropometric parameters and for pain thresholds and pain threshold tolerance, presented in Tables were expressed as mean  $\pm$  SD. Significance within the group was determined using Friedman's test. When significance was obtained, comparisons between the measurements were made using Wilcoxon signed ranks test. Values of  $p \leq 0.05$  were taken to be statistically significant.



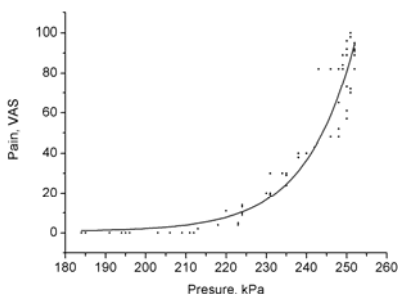
Compression rate	Pain threshold (kPa)		Pain threshold tolerance (kPa)	
	With biofeedback	Without biofeedback	With biofeedback	Without biofeedback
1 kPa/s	206.3 ± 17.2	206.4 ± 14.5	243.2 ± 14.7 <sup>b</sup>	240.3 ± 21.6 <sup>c</sup>
2 kPa/s	207.5 ± 16.4	205.7 ± 16.7	248.3 ± 19.5 <sup>b</sup>	252.3 ± 20.3 <sup>c</sup>
3 kPa/s	214.6 ± 17.1	208.1 ± 17.2	253.7 ± 18.1 <sup>b</sup>	251.3 ± 19.7 <sup>c</sup>
4 kPa/s	222.5 ± 17.5 <sup>a</sup>	207.0 ± 18.3	253.4 ± 19.6 <sup>b</sup>	255.3 ± 17.9 <sup>c</sup>

<sup>a</sup> Significant differences ( $p < 0.05$ ) versus the value for PT with biofeedback and compression rate 1 kPa/s;

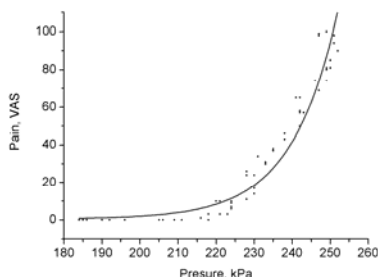
<sup>b</sup> Significant differences ( $p < 0.05$ ) versus the value for PT with biofeedback with the same compression rate;

<sup>c</sup> Significant differences ( $p < 0.05$ ) versus the value for PT without biofeedback with the same compression rate;

In case of 1 kPa/s and with biofeedback, the values for the pain threshold (PT) and pain threshold tolerance (PTT) were:  $206 \pm 10$  kPa and  $243,7 \pm 13$  kPa respectively. An increase ( $p < 0.05$ ) of PT was established following the changes of compression rates. The values without biofeedback were similar concerning PTT, while the values for PT were without changes.



a)



b)

Fig.3. Stimulus-response curves (experimental data and fitting curves) in case: a) 1 kPa/s and b) 4 kPa/s

Tab. 3. Coefficients of equations for fitting curves presented in fig.3.

	1 kPa/s	2 kPa/s	3 kPa/s	4 kPa/s
y0	-1.02971	-2.09574	0.48444	0.7522
A	8.49575E-8	5.38519E-6	1.12587E-7	1.44665E-7
T	10.94399	14.4096	12.17182	12.41968

#### **4. CONCLUSIONS**

The presented study :

ALLOW To obtain and analyze experimental stimulus-response data with computerized cuff pressure algometer;

(II) ESTABLISHED THAT The optimal approximation of the pressure-pain data was obtained with exponential growth function ( $y=y_0+A\exp(x/t)$ ).

(iii) précised the range of PT and PTT without and with biofeedback.

#### **5. ACKNOWLEDGMENTS**

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# An Integrated System for University Course Timetabling

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**Abstract:** *An integrated information system for university course timetabling is described in this paper. The functional requirements are formulated for this system. A new model of university course timetabling information system based on module organization is suggested. A scheme of relational database storing the necessary information used by the model is presented. An example session of work with elaborated information system using the suggested model is presented. The future trends of research are described.*

**Keywords:** *information system, database.*

## 1. INTRODUCTION

The creating of information system for preparing timetables requires practical skills in the development of software. Also, skills to use the existing new models or working out new ones are required. Using databases to store detailed information about timetables and possibilities for operations with these data are a good premise to work out information systems with such functions. The necessary information for this aim is collected and stored in database.

The model of integrated information system for preparing timetables is proposed in this paper. It is based on a module organization. The different items of the timetable are constructed simultaneously by the experts using the system. The developed integrated information system, described in this paper, is only one of the possible examples to apply the proposed model. The three components: experts, data and information system work together according to the model a timetable to be made.

This problem is examined by the scheduling theory. It researches problems whose limited resource is time [3]. A schedule (or timetable) is a document, that contains information about activities  $n$ , beginning time and end time for each activity  $t_s$ ,  $t_e$ , respectively, and instruments for executing  $m$ . It is presented through Gantt chart. By a given criterion  $k$  for effectiveness - time for executing of all the activities, an order of activities with which  $k$  has a minimum searched value [4].

Making a timetable is a combinatorial problem. A total number of possible variants with  $m$  instruments is  $N_{\Sigma} = (n!)^m$ , where  $n! = 1.2.3...n$ . For

large values of  $m$  and  $n$  approximate heuristic methods are used instead of the backtracking method [4].

## **2. FUNCTIONALITY REQUIREMENTS TO THE SYSTEM**

An integrated information system for making university timetable is described in this paper. Here the term "timetable item" stands for information about: owner, day (depending on timetable - periodically (weekly) or yearly); beginning time; end time; references to course, lecture and/or auditory depending on owner. In fact, a given timetable item (from course, lecturer or classroom) contains information about time, lecturer, with what course, in which classroom.

According to the hierarchical structure of universities they are divided into faculties and departments. Depending on this, the nine basic functional requirements to the information system are formulated:

1. Management of information about users, privileges, faculties, departments, subjects, curriculums, courses, semesters, timetables and timetable variants;
2. Simultaneous management of block timetable items among several departments;
3. Simultaneous management of lecturer timetables and classroom timetables from different departments;
4. Automatic verification and updated changes in common lecturer timetables and classroom timetables;
5. Possibility for setting-up the frequency of implementation and number of hours to items from a given timetable;
6. Possibility for inserting limitations and preferences from lecturers, classrooms manager and course representatives;
7. Preview and print of timetables;
8. Dynamic publishing of information for a given timetable in a world wide web;
9. Automatic generating of timetables by a given optimum criterion (for example, no vacant hours within the range of one day or a whole timetable).

After research and analysis of well-known information systems for preparing timetables [5, 6], such information systems corresponding to the above listed functional requirements were not found. To achieve the aim "Development of an information system for preparing university timetable", the following tasks were set:

1. A conceptual model of the information system to be developed;
2. A model of data to be chosen and a scheme of the database to be designed;
3. The modules of the information system to be developed and introduced.

### 3. A CONCEPTUAL MODEL OF THE INFORMATION SYSTEM

The use cases define the functionality requirements to an information system. They describe the typical interactions between users and the information system.

The use case is a set of scenarios bound by a common users aim. The scenario is a set of steps. One of the scenarios is defined as a main success scenario (MSS). The rest of scenarios are presented as extensions. They are described as variants of the main success scenario.

In the use cases the users are named "actors". The "actor" is a role that a user executes in reference to the information system. The actors execute the use cases. The relationship between the use cases and the actors is of the type many-to-many. The actor can be another information system.

More information is possible to be added to the use case:

- Precondition - describes what condition the system should check-up prior to execution;

- Guarantee - describes what state a system should assure after the use case;

- Trigger - defines the event that starts the use case [2].

The main use case of the information system is presented below:

Tab. 1: Main Use Case.

<b>Name of scenario: PREPARATION OF COURSE TIMETABLE</b>
Precondition: choice of current semester.
Trigger: after choice of the command "Create course timetable".
MAIN SUCCESS SCENARIO: 1. A user with role of "SECRETARY" starts module "CONSTRUCTOR". 2. A user starting command for generating the timetable items for a given course. 3. A user arranges timetable items by the function "drag and drop". 4. The information system checks-up the timetable for unconformities.
EXTENSIONS: 3.a. 1. The information system gets an error and stops executing the current operation because the related classroom and/or related lecturer are busy.
Guarantee: There is no possibility to preview the timetable until it has finished, except for users with role of "SECRETARY" or "ADMINISTRATOR".

The use case diagram is presented in Fig. 1.

Only the conceptual model of the information system is presented. Because of the limited size of the paper, the architecture scheme is not presented here. It will be published in the next paper by these authors.

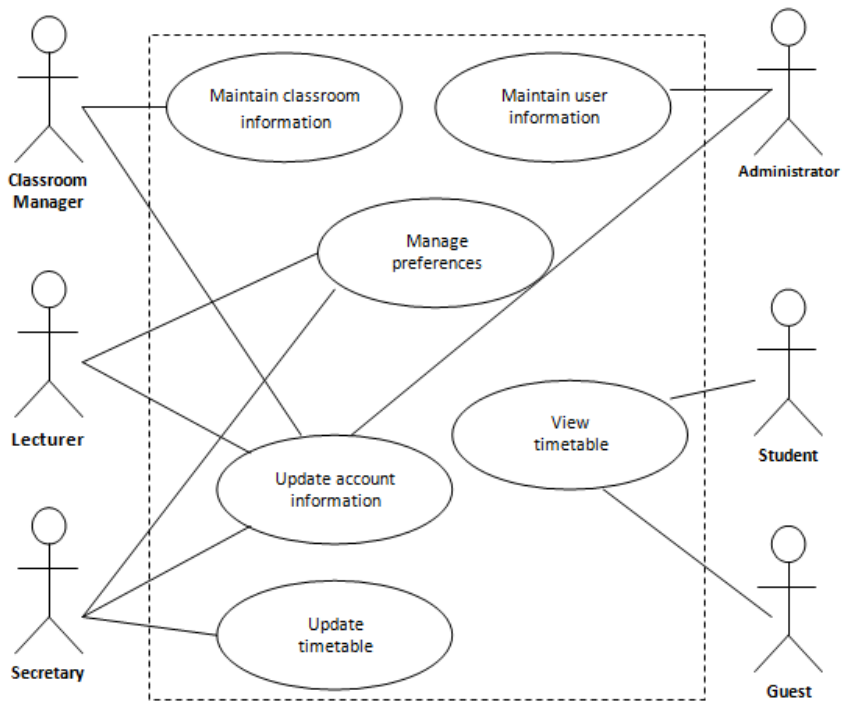


Fig. 1: Use case diagram of the information system.

#### 4. THE INFORMATION SYSTEM

The created information system demonstrates the use of the proposed conceptual model. The data are stored into a database system, which basically represents a computerized record-keeping system [1]. Users of the system can perform different operations with these data, for example: adding, inserting, selecting, deleting, editing (updating), etc. The relational model as most widely used is chosen for a data mode. Its advantages are described in [1].

Information about faculties, departments, lecturers, classrooms, timetables and timetable items is sorted in the relational database. The scheme of the relational database is shown in Fig. 2.

Because of limitation of the paper size only the names of the tables and the relationship between primary and foreign keys are shown in Fig. 2. Likewise only some of the tables are described. Additional characteristics like a domain, check constraints, etc. are not described.

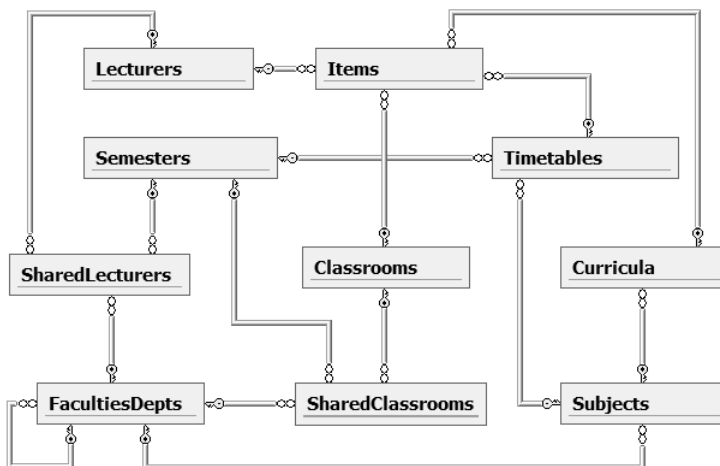


Fig. 2: Scheme of the relational database.

The information about the faculties and departments is stored into the table "FacultiesDepts". It contains the following fields: "pk" - primary key; "name" - the name of the department and "fk\_parent" - foreign key referring to the field "pk" from the same table.

With this recursion relationship unspecified hierarchical structure can be described only in one table.

The information about the subjects and curricula is stored into tables "Subjects" and "Curricula". Into tables "Lecturers" and "Classrooms", the information about the lecturers and the classrooms is stored.

The information about shared classrooms and lecturers among several departments is stored into tables "SharedClassrooms" and "SharedLecturers".

These tables contain information about the classroom used by a given department in a given semester. It is the same for lecturers.

The information about the timetables is stored into the table "Timetables". It has the following fields: "pk" - primary key; "fk\_semester" - foreign key referring to the field "pk" from the table "Semesters"; "fk\_subject" - foreign key referring to the field "pk" from the table "Subjects"; "num\_course" - course number; "students" - number of students in the course and "num\_groups" - number of laboratory groups.

The information about timetable items is stored into table "Items". It has the following fields: "pk" - primary key; "fk\_timetable" - foreign key referring to the field "pk" from the table "Timetables"; "fk\_lecturer" - foreign key referring to the field "pk" from the table "Lecturers"; "fk\_classroom" - foreign key referring to the field "pk" from the table "Classrooms"; "fk\_curriculum" - foreign key referring to the field "pk" from the table "Curricula"; "type" - type

of the item (lecture, laboratory lessons, etc.); "day" - day from the schedule; "start\_time" - beginning of the lesson and "end\_time" - end of the lesson.

## 5. INFORMATION SYSTEM DEVELOPMENT

On the basis of the conceptual model, the architecture scheme of the information system and the chosen relational data model, the following modules were developed:

1. The module, named "CONSTRUCTOR" is used from all of the departments. This is the most important and complicated module of the whole system. It is used for preparing and updating of the timetables. Sample session work with the module is presented in Fig. 3.

Конструктор - потребител: inf [Надя Борисова] - Секретар

Специалности		Курсове		Дисциплини		Елементи за дисциплина											
Иниц.		Но	см	лб	Наименование	Иниц	Л	см	лб	Тип	Иниц	Но	гр.	ч.	Преподавател	Зала	Блок
ИНФ-Б		I	2	4	Обектноориентирано програмиране (ООП)	3	0	2	Зад			0					
		II	2	4	Компютърни архитектури (КА)	3	1	0	Зад								
		III	2	3	Информационни технологии (ИТ)	2	0	2	ИЗБ								
		IV	1	3	Дискретна математика (ДМ)	2	2	0	Зад								

2 Курс | Информатика - бакалавър

	07.30-08.15	08.30-09.15	09.30-10.15	10.30-11.15	11.30-12.15	12.30-13.15	13.30-14.15	14.30-15.15	15.30-16.15	16.30-17.15	17.30-18.15	18.30-19.15	19.30-20.15
понеделник													
вторник		Дискретна математика (ДМ), ЛЕК доц. Сп. Шраков 1425		Информационни технологии (ИТ), ЛЕК доц. Д. Дурев 1425			ИТ, ст.ас. В. Кравев, 2 лб, 1429						
сряда		Дискретна математика (ДМ), ЛЕК доц. Сп. Шраков 1425		КА, ас. И. Тодорин 1 см, 1432	ДМ, ст.ас. И. Атанасова 2 см, 1431	ДМ, доц. Сп. Шраков 1 см, 1425	ООП, ст.ас. И. Димитров 3 лб, 1427	ООП, ст.ас. И. Димитров 1 лб, 1427					
четвъртък		Компютърни архитектури (КА), ЛЕК проф. Н. Синягина 1544				ИТ, ст.ас. В. Кравев, 1 лб, 1429	ДУП, М. Тасев	ИТ, ас. Гр. Илиев, 3 лб, 1428	Спорт, ст. пр. В. Христов 1 см, Тенисзала				
петък		Обектноориентирано програмиране (ООП), ЛЕК доц. Кр. Йорджев 1208				ИТ, ас. Гр. Илиев, 4 лб, 1428	ДМ, доц. Сп. Шраков 1 см, 1425	Диференциални уравнения и приложения (ДУП), лек. доц. д-р М. Тасев 1115, блок					
събота						КА, ас. И. Тодорин 2 см, 1425	ДМ, ст.ас. И. Атанасова 2 см, 1432						

Fig. 3: Sample session working with module "CONSTRUCTOR".

2. The module, named "ADMINISTRATOR" is used for inserting, updating and deleting of the information about faculties, departments, users and semesters.

3. The module, named "CLASSROOM MANAGER", is used for inserting, updating and deleting of the information about classrooms, also for searching and filtering of the classroom list. When a classroom is used at the same time from more than one department, the module automatically changes the status of this classroom at "shared".

## 6. CONCLUSION

This paper presents a conceptual model of information system for preparation of university timetables. The relational data model is chosen and on its basis, a database for storing the information used by the information system is described and created. A brief description of the functions of the system basic modules from the users' point of view is presented.

Depending on the organization of the work into some institutions (it is not obligatory to be educational), it is possible different elements of the timetable to be prepared in different departments. Each department could use separated unit of the developed informational system. In this way the system integrates the whole process.

The limited size of paper does not allow to describe all the aspects of the presented information system, but the ideas that were proposed are a good base for further development.

It is necessary that this system has to provide the possibility of automated timetable preparation, and also web-based report for the users.

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# On model architecture for a children's speech recognition interactive dialog system

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**Abstract:** *This report presents a general model of the architecture of information systems for the children's speech recognition. It presents a model of the speech data stream and how it works. The result of these studies and presented veins architectural model shows that research needs to be focused on acoustic-phonetic modeling in order to improve the quality of children's speech recognition and the sustainability of the systems to noise and changes in transmission environment. Another important aspect is the development of more accurate algorithms for modeling of spontaneous child speech.*

**Keywords:** *Children's speech recognition, Architecture model of spoken system.*

## 1. INTRODUCTION

Technologies for speech recognition are oriented towards the speech recognition of adults. Developed applications, the justification of these technologies are aimed primarily at elderly consumers. Recently children have become users of more and more automated devices like computer equipment, household appliances or toys. Under certain conditions the application of certain technologies can be successful, but in most cases they are hampered by major limitations in the treatment of children's speech. This is because there are too many differences in speech between adults and children. Most of the children are inexperienced in the formulation of words and sentences. It often happens, when the child is in its early age, he/she to replace one phoneme or word for another, to miss one up to several phonemes. Many children use the limited vocabulary of adults. They unlike adults have very strong imagination and association skills that help them create their own new words. Therefore, the dictionary used by children is very different from that of adults.

Therefore it may be argued that the creation of technology to be applied in children's speech recognition is an interesting and easy task. There are many studies on this matter. The authors are interested in testing the systems for the recognition of child speech in English.

This article proposes a model of information system architecture for children's speech recognition.

## **2. MODEL ARCHITECTUE FOR CHILDREN'S SPEECH RECOGNITION SYSTEM**

A speech recognizer might be divided into four parts: the digitizing, feature extraction, acoustic modeling, and language modeling part. When the signal is digitized an appropriate sampling frequency needs to be chosen to catch the high-pitched voices of children. Feature extraction often involves approximating the spectrum of the signal. During this phase it is possible to use signal processing to alter the spectrum prior to recognition. This may be used to decrease the sensitivity against background noise or to normalize some spectral characteristics of the recorded speech. Another method to target the current spectral characteristics may be to adapt the acoustic models to better match the speech. Adjustment of the language model may be used to take the children's vocabulary and pronunciation into account [1]. Adaptation may be performed on many levels. Adaptation has become linked with altering the acoustical model in the speech recognizer.

According to [2] and [3] using an adult speech recognizer without any adjustment to the needs and peculiarities of children speech gives a high word error rate. In particular, speech recognition in very young children becomes much more difficult problem to solve rather than speech recognition in older children. Therefore, the adaptation of existing methods and technologies working well at adult speech recognition is an often used practice with children's speech recognition.

Here we will present a model of the architecture of a speech recognition system which is based on classical models and adjusted to children speech recognition.

### ***2.1. Simple analysis for speech recognition***

Before we move on to presenting the architecture model of a children's speech recognition system, let us first examine the work of recognizers. Knowledge from various scientific fields such as mathematics, physics, acoustics, linguistics, etc. is necessary for the quality performance of this recognition process. This multiple knowledge level processing is still not well studied and this fact is the main reason for the automatic speech recognition to become a complex and not yet solved problem. However, there are a number of practical implementations, which in one way or another have managed to cope with this problem. Schematic summary presentation of the process of recognizing spoken language can be seen in Figure 1

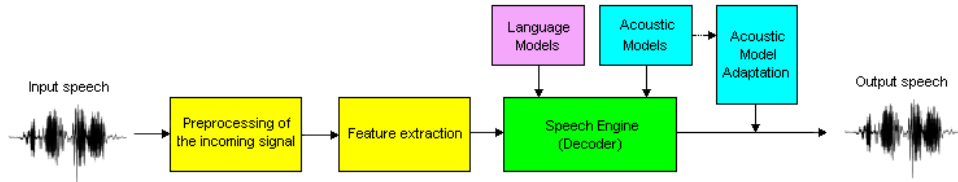


Fig. 1: Schematic structure of the basic steps of an automatic speech recognition system

First, the waveform received is preprocessed to enhance the signal by means of simple preemphasis filtering, or more sophisticated noise reduction or dereverberation algorithms. Then, the processed speech waveform is converted into a sequence of meaningful feature vectors, which are used to feed the speech decoder. The decoder seeks for the best match between a sequence of features and every possible sequence of acoustic classes, using the available information from the acoustic and language models, which are typically obtained in a training phase prior to the recognition step. Additionally, the recognition result can be used as feedback information to better adjust the acoustic models to the actual speaker or acoustic environment in a process generally named adaptation.

## 2.2. Description of the model architecture

The proposed architecture (figure 2) consists of five main components which are designed to work together. Modules "*Language model*" and "*Dialogue Manager*" can be used and integrated into other independent systems. Module "*Preprocessing of the incoming signal*" includes filters to clear the noise from the received signals or due to imperfections in the sensors. After this the cleared analogue signal is being converted into a digital one by means of an analogue/digital converter.

The "*Speech recognition*" module is performed by the formation of many characteristic features of object recognition by input digital data flow. Then a description of classes and data necessary to perform the classification (decoding) in the "*Classification*" block is included. This block is connected to the *Speech Database*, through which training, self-organization and recognizing words. After this the speech is converted into text.

Understanding natural language recognizes the importance of words and phrases in the context they are used. If the word is not recognized, then it returns to "*Classification*" block and is recorded in the database as associated with keyword depending on its context.

Interpretation and response to those carried out in the next module of the "*Automatic generation of speech.*" The tree of conclusions is determined in the "*Speech interpreter*" block. Then, the information which must be returned as a response to the user of the system is determined in the

"Response generation" block. The "Acoustic model" block generates the phonetic representation of the speech signal response of the system. In developing the software it will be selected and modified some existing methods of acoustic modeling, which will best match the characteristics of the Bulgarian language used by children.

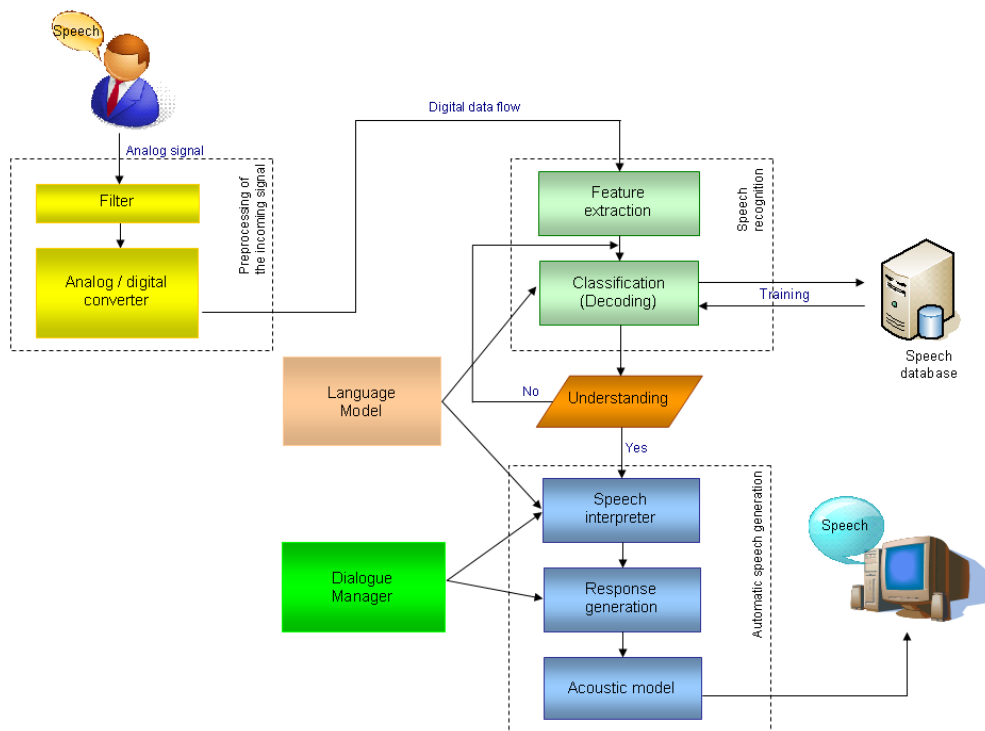


Fig. 2: Schematic structure of the basic steps of an automatic speech recognition system

The "Dialogue manager" module controls "Automatic speech generation" operations. The most appropriate response based on information submitted to the block appears here. Thus creating a prerequisite for conducting a real dialogue and retain its history. "Dialog manager" according to [5] can be seen as a solution to two specific problems: (1) providing a coherent overall structure to interaction that extends beyond the single turn, (2) correctly manage mixed-initiative interaction, allowing users to guide interaction as per their (not necessarily explicitly shared) goals while allowing the system to guide interaction towards successful completion.

Organization of the "Language model" will correspond to the peculiarities of the vocabulary of Bulgarian.

Organization of *Speech database* will be similar to the one used by the team of [4]. Separate words and short sentences covering all the features of the phoneme in Bulgarian will be kept. Recordings of the words will be made by a desktop microphone to eliminate the need of expensive and specialized equipment. Data set will be divided into sets for training, development and evaluation. Usability of the words will be determined by the frequency dictionary proposed by Botseva [6]. The record of the words will be made by English children in different age groups from 2 - 7 years of age and without speech defects. Each child will record 80-100 words, as their number will be determined later. The data base formed in this way will be used for training, testing and evaluation.

### **3. CONCLUSIONS**

The biggest advantage of the proposed model is its universality. This is because the *Dialog Manager* and *Language Model* are not dependent on the task being executed. They are separate modules that can be updated independently of the system.

The following tasks were set in this report:

- The process of recognizing speech was studied and presented.
- It was analyzed the specifics of the problem associated with the recognition of child speech.
- It was presented an architectural model of a system for recognition of child speech.

Future work:

- A prototype of an information system using the presented model, in order to study the problems related to children's speech recognition in children up to 7 years.
- A language adaptation of existing models will be carried out in order to meet the limited vocabulary used by children.
- • An adaptation of acoustic models and techniques will be carried out to meet the specifics of the speech in children

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# Learning Process Management in Moodle

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*Abstract: The paper presents research and experience in the learning process management using the Moodle Learning Management System (LMS). The possibilities are analyzed for managing the process of learning in LMS Moodle. An approach is offered for the management of the learning process which has been developed and applied in the E-learning Laboratory in SWU "Neophyte Rilski" Blagoevgrad.*

**Keywords:** *e-learning, LMS/LCMS, learning management at curriculum level*

## 1. INTRODUCTION

Learning management systems and/or Learning content management systems (LMS/LCMS) are becoming an inseparable part of the modern academic learning process. Through them the distance form of education is realized and they are also applied in the support of full-time and blended learning. The transition from the phase of enthusiasm and experimentation in the application of LMS/LCMS in the learning process to the phase of regular and effective "production" activities poses some serious problems regarding their practical use which are frequently overlooked. Such problems concern scalability, the realization of the learning process in a distributed environment and the management of a life cycle of an e-learning course of studies.

Traditionally the focus of LMS/LCMS application is placed upon activities that are concerned with learning process management within the framework of a single course of studies. They are realized mainly through planning and monitoring of the access to learning and evaluation materials and activities. Naturally enough, these activities are the subject of methodological interest on behalf of the designers of e-learning content and university lecturers who teach courses in which LMS/LCMS are applied. The evaluation of the qualities and the potential effectiveness of the development or introduction of a LMS/LCMS is usually done from their perspective which, unfortunately, is too unbalanced.

Managing the learning process within the framework of the syllabus through LMS/LCMS is connected with planning and control of students' access to the e-learning courses. The provision of such courses can be centralized (coming from a single LMS/LCMS in an educational institution) or distributed (from several identical or different LMS/LCMS within one or

several educational institutions). These activities are traditionally considered to be the priority of the Registrar and are therefore (probably) ignored by lecturers and e-learning course designers, who initiate the introduction of a LMS/LCMS.

An important element in the transition from experimental to regular tuition is the separation of the experimental (design, development, testing) from the production (educational process and support) activities through establishing an adequate management structure for the life cycle of the e-learning courses within the LMS/LCMS in use. This is connected both with the management of the access to courses of e-learning content authors, lecturers, testers, and students in pilot courses, and with the possibility for an exchange of e-learning content and users' profiles.

The purpose of the present paper is to present our research and experience with the management of the learning process using LMS/LCMS Moodle. In part two the possibilities are analyzed for managing the process of learning in LMS Moodle. Part three offers an approach for the management of the learning process which has been developed and applied in the E-learning Laboratory in SWU "Neophyte Rilski" Blagoevgrad.

## **2. ANALYSIS OF THE POSSIBILITIES FOR MANAGING THE LEARNING PROCESS IN MOODLE**

User management in LMS Moodle [2] is divided into two levels: granting access to the system in general (user registration) and delegating rights in the system (access to e-learning content). From the point of view of the management of the learning process of importance are the registered users' data and the ways to control the access of registered users to the e-learning courses as a whole (management at the curriculum level) and to elements of their content (management at the syllabus level). The inbuilt possibilities for registration and management of user rights can be local (with validity limited to only one installation of Moodle) or external (using the capacities of other information systems or other LMSs Moodle active in one or several academic educational institutions). Through them three possible scenarios can be realized for the administering of the learning process: local self-registration, local institutional administration and external institutional administration.

It should also be noted that LMS Moodle targets both formal and informal education. That is why in its standard mode the system registers the participants in the learning process with compulsory general data such as name, surname, E-mail address, city and state, which allows identification in the general citizenship sense. Identifying elements typical for university education are not included, such as identification (faculty) number of the learner, speciality (registration in a particular course) and

year of study, which allows formal management of learners within the framework of a curriculum.

The initial self-registration of users in the system with confirmation by e-mail, however, tends to lead to uncontrolled self-registration of users who are not connected with the educational institution and who could use their registration to send unwanted mail and messages/spam/ to other users and/or initiate non-academic discussions in the forum.

Self-registration in the courses is realized through an enrollment code which is provided to students by the lecturer and which is used when they first try to access the course. This method, although it seems easy and convenient, causes certain problems: students usually register unenthusiastically and over a long period of time; it often turns out that the code is unknown or forgotten, or it is already well-known within the group of students in this particular course. Generally, self-registration is not suitable for application in the educational institutions, especially when e-learning is part of the regular academic process.

Local institutional administration is realized in several ways:

- Manual registration of users in LMS Moodle by the system administrator (labour-intensive, time-consuming activity, applicable only with a small number of users).
- Manual signing-in of course applicants by the system administrator or lecturer. This method is effective with a small number of students or with registering of data suitable for academic identification (faculty numbers, speciality, course). A certain degree of automation of this process can be achieved through defining an e-learning course in Moodle as a "meta-course" of another one (child course) whose participants have already been registered, which allows their automatic dynamic succession in the meta-course. Every time when a student is signed in or out of the child course, the same student is signed in or out of the meta-course. This is one of the ways to manage the education of a group of students attending the same courses (e.g. for the period of one term within a curriculum, excluding optional and elective subjects).
- Importing of data necessary for registration in LMS Moodle and participation in certain courses from a file with a pre-defined format, generated from another information system, for instance that of the Registrar. This is very convenient if the necessary information exists in electronic format and the educational institution uses a single centralized installation of LMS Moodle. It should be born in mind that in such a case user management is not dynamic: if changes occur in the current status of a student or a course, they should be registered manually or imported once again through an external file.
- External institutional administration allows registration of users (learning process management at the level of the curriculum) to be made

dynamically through a different, already existing, information system in an educational institution. LMS Moodle has the capacity for integration with other systems regarding:

- Registering users in the system – an existing registration can be used of another network-accessible server (LDAP [3], RADIUS, CAS, NNTP, another DBMS, others LSM Moodle/FirstClass).
- Registering users in e-learning courses – the information from LDAP or DBMS server can be used.
- External institutional administration provides a large capacity for integration with other information systems. It ensures the use of a minimum of one combination of user name and password for accessing all or a limited number of services provided through Internet/Intranet/Extranet networks within one or more educational institutions. Another possibility in this case is a centralized learner management through the realization of a distributed learning within one educational institution or of joint programs shared with different educational institutions.

From the possibilities, analyzed so far, for learning process management in LMS Moodle it can be deduced that the method most suitable to be applied in academic environment is that of external institutional administration.

### **3. AN APPROACH FOR LEARNING PROCESS MANAGEMENT AT THE CURRICULUM LEVEL**

Based on the experience acquired in the last four years with educating students at the Educational and Technological Center for E-learning and research conducted at the E-learning Laboratory in the Southwestern University Blagoevgrad, a model has been developed for e-learning management in LMS Moodle to be used in blended learning. The model is based on the following principles:

- Adequate formal information about students and lecturers. For the learning process management to be realized successfully in the LMS/LCMS information stored for the registered students, it should allow that they be registered in the academic sense. A required minimum are the student's name, faculty number, speciality and the year of study in which he or she is enrolled. The information on lecturers should include their names, degree awarded and position, as well as the department in which the lecturer works.
- Separating experimentation from the regular educational process conducted with the aid of ISEL. This principle contributes to the quality improvement of both activities. The greater stability and sustainability of the regular learning process aided by ISEL will make the activities associated with e-learning more realistic and will successfully fight the prejudice that ISEL is only good for experimenting.

- E-learning process management within the curriculum is realized through external institutional administration. In this way possibilities are created for integration with existing and/or future information systems within the academic institution or several institutions.

- Minimal changes in the standard installation of LMS/LCMS which do not involve the structure of the system fundamentally. This principle ensures maximum compatibility with future versions of LMS Moodle.

The practical realization of this approach was performed jointly by the Educational and Technological Center for E-learning (regular education) and the E-learning Laboratory (development and testing of modules and learning materials) in the Southwestern University of "Neophyte Rilski" Blagoevgrad. The data necessary for academic identification of students and lecturers was added through a change in the semantics of the fields in the existing framework of the Moodle database without changing the framework itself, which ensures compatibility with future Moodle versions. The institutional administration was realized with a LDAP server [3] with an additional user management module [1] developed for this purpose.

#### **4. CONCLUSIONS**

The approach offered in this study allows the realization of a learning process management within the framework of the curriculum using LMS Moodle in the academic institution environment. The same model is applicable to the learning process management with joint educational programs of several academic institutions. In addition, it ensures efficient separation of experimental activities from the regular learning process without it being necessary to perform multiple registrations of students and lecturers in various LMSs Moodle used for this purpose. The model also provides the opportunity for integration with other information systems and LMS/LCMS which support LDAP as a possibility for user management.

#### **5. ACKNOWLEDGMENTS**

This study is partially supported by National Scientific Fund under contract VU MI203/2006.

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## Prediction secondary structure of RNA

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**Abstract:** In this article we will represent facts about structure of RNA and some available products on the prediction of secondary structure of RNA. We will show the advancement of foreign institutes and specialists in this area. We will describe the computer programs used for prediction of the secondary structure of RNA.

**Keywords:** bioinformatics, RNA, secondary structure.

### 1. INTRODUCTION

Ribonucleic acid (RNA) is a type of molecule that consists of a long chain of nucleotide units linked together by covalent chemical bonds. Each ribonucleotide contains one of the four bases: adenine (A), cytosine (C), guanine (G) or uracil (U)

The main thing in the formation of the three-dimensional structure of an RNA molecule is hydrogen bonds, called *base pairs*. A can connect with U and G with C. These Watson-Crick base pairs permit the molecule to assume a stable three-dimensional conformation characterized by various loops and twists. This tertiary structure determines the biochemical activity of the RNA molecule. Biologists have simplified the study of the tertiary structure of an RNA molecule by focusing attention simply on what base pairs are involved in it. This collection of base pairs is referred to as its secondary structure [9].

### 2. VISUALIZATION OF THE SECONDARY STRUCTURE OF RNA

There are three techniques which have been used to predict secondary structure. The first is to examine all possibilities, usually with the help of graphical procedures. The second is to invoke the laws of thermodynamics and to try to compute a conformation of minimum free-energy. The third approach uses phylogeny, and can be used if the sequences for functionally identical molecules have been determined for several organisms or organelles[8]. If two or more molecules have closely related primary structures or identical biological functions, the strategy is to search for a secondary structure common to all of them[8, 9].

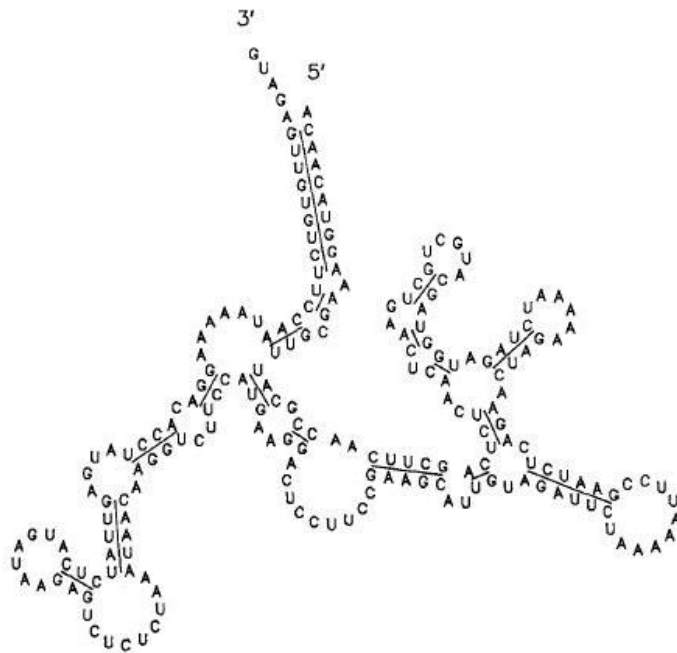


Fig. 1: Secondary structure of a fragment of the Cauliflower Mosaic Virus copied by Zuker and Sankoff (1984)

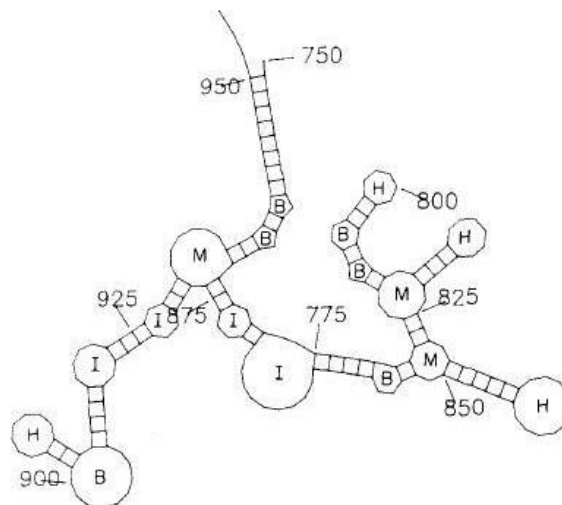


Fig. 2: Another representation of the secondary structure of the fragment from Fig. 1  
There are a number of ways of representing a secondary structure which are more useful than simply listing a set of pairs. The most straight-

forward way is pictorially, as in Figures 1 and 2, where the RNA chain is represented by a curved line connecting a series of equidistant points disposed in such a way as to ensure that pairs of complementary bases in the secondary structure can be joined by short segments of fixed length. In figure 2 B is a bulge loop; I - an interior loop and H is a hairpin loop; M, multi-loop. Such two-dimensional representations are used universally by biologists and have been used since the beginning of investigations on RNA secondary structure. A more abstract type of representation was introduced by Nussinov *et al.* (1978) [3]. The bases of the RNA molecule are placed equidistant to one another along the circumference of a circle. The covalent bonds linking bases are represented by the arcs of the circle between them. Hydrogen bonds are represented by chords joining base-paired nucleotides, as in Figure 3.

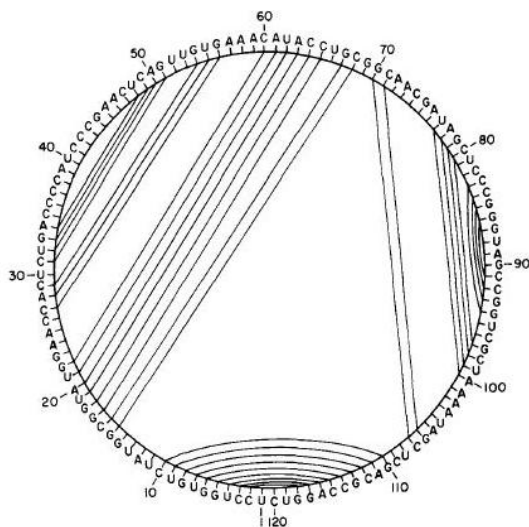


Fig. 3 A circle representation of the secondary structure of the *Anacystic* copied by Zuker and Sankoff (1984)

A third type of representation is in terms of a rooted tree or forest of rooted trees, in graph theory terms.

### 3. . HISTORICAL REVIEW

The first systematic approach to the prediction of secondary structure involved the construction of an  $N \times N$  matrix where both the  $i$ th row and  $i$ th column correspond to the  $i$ th position of the sequence, and the  $(i, j)$  entry indicates whether  $i, j$  is a Watson-Crick pair. Potential stems, or long stacks of base pairs, appear as diagonal patterns in the matrix. This information can then be used as the basis to a heuristic search for combinations of base-paired and unpaired regions which optimize the free energy [6]. Such methods are by no means obsolete. Quigley *et al.* (1984) [5] use a matrix

diagonal method which filters out less stable stacks of base pairs and also regions which are incompatible with data from chemical and enzymatic probes. Trifonov and Bolshoi (1983) [7] combine a matrix method with filtering ideas borrowed from image processing to search for common base-pairing regions in related sequences.

The Pipas and McMahon (1975) [4] algorithm represented the next logical step forward from the heuristic inspection of a matrix. A first routine in their program constructs a list of all possible stems or helical regions (sets of three or more base pairs stacked one over the other). A second routine compares all pairs of these regions for compatibility; two helical regions are compatible if they contain no base in common and produce no knot. The final part of the algorithm searches for the set of compatible regions having the lowest overall free energy. It does this by an exhaustive search, and keeping in storage the best M structures (where M may be fixed at any value) at all stages. Though the Pipas-McMahon program contains a number of approximations and simplifications, it works well for relatively small molecules and can easily be improved to take into account more accurate energy calculations.

#### **4. COMPUTER PROGRAMS WHICH PREDICT THE SECONDARY STRUCTURE OF RNA**

We will represent two products which predict the secondary structure of RNA [1]. First one is RNA-DV. We choose this program is free and easy to use. The main GUI of RNA-DV is divided into 6 regions, as shown in the picture below.

With the menu we can save or load files, Change the view and learn more about RNA-DV. On the animation window we can modify base, connect two nucleotide bases or disconnect pairing. We can input structure and sequence alone with structure input panel. In this program there are two available visualizations of the secondary structure. We change them with:

Click View => Circle View to activate Circular Feynman view or  
Click View => Tree View to activate Classical planar graph view

The second product which we choose is the Bioinformatics Toolbox for MATLAB. It is an integrated software environment for genome and protein analysis. With this software scientists and engineers can answer questions, solve problems, prototype new algorithms, and build applications for drug discovery and design, genetic engineering, and biological research. The Bioinformatics Toolbox product includes many functions to help you with genome and proteome analysis. Most functions are implemented in M-code (the MATLAB programming language) with the source available for you to view. This open environment lets you explore and customize the existing

toolbox algorithms or develop your own. The toolbox accesses many of the databases on the Web and other online data sources. It allows you to copy data into the MATLAB Workspace, and read and write to files with standard bioinformatic formats. It also reads many common genome file formats, so that you do not have to write and maintain your own file readers.

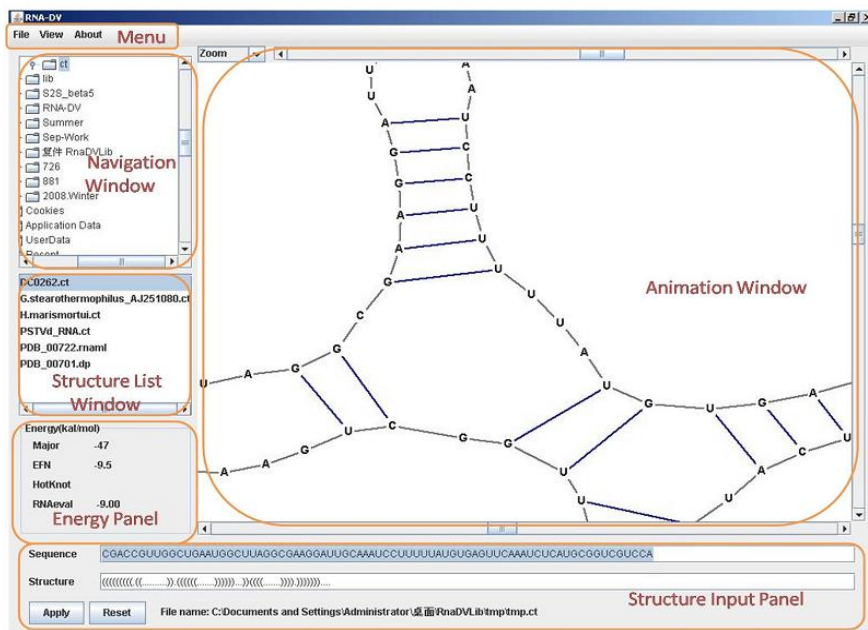


Fig. 4: Graphical user interface of RNA-DV

You can directly access public databases on the Web and copy sequence and gene expression information into the MATLAB environment [2]. For the sequence alignment we can select from a list of analysis methods to compare nucleotide or amino acid sequences using pairwise or multiple sequence alignment functions. The toolbox also includes standard scoring matrices such as the PAM and BLOSUM families of matrices. We can manipulate and analyze your sequences to gain a deeper understanding of the physical, chemical, and biological characteristics of your data. For make it easier we can use a graphical user interface (GUI) with many of the sequence functions in the toolbox. The toolbox provides routines for common operations, such as converting DNA or RNA sequences to amino acid sequences, that are basic to working with nucleic acid and protein sequences. The MATLAB environment is widely used for microarray data analysis, including reading, filtering, normalizing, and visualizing microarray data. For example generating of 3D structure of the molecules is possible with this script:

```
molviewer('aspirin.mol')
```

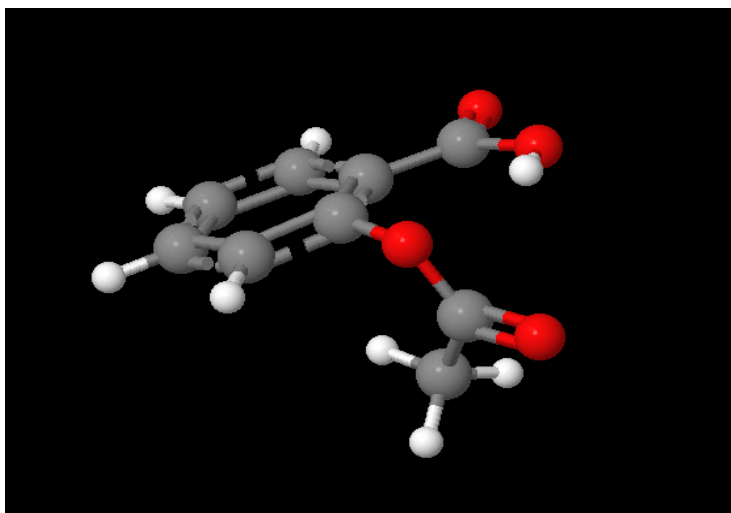


Fig. 4 3D structure of molecule aspirin created by MATLAB

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## Description of the biological databases

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**Abstract:** *Biological databases are libraries of scientific information. These libraries are brought together in a group from scientific experiments, articles, high throughput experiment technology, and scientific analyses. They contain information from research areas including genetic information, proteins, microarray gene expression, and etc. There are two main functions of biological databases: to make biological data available to scientists and to make biological data available in computer-readable form. In this article we will present the creating of data bases and their main functions. We will review the languages from high level like BioJAVA, BioPerl, BioPython, BioRuby etc.*

**Keywords:** *Bioinformatic, Biological databases.*

### 1. INTRODUCTION

As the time goes by, the human knowledge is getting larger and larger. The human thirst of discovering is unstoppable. This situation is in every science that exists, including the biology. All that information about all the results of experiments, discoveries, etc, should be stored and systemized in some data base, in order to make the access to it a lot easier to the scientists or whoever is needed the information. Biological databases are not just ordinary databases. They are large libraries that contain life science information. All this information are collected from scientific experiments, some published literature etc. Biological databases contain information from many research areas, such as: proteomics, genomics, phylogenetics, metabolomics, etc. This information included in biological databases contain gene localization (both cellular and chromosomal), function, structure, clinical effects of mutations as well as similarities of biological sequences and structures.

### 2. REVIEW OF BIOLOGICAL DATABASES

#### **Genomic Databases**

The best known genomic database is GenBank, the database of genomic series preserved by the NCBI (National Center for Biotechnology Information) [7]. It's full of all explained nucleic acid and amino acid sequences. Its contents are represented by two other databases, the EMBL (European Molecular Biology Laboratory) database and DDBJ (DNA Data

Bank of Japan). Distant from presenting and interpreting sequences, these databases suggest many functions related to searching and browsing sequences. They achieve services concerning submitting new sequences to GenBank, and also contain links to various bioinformatic internet sites. Many databases have more specialized information on genomic sequences.

### ***Proteomic Databases***

Be indebted in communication between amino acid and codon sequences, there are strong links between protein and nucleotide databases. Data on series of amino acids, on the nomenclature, functional characteristics of proteins, protein families and domains, as well as data on known secondary and 3D structures of proteins, are stored in proteomic databases, Swiss-Prot, Uni-Prot, and ExPASy (Expert Protein Analysis System) involving information including the function, taxonomy, amino acid sequences in proteins and structures of proteins[1-3].

### ***RNA Databases***

Information on series of ribonucleotides in RNA, coding and noncoding RNA sequences, the functions of RNA molecules and their spatial configuration, will be available in the databases if necessary. Rfam database stockpiles noncoding RNA (ncRNA) families. Rfam also consist of multiple series databases of Genetic and Proteomic Pathways alignments and covariance models [4, 5]. The GtRNA database stockpiles genomic tRNA ribonucleotide series and secondary structures. The Jena index of RNA structures provides a lot of information about RNA, including indexes of the locations of molecular structures in the PDB database. Records on ribonucleic acid sequences in RNA can also be found in GenBank [6].

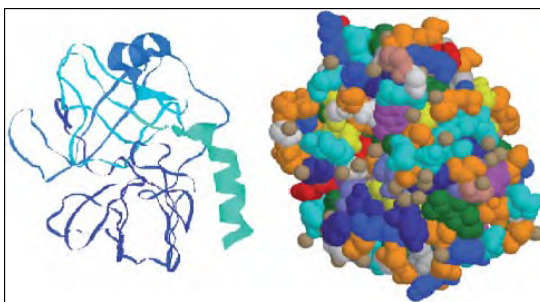


Fig.1. Graphical arrangement of the enzyme trypsin took with the use of spatial coordinates of atoms from Protein Data Bank (accession symbol 2ptn), and the molecular-graphics program Ras Mol.

### ***Gene Expression Databases***

Many databases include data on expression levels measured in various experiments. Here in this article we list some of the best known. They are designed at making possible the distributing of data in the new

field of microarray experiments. A component of the NCBI database, NCBI Gene Expression Omnibus (GEO), is a database containing links to microarray-based experiments measuring mRNA, genomic DNA, and protein loads, as well as non array techniques such as serial analysis of gene expression (SAGE), and mass spectrometric proteomic data. The MGED database is full of datasets from many experimental studies occupying gene expression. It also includes links to gene expression data-processing procedures and ontologies. The databases CGED (Cancer Gene Expression Database) and ONCOMINE carry published cancer gene expression data to the research community [5, 7, 8, 12].

### ***Ontology Databases***

Perhaps the most extensively used ontology database is GO (Gene Ontology), which provides controlled vocabularies for supporting analyses of gene expression measurements and other molecular-biology experiments. But other ontologies are also developing at a fast rate. One good example of database containing links to many Internet ontologies is OBO (Open Biomedical Ontologies). It supplies Web addresses of many sites full of biomedical structured vocabularies, containing GO, the Generic Model Organism Project (GMOD), Microarray Gene Expression Data (MGED), The National Center for Biomedical Ontology vocabulary [7, 10, 11].

### ***Databases of Genetic and Proteomic Pathways***

The area of genetic trails is a very fast-growing field for bioinformatic data. One large database containing such data on the genetic lane is KEGG, the Kyoto Encyclopedia of Genes and Genomes, a Web site that categorizes databases and associated software. The BioCarta database supports proteomic studies by granting information on proteomic lanes, as well as on reagents, antibodies, proteins, cells and cell-based tests. Trail databases suggest a graphical presentation of their contents, which provides 352 12 Bioinformatic Databases and Bioinformatic Internet Resources a useful support for qualitative understanding of signaling, regulatory, and other mechanisms [12].

### ***BioSQL***

BioSQL (Biological Structured Query Language) is a generic relational model covering sequences, features, sequence and feature annotation, a reference taxonomy, and ontologies (or controlled vocabularies).

The beginnings of this project start in 2001, mainly by Ewan Birney's idea. This project became collaboration between the BioJAVA, BioPerl, BioPython and BioRuby projects. The idea, or should we say: the goal of this project is to build a generic schema for permanent storage of features, sequences and annotation in a way that is interoperable between the Bio projects. Each Bio\* project has a language binding to BioSQL [7].

### ***BioPerl***

It is a group of modules from the high-level dynamic programming language Perl, that is making development of Perl scripts for bioinformatics applications a lot easier. This project is an active open source software project supported by the OBF (Open Bioinformatics Foundation).

### ***BioJava***

BioJava also is an open-source project that is providing a Java framework for the processing of biological data. Java is a Object-Oriented language from high level. BioJava, however, contains objects for manipulating file parsers, biological sequences, access to BioSQL. One of the most powerful advantages that BioJava has is the tools for making sequence analysis GUIs and powerful analysis and statistical routines including a dynamic programming toolkit.

## **3. EXAMPLES**

### **PostgreSQL**

PostgreSQL is an open source object-relational DBMS (database management system). Its architecture is very strong and provides good qualities for data integrity, reliability and correctness. This DBMS runs on all major operating systems - Linux, UNIX and Windows. It includes SQL92 and SQL99 data types. This DBMS also supports the storage of binary large objects. It has programming interfaces for different languages which are object-relational based.

PostgreSQL has sophisticated features like: tablespaces, backups, query planner/optimizer, it also supports international character sets, Unicode, and it is locale-aware for sorting, case-sensitivity, and formatting. There are PostgreSQL systems managing 4 TB of data. This database system has won many awards in different spheres.

PostgreSQL prides itself in standards compliance. It has full support for subqueries, read-committed and serializable transaction isolation levels. While PostgreSQL has a fully built in relational system catalog which itself supports multiple schemas per database, its catalog is also accessible through the Information Schema as defined in the SQL standard.

Data integrity features include many different compounds such as primary keys and other. It also consists of a host extension and advanced settings. Among the conveniences are auto-increment columns through sequences, and LIMIT/OFFSET allowing the return of partial result sets. PostgreSQL supports compound, unique, partial, and functional indexes which can use any of its B-tree, R-tree, hash, or GiST storage methods.

GiST (Generalized Search Tree) indexing is an advanced system which brings together a wide array of different sorting and searching algorithms including B-tree, R-tree, partial sum trees and many others. It also provides an interface which allows both the creation of custom data types. Thus, GiST offers the flexibility to specify what you store, how you store it, and the ability to define new ways to search through it [1, 2, 7].

The other options that are included in the advanced settings we won't mention. Even better, PostgreSQL supports both single and multiple inheritances in this manner.

PostgreSQL runs stored procedures in more than a dozen programming languages. Included with its standard function library are hundreds of built-in functions that range from basic math and string operations to cryptography and Oracle compatibility. Triggers and stored procedures can be written in C and loaded into the database as a library, allowing great flexibility in extending its capabilities. Similarly, PostgreSQL includes a framework that allows developers to define and create their own custom data types along with supporting functions and operators that define their behavior. As a result, a host of advanced data types have been created that range from geometric and spatial primitives to network addresses to even ISBN/ISSN data types, all of which can be optionally added to the system.

Best of all, PostgreSQL's source code is available under the most liberal open source license: the BSD license. This license gives you the freedom to use, modify and distribute PostgreSQL in any form you like, open or closed source. Any modifications, enhancements, or changes you make are yours to do with as you please. As such, PostgreSQL is not only a powerful database system capable of running the enterprise; it is a development platform upon which to develop in-house, web, or commercial software products that require a capable RDBMS.

## **ORACLE**

To use an Oracle database we need to install the latest version of the JDBC drivers. BioJava is tested with BioSQL using Oracle 9i and 10g. For

the Original schema, we will also need sysdba access, or get our DBA to help us if we do not have this ourself. Things that require sysdba access/DBA assistance incorporate creating tablespaces (or being assigned one to use), creating or assigning tasks, and creating or assigning additional user accounts other than our own. If our DBA does any of this for us, then we will need to mention out the correct steps in BS-

All headings have to be written as „ Heading 1“ format, Arial 11 pt, single line spacing, 24 pt spacing before and 6 pt spacing after the capital letters.

#### **4. KNOWLEDGE**

This article is supported by a project DVU-01/0197-NSF of Bulgaria.

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# Computer administering of psychological tests

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**Abstract:** *The subject of this piece of writing is considering the advantages and disadvantages of computer psychological assessment in comparison with the classic psychological testing. An important condition in order to achieve a high efficiency of psychologist's research work is the automation of all phases of the test – the test construction, test implementation, data storage, rough score evaluation; and assessment results output and interpretation. Some of the aspects of developing specialized software for certain types of psychological assessments are examined in this relation.*

## 1. INTRODUCTION

*Psychological assessment* will be called any psychological testing made with the help of a preliminary prepared test – a list of questions or statements, that the assessed person or group of people has to answer or to give their opinion for. The separate parts of the test are called *items*.

We will call *computerized psychological assessment* any psychological testing, where one or several phases of the testing are made with the use of a computer. A brief historical overview for the computerized testing has been given in section 2. Some of the advantages and disadvantages of computer assessment are reviewed in Section 3.

*Computer administering of psychological tests* is the computer representation of the entire procedure of psychological assessments – test construction, test implementation, results evaluation, storage and maintenance of the developed database, its statistical processing, analysis and interpretation.

*Personality questionnaires* are those psychological tests, which are purposed for description and evaluation of the characteristics of conative (behavioral), emotional and motivation sphere, the interpersonal relations and attitudes of an individual [7]. It's typical for the Personality questionnaires (in contrast to Achievement tests or Intelligence tests) that the items are questions or statements, for which answers the respondent has to report certain information concerning himself, his experience and relations. The format of the answers to items is also specific – most often they are described with the help of a definite multitude of preliminary known answers or statements, which we will mark by *Ans*. In our examinations we will accentuate mainly on definite multitudes of possible responds to each

item of the test. For example  $Ans = \{\text{"Yes"}, \text{"No"}\}$ ,  $Ans = \{\text{"True"}, \text{"False"}\}$ ,  $Ans = \{\text{"I like it"}, \text{"I don't like it"}\}$ ,  $Ans = \{\text{"Often"}, \text{"Sometimes"}, \text{"Never"}\}$ ,  $Ans = \{\text{"True"}, \text{"I don't know"}, \text{"False"}\}$ ,  $Ans = \{\text{"Agree"}, \text{"I'm not sure"}, \text{"Disagree"}\}$ . Items with rating scales are also used in practice, but we will examine just rating scales that represent definite and consequently discreet multitude of real numbers.

In section 4 are examined some general requirements for development of specialized software for psychological assessments administering based on computer testing, which are in conformity with the conventional requirements for excellent software technologies [1,3,6] as well as with the tightly concrete requirements in the field of experimental psychology [7,8].

## **2. HISTORICAL OVERVIEW**

During the last years computers have a reasonable effect upon all phases of the testing process – test design, test implementation, rough score evaluation, results output and interpretation (for more details see [2,5]). The apparent advantage of computer utilization is the multiple increase of the speed of data analyses and results calculation. It's equally important not just to ease the testing procedure, but to develop new methods and approaches in psychological testing, which could not exist without the flexibility and the power of data processing, ensured by modern computers. This way appears the newest tendency in psycho diagnostic research related to computers utilization – the computer testing.

At this stage of psycho diagnostics development computer has become an indispensable part of psychologist work. However the introducing of computer in psycho diagnostics is a gradual process which history is connected with the development of information technologies.

The first attempts to automate the represented incentive material and the subsequent processing of the results start from the beginning of the 1930s of XXth century. But only just in 1960s the utilization of computers in psycho diagnostics becomes wide-spread. At that stage of the development of information technologies the computer function has been limited to representation of simple incentives, fixation of the elementary reactions and statistical processing of the obtained data. The computer has been a subsidiary instrument in researcher's work, accomplishing the most time-taking and routine operations. At the same time begins the development of machine interpretation of the tests.

Just only in the 1970s, with introduction of new generation computer psycho diagnostic systems based on personal computers, begins the strong development of computer psycho diagnostics. The process of introducing into practice of automated test methods/techniques/ also accelerates. A base for subsequent formalization and automation of collecting and processing of psycho diagnostic information is established.

During the 1980s of the previous century, computerized tests are widely developed. The procedure of computer testing changes – the communication with the assessed individual becomes a dialogue between him and the computer. Thus gives the opportunity to change the research strategy during the testing process depending on the obtained interim results.

A later stage of introducing the information technologies in psycho diagnostic practice (the 1990s of XXth century) is use of computer methods with no paper-and-pencil counterpart – computer tests specially designed for computer environment. From there starts the division of the tests to computerized (typical tests, adapted for computer testing) and computer tests – those that have no paper-and-pencil counterpart.

During the last decade of the XXth century computers are available not just in big universities and laboratories, but are in aid of average researchers, too. Recently the complex psychological assessments are made with the aid of powerful personal computers, fitted with a certain number of peripheral devices.

The beginning of the XXIst century is characterized by a very broad use of computers at all phases of computer testing. If so far just certain phases of the testing process were automated (for example representation of the material, data processing, results interpretation), recently ever more often there are programs designed so, that they implement the whole testing procedure – from the instruction before test implementing to the interpretation of the results, thus reducing to minimum the participation of the psychologist.

### **3. ADVANTAGES AND DISADVANTAGES OF COMPUTER TESTING**

Except for indisputably obvious **advantages** of computer testing (like fast administering, high speed data processing and easy results storage) to the merits of contemporary computerized methods in comparison with the traditional ones we could also list the following:

- Invariability of computer programs ensures constant test conditions, which is difficult to achieve in traditional tests;
- Minimizing the subjective influence of the psychologist at test results.
- Possibility to exclude psychologist as an additional stress factor during the test administering, and thus to increase sincerity and thence the reliability of the test;
- Ensuring correct and simple registration of reactions set of the assessed individuals;

- There is a possibility to recover and track in consistency the actions of the assessed individuals;
- It's comparatively easy to create a common database for the assessed individuals;
- There is a possibility for automated test construction;
- Psychologists are exempt from the routine and time-taking work of data evaluation as well as test construction and adaptation;
- It's possible to broaden the group testing practice;
- The possibility to use powerful mathematics – statistical equipment for data evaluation broadens, which facilitates the development of new procedures for analysis;
- It's easier to ensure confidentiality of personal results from the testing;
- It becomes possible to administer large-scale assessments (for example on Internet);
- The storage of diagnostics data becomes easier (on magnet instead of paper carries), which helps to decrease the assessments prime cost;
- There are favorable conditions for application of express methods, which implementation allows obtaining results very fast. In a number of cases (for example in professional psycho diagnostics) that could be crucial;
- There is a possibility for merging the tests into assessment batteries;
- Computer procedure has minimal negative influence in comparison with the direct contact between examiners and respondents (the influence of self defense mechanism in respondent is minimized);
- Gives a possibility to awaken the playing motive in test respondent (by creating a test that looks like a game), which makes the testing process more attractive and increases the reliability of the results;
- Gives the opportunity to carry out analysis of the respondent's behavior in the course of testing, to consider a great number of parameters in various situations, to organize a dialogue in program's work conditions (the so-called adaptive tests);
- By the means of computer graphics there is a possibility to present dynamic objects to the respondent (dynamic stimulated environment), it becomes possible to use poly-modal incentives;
- There is a possibility for individualization of psycho diagnostic assessments;
- Ensures a close relation to solving of practical tasks.

Besides the advantages of computer testing, there inevitably are **disadvantages** as well:

- New computer tests development is a complex, time-consuming and expensive task, which could be accomplished by good professionals-programmers only;
- It's necessary for the operators of such programs to pass a special training for work with the computer tests;
- There is no individual approach in test processing;
- The latency of processing phases and interpretation of results (they are preliminary settled by the programmer in the computer program);
- Some of the approved tests that had become example tests, when used in electronic version lead to significant changes in their diagnostic abilities, most of all concerning their validity and reliability. That is to say that to make use in psycho diagnostic practice of automated versions of tests, which are already standardized; they need to pass revalidation first. It is necessary to recheck the reliability of computer methods and their standardization as well;
- For the processing of the obtained results is often used a powerful general purpose software like SPSS, MatLab, Statistica, S-Plus or other similar systems for example, for the development of which considerably much efforts are needed, while in computer testing is not used a great part of their possibilities; and this leads to a certain lack of efficiency in psychologist's research work;
- The absence of direct observation and personal contact with the respondent is a cause for the same difficulties and limitations as those ensued from group testing;
- In approximately 30% of all assessed individuals is observed a psychological barrier [4], the so-called "phenomenon of computer anxiety", even more, in 5% of all cases are registered conditions similar to phobias;
- Some of the tests could not possibly be transferea for computer use (like the most of projective methods);
- It is difficult to put into practice computer tests in field conditions. A mandatory condition for their application in such terms is the use of portable computers.

The above mentioned disadvantages provoke the negative reaction to computer tests among the psychologists. For example the use of such tests in clinical psycho diagnostics is very limited because the price for errors in decision-making could be too high. However it's evident that computer tests have a great future, where most of the faults in the procedure would be eliminated due to further development of computers. That optimism is visible in the mounting interest in computer psycho diagnostics, in which there are more than 1000 computer tests, included [4].

#### **4. SOFTWARE FOR COMPUTER ADMINISTERING OF PSYCHOLOGICAL ASSESSMENTS**

The development of a new generation specialized software for psychological assessments (expert system in psychology) can help to overcome the greatest part of the disadvantages of computer testing, listed in section 3.

The development of necessary software for computer administering of psychological tests requires certain knowledge and skills in computer programming field, which rather often is not in the competence of the research psychologist. On the other hand the test construction, test implementation, data processing and analysis of the results require profound knowledge in the field of psychoanalysis. In this aspect development of specialized software require active collaboration of specialists in both fields of science. The result is development of software – generator and analyzer of psychological tests, which automates to the maximum all the activities connected with computer administering of psychological tests. As that will save a lot of time and human resources, it will be very profitable and will justify the expenses.

By the use of generator and analyzer of individual tests the research psychologist (having base knowledge in computers) would be able to design his own computer test and implement independently all phases of computer administering of an arbitrary psychological individual test.

A computer system for psychological tests administering is a type of an expert system in the field of psychology and psycho diagnostics. The components of that system include: a system for management of relation type database, designed for input, storage and processing of data related to the different items of the tests; all possible multitudes form the *Ans* type; distinguished characteristics of human personality; psychological categories; results from the implemented individual or group testing; etc. The system will also include knowledge bases concerning the links between the separate units of the database, calculating schemes and algorithms for processing the value  $n$  quantity characteristics obtained in testing process, as well as psychological analysis and interpretation of the possible results from the work with the system.

In conclusion we must emphasize that the authors are in process of developing a system with the above described characteristics. More detailed description of the software development could be found in the continuation of this work given for publishing in present volume [10].

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# Reserch of the Effectiveness of the Parametrical Algorithm based on binary matrices

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**Abstract:** The work examines four parametric family of algorithms for calculating the estimates on the number of binary tables (matrices), caused by monotonous Boolean functions. Estimate calculating algorithms (ECA) are based on the classification of the recognition subject in the class depending on the value of quantitative performance - estimates (where comes the name of the method). We prove that under some additional restrictions on the set of admissible tables, algorithms of this family have a high accuracy of recognition.

**Keywords:** pattern recognition, estimate calculating algorithms

## 1. DESCRIPTION OF THE MODEL

The set of objects to be recognized by the system is described by  $n$  binary features, i.e.  $\sigma_i = \{0, 1\}$ ,  $i = 1, 2, \dots, n$ . The tables for training and supervision are sets of admissible rows, broken down into two classes -  $\mathbf{m}$  for the training table  $T_1$  and  $\mathbf{t}$  - for control table. Sets of admissible rows for the classes  $K_1$  and  $K_2$  are described as follows:

Let  $f(x) \equiv f(x_1, x_2, \dots, x_n)$  be monotonic Boolean function;

$D_1 = \{x = (x_1, x_2, \dots, x_n) \mid f(x) = 1\}$  be the set of function's units;

$D_0 = \{x = (x_1, x_2, \dots, x_n) \mid f(x) = 0\}$  be the set of zeros for the function  $f(x)$ .

The point  $x \in D_1$  is defined as a limit point in the set  $D_1$  for the point  $y \in D_0$  such that  $\rho(x, y) = 1$  (The distance  $\rho(x, y)$  is in terms of Heming, i.e. a number of different components). Similarly, we define the limit point in the set of zeros of monotonic Boolean function: the point  $x' \in D_0$  is called the limit, if there is a point  $y' \in D_1$  such that  $\rho(x', y') = 1$

Let  $\Gamma_1$  be the set of limit points of the set  $D_1$  and  $\Gamma_0$  be the set of limit points of  $D_0$ . The set  $\Gamma = \Gamma_0 \cup \Gamma_1$  is the set of limit points of the Boolean function  $f(x)$ .

Let  $\varphi$  be any natural number. We define the following subsets  $D_1^\varphi$  - the set of units and  $D_0^\varphi$  - the set of zeros of the function:

$$D_1^\varphi \equiv \{x \mid x \in D_1 \text{ и } \rho(x, \Gamma) \geq \varphi\},$$

$$D_0^\varphi \equiv \{x \mid x \in D_0 \text{ и } \rho(x, \Gamma) \geq \varphi\},$$

$$\text{with } \rho(x, \Gamma) = \min_{z \in \Gamma} \rho(x, z).$$

The set of admissible objects for the class  $K_1$  coincides with the set of coordinates of points belonging to the set  $D_1^\varphi$  (briefly it coincides with the set  $D_1^\varphi$ ). Similarly, the set of admissible rows for the class  $K_2$  forms the set  $D_0^\varphi$ . In further work with tables  $T_1, T_2$  filled with admissible rows by the sets constructed above we will denote with  $T_1^\varphi, T_2^\varphi$ .

The set of admissible objects for the class  $K_1$  coincides with the set of coordinates of points belonging to the set  $D_1^\varphi$  (briefly it coincides with the set  $D_1^\varphi$ ). The set of admissible rows for the class  $K_2$  forms the set  $D_0^\varphi$ . In further work with tables  $T_1, T_2$  filled with admissible rows by the sets constructed above we will denote with  $T_1^\varphi, T_2^\varphi$ . But any arbitrary algorithm belonging to the class algorithms  $A(k, \varepsilon, \delta_1, \delta_2)$  described in [1,2] are supplied sequentially to recognition rows (objects) of a fixed control table, as decision set and use table. We define the **quality** of the algorithm by the proportion of correctly recognized control rows:

$$Q(A) = \frac{t'}{2t},$$

where  $t'$  is the number of correctly identified rows of the table  $T_2^\varphi$  by algorithm A.

The extremal algorithm  $A^*$  is determined as:

$$Q(A^*) = \sup_{A \in A(k, \varepsilon, \delta_1, \delta_2)} Q(A).$$

As performance characteristics of the given family (the given class)  $A(k, \varepsilon, \delta_1, \delta_2)$  of the algorithms on a set of ordered pairs  $\{(T_1^\varphi, T_2^\varphi)\}$  of admissible tables is used value, specified by the condition:

$$Q_\varphi(A^*) = \min_{\{(T_1^\varphi, T_2^\varphi)\}} Q(A^*)$$

The task is to find the minimum value of the parameter  $\varphi$  (if it even exists for the function  $f$ ), where the algorithm detects extreme permissible faultless couple tables.

We will attempt to formulate a criterion for correct recognition to formulated procedure to reduce the checks in order to solve the problem.

We will show that for a sufficiently wide class of monotonic function there is integer non-negative value  $\varphi$ , such that for any pair  $(T_1, T_2)$  of corresponding set, the algorithm is recognized unmistakably.

## 2. CRITERION FOR CORRECT RECOGNITION

Let the rows of  $K_1$  and  $K_2$  be arbitrary and not intersected subsets  $G_1$  and  $G_2$  of the set of tops of unit  $n$  - metric cube  $E_n$ .

For convenience, let us introduce the following variables:

$$\begin{aligned} R(G_1) &= \max_{y \in G_1} \left[ \max_{x_1 \in G_1} \rho(x_1, y) - \min_{x_2 \in G_2} \rho(x_2, y) \right], \\ R(G_2) &= \max_{z \in G_2} \left[ \max_{x_2 \in G_2} \rho(x_2, z) - \min_{x_1 \in G_1} \rho(x_1, z) \right], \\ R(G) &= \max \{ R(G_1), R(G_2) \} \end{aligned}$$

**Theorem 1.** The extremal algorithm recognizes correctly each pair of admissible tables then and only then when  $R(G) < 0$ .

*Proof:* 1. *Sufficiency.* Let  $R(G) < 0$ . Consider algorithm  $A \in A(k, \varepsilon, \delta_1, \delta_2)$  with parameters  $k, \varepsilon$  satisfying the conditions (parameters  $\delta_1, \delta_2$  are not fixed so far):

$$\varepsilon + 1 \leq m(G), \quad (1)$$

$$n - k + \varepsilon \geq M(G), \quad (2)$$

where

$$m(G) = \min_{x \in G_1} \min_{y \in G_2} \rho(x, y), \quad M(G) = \max \{ M(G_1), M(G_2) \},$$

$$\text{and } M(G_1) = \max_{x, y \in G_1} \rho(x, y), \quad M(G_2) = \max_{x, y \in G_2} \rho(x, y).$$

Inequalities system (4.1) (4.2) is compatible, as the sets  $G_1$  and  $G_2$  do not intersect, and  $m(G) \geq 1$ , but by condition  $R(G) < 0$ , where  $M(G) \leq n-1$ .

Let  $T_1 = (S_1, S_2, \dots, S_{2m})$ ,  $T_2 = (S'_1, S'_2, \dots, S'_{2t})$  us have arbitrary admissible tables for training and supervision, ie

$$\begin{aligned} S_i &\in G_1, \quad S_{i+m} \in G_2, \quad i=1, 2, \dots, m, \\ S'_j &\in G_1, \quad S'_{j+t} \in G_2, \quad j=1, 2, \dots, t. \end{aligned}$$

Algorithm with parameters  $k, \varepsilon$  satisfying conditions (1), (2), assigned, according to (1.1), the following estimates for the row  $S'_i (1 \leq i \leq t)$ :

$$\begin{aligned} \Gamma_1^{S'_i} &= \sum_{q=1}^m \sum_{\lambda=0}^{\varepsilon} \binom{n - \rho(S_q, S'_i)}{k - \lambda} \binom{\rho(S_q, S'_i)}{\lambda}, \\ \Gamma_2^{S'_i} &= \sum_{q=m+1}^{2m} \sum_{\lambda=0}^{\varepsilon} \binom{n - \rho(S_q, S'_i)}{k - \lambda} \binom{\rho(S_q, S'_i)}{\lambda}. \end{aligned}$$

Therefore have satisfied the following inequalities:

$$\begin{aligned} &\Gamma_1^{S'_i} - \Gamma_2^{S'_i} \geq \\ &\geq m \cdot \min_{S' \in G_1} \left[ \min_{S \in G_1} \sum_{\lambda=0}^{\varepsilon} \binom{n - \rho(S, S')}{k - \lambda} \binom{\rho(S, S')}{\lambda} - \max_{S \in G_2} \sum_{\lambda=0}^{\varepsilon} \binom{n - \rho(S, S')}{k - \lambda} \binom{\rho(S, S')}{\lambda} \right] \\ &\quad i=1, 2, \dots, t \end{aligned} \quad (3)$$

for  $\rho(x_1, y) - \rho(x_2, y) \leq R(G_1) \leq R(G) < 0$ ,  $\rho(x_1, y) < \rho(x_2, y)$ , for any  $x_1, y \in G_1$ ,  $x_2 \in G_2$ . After applying the theorem 1.1. receive:

$$\sum_{\lambda=0}^{\varepsilon} \binom{n - \rho(x_1, y)}{k - \lambda} \binom{\rho(x_1, y)}{\lambda} \geq \sum_{\lambda=0}^{\varepsilon} \binom{n - \rho(x_2, y)}{k - \lambda} \binom{\rho(x_2, y)}{\lambda}.$$

Since it is implemented and

$$\begin{aligned} \rho(x_1, y) &\leq M(G_1) \leq M(G) \leq n - k + \varepsilon, \\ \rho(x_2, y) &\geq m(G) \geq \varepsilon + 1, \end{aligned} \quad (\text{see (1) и (2)})$$

Then according to the inequality:

$$\sum_{\lambda=0}^{\varepsilon} \binom{n - \rho(x_1, y)}{k - \lambda} \binom{\rho(x_1, y)}{\lambda} > \sum_{\lambda=0}^{\varepsilon} \binom{n - \rho(x_2, y)}{k - \lambda} \binom{\rho(x_2, y)}{\lambda}$$

for arbitrary  $x_1, y \in G_1$ ,  $x_2 \in G_2$  and inequality (3) follows:

$$\Gamma_1^{S'_i} - \Gamma_2^{S'_i} \geq m, \quad i = 1, 2, \dots, t. \quad (4)$$

Reflect similar with respect to any order of the class  $K_2$  of the control table, we get:

$$\Gamma_2^{S'_i} - \Gamma_1^{S'_i} \geq m, \quad i = t+1, t+2, \dots, 2t. \quad (5)$$

Consider the value  $\frac{\Gamma_1^{S'}}{\Gamma_1^{S'} + \Gamma_2^{S'}}$  of arbitrary row  $S' \in G_1$ . Since, under (4) is satisfied:

$$\frac{\Gamma_1^{S'}}{\Gamma_1^{S'} + \Gamma_2^{S'}} \geq \frac{1}{1 + \max_{S' \in G_1} \frac{\Gamma_2^{S'}}{\Gamma_1^{S'}}} \geq \left[ 1 + \frac{\max_{S' \in G_1} \Gamma_2^{S'}}{\min_{S' \in G_1} \Gamma_1^{S'}} \right]^{-1} \quad (6)$$

Similarly for arbitrary row  $\tilde{S}' \in G_2$  is fulfilled:

$$\frac{\Gamma_1^{\tilde{S}'}}{\Gamma_1^{\tilde{S}'} + \Gamma_2^{\tilde{S}'}} \geq \left( 1 + \frac{\max_{\tilde{S}' \in G_2} \Gamma_1^{\tilde{S}'}}{\min_{\tilde{S}' \in G_2} \Gamma_2^{\tilde{S}'}} \right)^{-1} \quad (7)$$

and using inequalities (6) and (7) we get:

$$\min \left\{ \min_{S' \in G_1} \frac{\Gamma_1^{S'}}{\Gamma_1^{S'} + \Gamma_2^{S'}}, \min_{\tilde{S}' \in G_2} \frac{\Gamma_1^{\tilde{S}'}}{\Gamma_1^{\tilde{S}'} + \Gamma_2^{\tilde{S}'}} \right\} \geq \left[ 1 + \frac{\sum_{\lambda=0}^{\varepsilon} \binom{n-m(G)}{k-\lambda} \binom{m(G)}{\lambda}}{\sum_{\lambda=0}^{\varepsilon} \binom{n-M(G)}{k-\lambda} \binom{M(G)}{\lambda}} \right]^{-1} \quad (8)$$

Let the parameters  $\delta_1, \delta_2$  are such that

$$\delta_1 \leq m, \quad \delta_2 \leq \left[ 1 + \frac{\sum_{\lambda=0}^{\varepsilon} \binom{n-m(G)}{k-\lambda} \binom{m(G)}{\lambda}}{\sum_{\lambda=0}^{\varepsilon} \binom{n-M(G)}{k-\lambda} \binom{M(G)}{\lambda}} \right]^{-1}. \quad (9)$$

From inequalities (4) (5), (8) follows that the algorithm with parameters  $k, \varepsilon, \delta_1, \delta_2$  satisfying the system of conditions (1), (2), (9) will unmistakably recognize in each pair admissible tables.

This sufficiency is proven.

*II. Necessary.* Let an extremal algorithm work faultless on any pair of admissible tables. Will be shown that the inequality  $R(G) < 0$  is satisfied. Let to assume the contrary, ie  $R(G) \geq 0$ . Let for certainty has been met  $R(G_1) \geq 0$ , then exist  $x_1, y \in G_1, x_2 \in G_2$ , such that  $\rho(x_1, y) \geq \rho(x_2, y)$ .

To build a training table in the following way:

$$S_i = x_1, S_{i+m} = x_2, \quad i = 1, 2, \dots, m.$$

Table for control contains at least one row, equal to y in the  $K_1$  class, then:

$$\Gamma_1^y - \Gamma_2^y = m \left[ \sum_{\lambda=0}^{\varepsilon} \binom{n-\rho(x_1, y)}{k-\lambda} \binom{\rho(x_1, y)}{\lambda} - \sum_{\lambda=0}^{\varepsilon} \binom{n-\rho(x_2, y)}{k-\lambda} \binom{\rho(x_2, y)}{\lambda} \right] \leq 0$$

for any value of each parameters  $k, \varepsilon$ .

For arbitrary algorithm of the family algorithms  $A(k, \varepsilon, \delta_1, \delta_2)$  decision rule will include the row y in the class  $K_2$  or will refuse to classify it, they extremal algorithm will not work properly, which contradicts the assumption that  $R(G_1) \geq 0$  assumption leads to contradiction. This need has been demonstrated.

Let us introduce the following variables:

$$R_1(\varphi) = R(D_1^\varphi), R_0(\varphi) = R(D_0^\varphi), R(\varphi) = \max \{R_1(\varphi), R_0(\varphi)\}.$$

**Consequence of theorem.** Let  $\varphi$  is fixed and such that the sets  $D_1^\varphi$  and  $D_0^\varphi$  are not empty. The extremal algorithm works unmistakably for each pair admissible tables  $(T_1^\varphi, T_2^\varphi)$  if and only if  $R(\varphi) < 0$ .

If for the set of monotonic Boolean function  $f(x_1, x_2, \dots, x_n)$  can be found  $\varphi$ , such that  $D_1^\varphi$  and  $D_0^\varphi$  both are not empty, and  $R(\varphi) < 0$ , the largest interest causes "the richest" set of admissible rows corresponding to maximum  $\varphi$  satisfying inequality  $R(\varphi) < 0$ .

The problem of finding a value of the parameter  $\varphi$  allows a trivial solution by the method of brute force enumeration, but for large enough n, the amount of work is big..

### 3. STRUCTURE OF THE SETS $D_1^\varphi$ AND $D_0^\varphi$

Let  $x \in E_n$ ,  $x = (x_1, x_2, \dots, x_n)$  and by  $J_x$  is denoted the set of all unit coordinates of point  $x$ , i.e.  $J_x = \{j \mid x_j = 1\}$ . Obviously, for  $x \prec y$ ,  $J_x \subseteq J_y$  and conversely, if  $J_x \subseteq J_y$  then point  $x$  precedes  $y$ , i.e.  $x \prec y$  and  $J_x = J_y$  if and only if  $x = y$ .

For structure of these sets are valid:

**Lemma1.**  $\rho(x, y) = |(J_x \cup J_y) \setminus (J_x \cap J_y)|$  (By  $|y|$  is denote cardinality of the set), i.e. the distance between tops  $x, y$  of the unit of  $n$  - metric cube is equal to the number of non-coincidence coordinates

**Corollary:** If  $x \prec y$ , then  $\rho(x, y) = |J_y \setminus J_x|$ .

**Theorem 2.** For any  $\varphi$  ( $\varphi \geq 0, \varphi \in \Gamma$ ) there are monotonous Boolean functions  $f_\varphi^1(x), f_\varphi^0(x)$  such that a set of the units of the function  $f_\varphi^1(x)$  coincides with the set  $D_1^\varphi$  and the set of zeros of the function  $f_\varphi^0(x)$  coincides with  $D_0^\varphi$

### 4. CONCLUDING REMARKS

Let  $\psi(n, \tau)$  be the set of Boolean functions defined on the collections, whose number of units is in the range from  $\left\lfloor \frac{n}{2} \right\rfloor - \tau$  to  $\left\lfloor \frac{n}{2} \right\rfloor + \tau$  (in the collections we set the choice of values for the coordinates). We believe that outside this interval with fewer units in the collection, the value function is equal to 0, where a larger number of units is equal to 1. Then  $\varphi < \left\lfloor \frac{n}{2} \right\rfloor - \tau$  for each function  $f \in \psi(n, \tau)$  the sets  $D_1^\varphi$  and  $D_0^\varphi$  are not empty. On the other hand a set of many collections, corresponding to the lower units of the function  $f_\varphi^1(x)$  contains not less than  $\left\lfloor \frac{n}{2} \right\rfloor - \tau + \varphi$  units, and each set of many sets, corresponding to the zeros of functions  $f_\varphi^0(x)$  contain no more than  $\left\lfloor \frac{n}{2} \right\rfloor + \tau - \varphi$  units. From here following to the criteria for recognition and

faultless formula (1), (2), it follows that  $\varphi \geq \left\lceil \frac{n}{4} \right\rceil + \tau$  for each function  $f \in \psi(n, \tau)$  the extremal algorithm from family of algorithms  $A(k, \varepsilon, \delta_1, \delta_2)$  made recognition for each pair admissible tables  $(T_1^\varphi, T_2^\varphi)$  unmistakably.

Let  $\bar{\psi}(n)$  be the number of monotonous Boolean functions for which there is a parameter  $\varphi$ , extremal algorithm from family of algorithms  $A(k, \varepsilon, \delta_1, \delta_2)$  recognized for each pair admissible tables  $(T_1^\varphi, T_2^\varphi)$

rightly, then  $\log \bar{\psi}(n) : \log \psi(n) : \left( \frac{n}{\left\lceil \frac{n}{2} \right\rceil} \right)$ .

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# Software for Building Load Calculations

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**Abstract:** *In this paper, a software tool for thermal design and energy simulation related to buildings is proposed. In design mode, software covers the calculation of heating, cooling and latent room loads, internal comfort analysis and codes/standards checks. Linked modules deal with the performance of HVAC (Heating, Ventilating, and Air Conditioning) plant and natural ventilation. Components prepared as a library of working code modules are ready for immediate implementation as stand-alone performance model or as components to be integrated with a complete building simulation program.*

**Keywords:** *thermal design, thermal analysis, building loads, heat balance model, heat transfer*

## INTRODUCTION

Building energy consumption accounts for approximately 40% of the global energy demands; the bulk of this energy is needed to compensate for thermal energy losses or gains that occur in building envelope systems. Conventional strategies to mitigate thermal energy losses or gains in enclosures rely on passive insulation materials, separate heating and cooling systems then compensate for energy losses or gains that do occur.

Large commercial buildings that require air conditioning all year round are energy-intensive. Air conditioning typically contributes more than half of the energy consumption of a commercial building. As the building sector accounts for more than one-third of the total electrical consumption, it is imperative that today's buildings be designed for energy efficient operation throughout its lifetime. To achieve this, the response of a building to weather conditions and load changes need to be well understood. Conventional design methodologies are now being surpassed by computerized engineering tools that allow the performance of the building to be simulated long before its construction.

Meanwhile, building authorities worldwide have begun or completed the drafting of building performance standards taking advantage of the proliferation of personal computers and the rapid increase in computational power available to run sophisticated building norms and simulation programs. Concentrated efforts to reduce energy consumption will help to mitigate adverse impacts on our environment. Achieving energy efficiency

also helps to reduce our dependence on fuel imports and improve our economic competitiveness.

European Committee for Standardization (CEN) formulated EUROPEAN STANDARD NORME **EN 12831** in March 2003, as part of Europe's efforts to improve building energy efficiency. This Standard gives the method of calculation of the thermal transmittance of building elements in contact with the external air and deals with elements in thermal contact with the ground.

On the base of this Standard Bulgarian National Calculation Tool (Method) be developed and published. The calculation method is based on the delivered energy needed under standard indoor and outdoor conditions. The basic process of the calculation is divided into two stages:

- Calculation of energy demand (calculated on the standard use) of the building, or its zones; the calculation of heat losses, and heat gains, required in each space in order to maintain specified internal conditions;
- Calculation of energy consumption (building, zones, according to the energy demands); the calculation of the energy required by the energy systems (boilers, AHU units, DHW systems, lighting, etc.) needed to provide the necessary heating or cooling, or humidity control, etc.

The procedure for demonstrating compliance with the Building Regulations for buildings other than dwellings is by calculating the annual energy use for a proposed building and comparing it with the energy use of a comparable 'notional' building. Both calculations make use of standard sets of data for different activity areas and call on common databases of construction and service elements.

This standard specifies a calculation method for calculation of the heat supply needed under standard design conditions in order to make sure that the required internal design temperature is obtained. The standard describes calculation of the design heat load:

- On a room by room or heated space by heated space approach, for the purpose of dimensioning the heat emitters;
- On a whole building or building entity approach, for the purpose of dimensioning the heat supply.

The standard also provides a simplified calculation method.

The set values and factors required for calculation of the heat load should be determined in a national annex to this standard. Annex tabulates all factors, which may be determined on a national level and gives default values for cases where no national values are available.

## **SCOPE of EN 12831 Standard**

The standard specifies methods for calculating the design heat loss and the design heat load for basic cases at the design conditions.

Basic cases comprise all buildings:

- With a limited room height (not exceeding 5 m);
- Assumed to be heated to steady state conditions under design conditions.

Examples of such buildings are: residential buildings; office and administration buildings; schools; libraries; hospitals; recreational buildings; buildings used in the catering trade; department stores and other buildings used for business purposes; industrial buildings.

## **Principle of the calculation method**

The calculation method for the basic cases is based on the following hypotheses:

- The temperature distribution (air temperature and design temperature) is assumed to be uniform;
- The heat losses are calculated in steady state condition assuming constant properties, such as values for temperature, characteristics of building elements, etc.

The procedure for basic cases can be used for the majority of buildings:

- With a sailing height not exceeding 5 m;
- Heated or assumed to be heated at a specified steady state temperature;
- Where the air temperature and the operative temperature are assumed to be of the same value.

## **Data required**

The Standard provides information on the appropriate data required for performing the heat load calculation. The following data is required:

- *Climatic data.* The following climatic data is used: external design temperature (winter and summer), annual mean external temperature, solar radiation (zone)
- *Internal design temperature.* The internal temperature used for calculation of the design heat loss (gains) is the internal design temperature. For the basic case, the operative temperature and the internal air temperature are assumed to be of the same value.
- *Building data.* The building data include geometrical characteristics of building and all rooms; thermal characteristics of envelope elements; thermal characteristics of linear thermal bridges, internal heat sources, optical characteristics of windows; thermal accumulation characteristics of building elements and other.

The objectives of calculating the design heat load is to ensure an acceptable internal thermal environment at design exterior temperature conditions. The internal design temperature for heating is given at a national level. The design for internal thermal environment should be based on EN ISO 7730, where the quality of the thermal environment is expressed by the PMV (Predicated Mean Vote) and PPD (Predicated percentage of dissatisfied) values.

### **Introduction to CDLoad**

There are currently many computerized Building design calculation (BDC) codes and programs available to professionals. As different BDC codes vary in complexity, calculation algorithms, ease of use and cost, the codes have their advantages and disadvantages. The user's experience and computer literacy skills also play an important role in performing building energy simulation. It is foreseen that BDC will be more frequently and widely applied in building design and analysis as it can be under-taken with greater ease and lower costs using personal computers.

Despite their great popularity the BDS codes have some drawbacks. As a basic drawback of these software products can be pointed the difficult inserting in system the specific requirements of national standards and build a specific climatic and other data for calculations.

Another drawback of the BDS programming systems is that it is difficult to make analyses about long-term system characteristics. Apart from that they do not allow to be made analyses about the influence of separate constructive parameters in the installation scheme.

**CDLoad** is a computer program that provides a heat losses and heat gains in rooms of building, the total design heat load of the building entity, analysis of a building's energy consumption. CDLoad calculates designed heat loads and gains for building and rooms and yearly energy use of a building given a description of the building geometry, construction, use and HVAC and lighting equipment. It was originally based on the CEN Standards.

The organization of the programming system contains three basic modules. As a basic infrastructural part of the system it appears the module of collecting the constructive and climatic data for building.

The second structural part of the programming system is a set of programming modules for calculating and analyzing the thermal performance and design load of building. They are organized as separate programming structures according to the common infrastructural part of the programming system.

The third part of the programming system organizes the preservation of results from the calculations and a preparation of the necessary data. It is worked out a universal system for showing results for different periods of the

simulation interval. Technical and economical estimations for building systems can be generated on the base of received results.

The main problem in algorithm for such kind of programs is organization of data base system for a project. The part of data can be prepared as a specialized data for project and other data can be prepared as a common data, which can be used for all projects. This data organization must be very flexible. On figure 1 is presented a scheme of data files and relating binds in this system.

Files specified for a given project are saved in separated directory, created for the project and that files are prepared as a special files with direct access in Pascal programming tool (Delphi). Files containing the common data base are prepared as a standard base data – Paradox. Data from this files is accessible for all projects.

WINDOWS environment for the CDLoad Delphi program (fig.2) provides for user friendly input of data, processing and viewing of the results. The program estimates the energy heat loss and gains and energy consumption of a building taking into account the site location, the building structure and the type of building services installed to maintain the desired environmental conditions. It enables a designer to investigate alternatives and make energy comparisons quickly and effectively for a very wide range of building configurations and air conditioning systems using actual measured climatic data.

### ***Computer Platform***

CDLoad program needs PC running Windows 95, 98, XP, Vista, 100 MB Ram or paging disk, 100 MB disk space, CD-Rom drive.

Data input is interactive (mouse driven) via WINDOWS dialogue boxes, selection lists drop down lists and entry fields on a series of screens running through general Project information to individual space data and for all the building services plant, capacities, operating schedules, etc. Buttons on the toolbar and special keys allow the user to copy individual values, columns of data or complete screens from space to space or system to system and there is a facility for making global changes.

### **CONCLUSION**

New technologies in planning, design and operation for energy efficiency of buildings often require the use of computers, and with the developing of desktop computing, building energy simulation is expected to grow in importance. A new energy performance standard is being proposed for use in European countries so as to achieve higher efficiency levels and greater energy savings. We demonstrated engineering compliance software, **CDLoad**, tailored for use by professionals to perform calculations aimed at achieving energy efficiency in buildings and compliance of energy

performance standards. Software is approved in CHAMBER OF ENGINEERS IN THE INVESTMENT DESIGN and is adopted as official design software for HVAC ([Heating](#), [Ventilating](#), and [Air Conditioning](#)) projects.

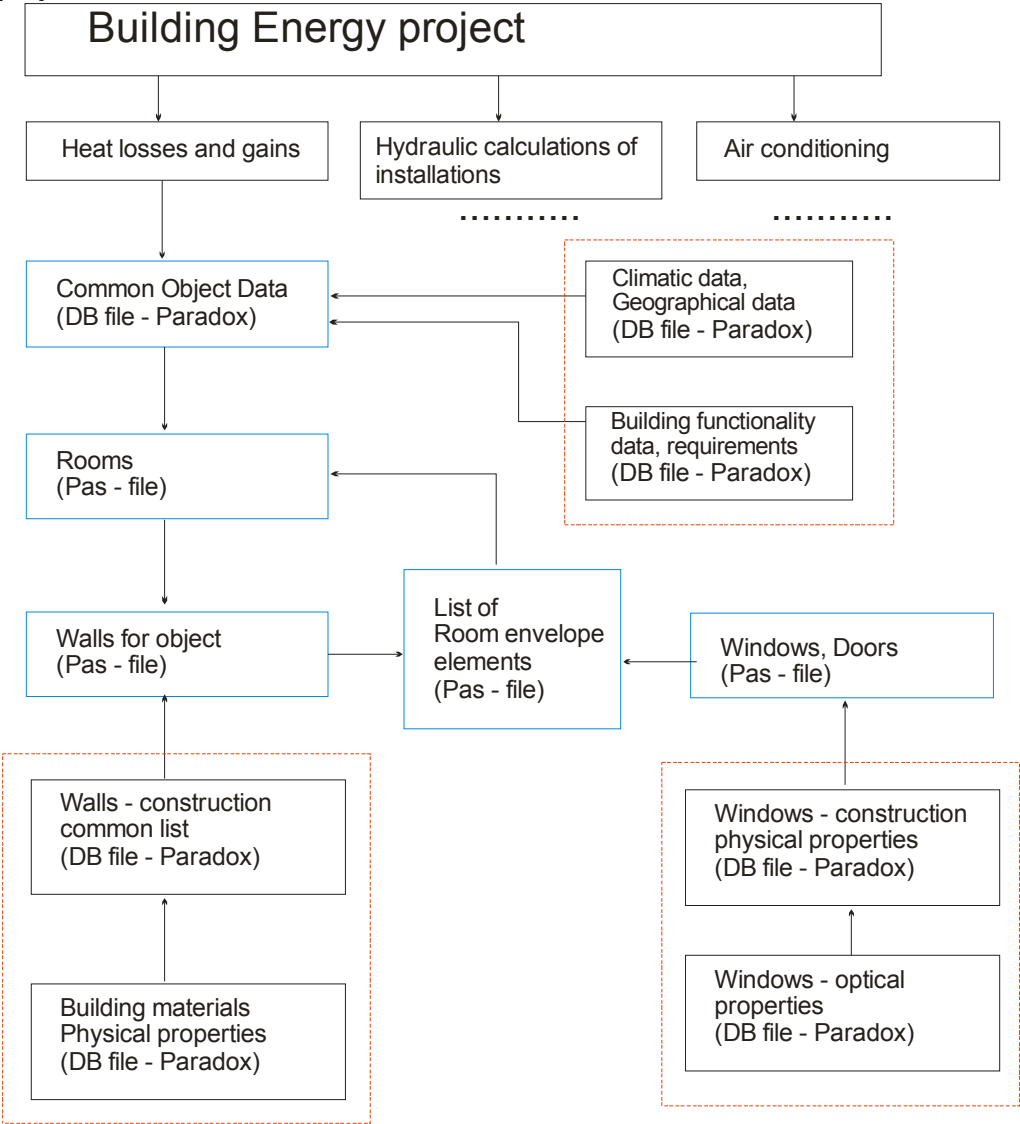


Fig.1 . Data files for **CDLoad** software

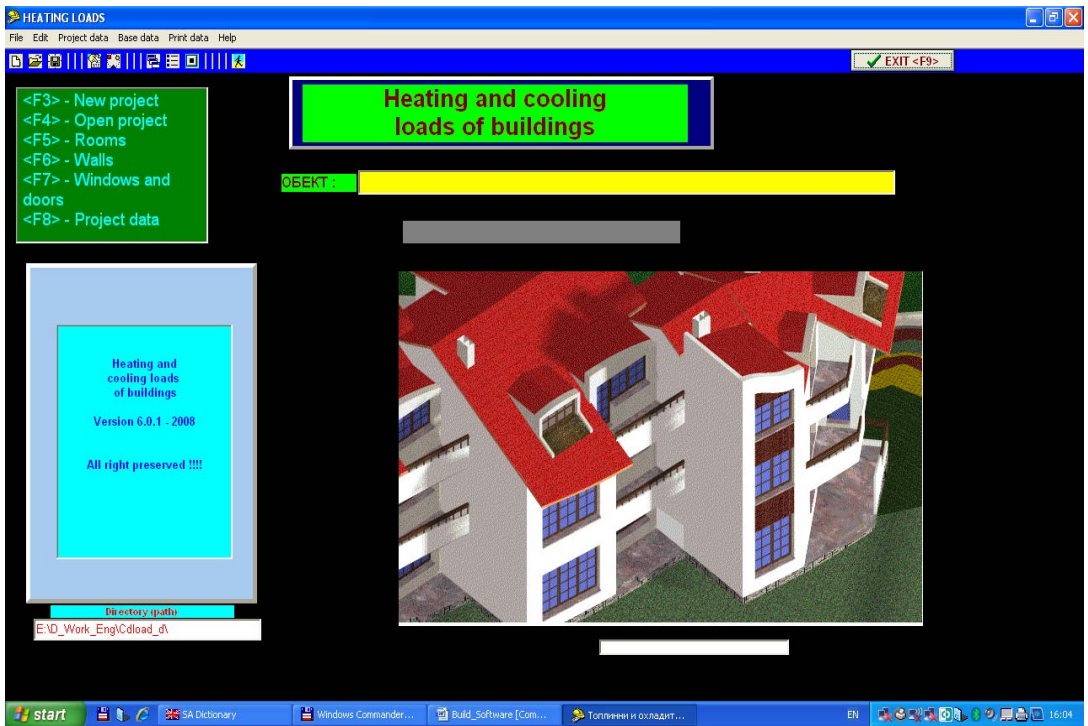


Fig. 2. Main screen of the program CDLoad

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## Network Access. Actual situation and growing tendencies in southeastern part of Albania.

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**Abstract:** *Minimal necessary conditions for e-readiness are good access to network infrastructure. Access can be defined as a combination of availability and affordability of the network including hardware and software needed for network interface. Quality and speed of the network are also important to define its usage. The main objective of this study is the calculation of the level of all indicators which assess the network access and directly and indirectly linked to e-readiness in our region.*

*For this evaluation the network access it is divided into some categories and an analysis is made to the qualitative and quantitative features of these categories.*

**Keywords:** *e-readiness, internet, network access, Albania.*

### 1. Introduction

Continuous growth and evolution of information and communication technology has fundamentally changed global relations, with a growth of possibilities for a great economical and social development and competitiveness. Technologies like Internet, personal computers and wireless telephony have made the globe a network of individuals, businesses, governments and schools in continuous growth interacting with one-another.

The new ICTs are a powerful, yet neutral tool that can be used to address a host of issues in every community - their real power, therefore, lies in their ability to support holistic development that promotes long-term social and economic benefits, [ITG Harvard University, 2008].

Bearing in mind the recent situation, I will take into consideration, in my paper, the evaluation of network access in the southern eastern part of Albania.

### 2. NETWORK ACCESS

One of the minimal necessary conditions for the e-readiness is an acceptable access to the network infrastructure. Without the worldwide global network access no community can be part of the network connected world. Access is determined by a combination of the availability and affordability for the network usage, also hardware and software needed for the network interface. Network quality and speed are also important to determine the usage of this network. Client oriented service from the companies which as-

sure access to the network is a main factor for adoption and usability of network applications.

Because of the growth of importance and unique characteristics of Internet, which secures a global platform as far as voice service, videos and data are concerned, the evaluation for the network access will be calculated on the Internet access context. Also citizens of different ages, genders and professions have answered a questionnaire whose results are presented in this paper.

In order to evaluate the network access we think to divide it into some subcategories which are presented below:

1. Penetration of technologies for the network access.

The lack of access in voice and data services remains a serious obstacle at the network e-readiness for the greatest part of communities in developing countries. Communication infrastructure is distributed in a widely changing local and regional penetration proportion which depends on the factors such as incomes and geographical position.

2. Network connection

Bandwidth valuable for individuals' local connections as for the Internet connection of the community determines the number of users and the kind of network activities that this line supports. Activities which intensively use bandwidth as for transferring big files and video streaming can be worthless to the limited network accessed communities.

3. Network affordability

Prices which companies and individuals pay for Internet widely depend on the services ISP offers, from which Internet is distributed. When these prices are high, individuals have the tendency to work less with the internet. As a result, there is a low access to the net.

4. ICT market and services

A market with a great number of choices of hardware and software may encourage a more specialized network usage including special choices in special local conditions. Prices are also an important aspect, especially in developing countries, where individuals have low incomes and can not support high prices.

### **3. Assessment for Network Access**

Korca's region telecommunication infrastructure, like all over Albania, has been undeveloped before the year 1990. After the 1990s this infrastructure has developed with slow steps. Only in the last five years, it is seen a great development of Internet technologies. Internet services started with dial up and later with other forms like ISDN, DSL. In 2007 wide entrance of ADSL from the Albanian Telecom brought a quick diffusion of Internet in Korca region, which forced the private companies to lower their prices up to 40-50 %. Private companies which operate in Korca region in the field of

Internet services such as: Abissnet and Abcom have a limited clientele which can reach a maximum of 200 clients for each of them. Here after let's have a look at all the indicators of this category.

### **3.1 Technologies penetration for the network access.**

To evaluate the penetration grade of technologies for the network access we need to see the progression of some indicators which play an important role in the evaluation of this category.

These indicators are:

1. Teledensity ( number of telephone lines per 100 people).
2. Percentage of families with an installed telephone line.
3. Percentage of ISDN telephone lines.
4. Percentage of families which have a TV and Internet cable.
5. Percentage of failed attempts for dial-up connection.
6. Percentage of Internet users with security problems.
7. Percentage of families which have at least a mobile phone at home.
8. Percentage of the population who use mobile Internet.
9. Percentage of the population which own a computer.

Let us see these indicators in details:

1. *Teledensity is an important indicator for the e-readiness evaluation.* In Korca city only Albtelecom Company offers this service. Lines within the city are digital with a link speed of 56 kbps maximum. The number of PSTN lines reaches up to 18 lines per 100 people.
2. *Telephone line penetration* in the family is another important indicator for the e-readiness. There are 25 000 families and 10 885 lines for the familiar telephone subscribers in Korca.
3. *ISDN telephone line penetration* of 128 kbps is very small, even though this technology has been presented from Albtelecom some years ago. This may come as a result of the relatively high costs of the offered services. The penetration of these lines goes to 32 links in total for Korca city which is an insignificant quantity.
4. *The percentage of families which have a TV and Internet cable.* The cable TV has entered into our country from more than 5 years. Because of the cheap price that the private company offers for this service, today about 32% of Korca's families have this cable at their homes. As the private company which owns the cable TV presented Internet cable only two years ago, relatively late in comparison to the time it presented the TV only a small number of families have Internet cable which are in total not more than 300 families..
5. *Percentage of failed attempts for dial-up connections.* Data were collected from Albtelecom as the only company offering Internet dial-up service in Korca and it can be said that the percentage of failed at-

tempts for dial-up connections is very small and inconsiderable as to affect the network quality.

6. *Percentage of Internet users with security problems.* It is worth mentioning, from the answers of the questionnaires, which comes out of 74% of the Internet users have had problems, especially with viruses while working in Internet. There are not any data about economical damages while working in Internet even though small parts of the population use the Internet for purchasing goods. From the questionnaire it comes out that 8% of the interviewed use the Internet for this reason.
7. *The percentage of the families which have at least a mobile phone at home.* This is shown from the questionnaire according to which 94% of the interviewed have at least a mobile phone in their families.
8. *The percentage of the population who uses the mobile Internet.* Because of the very high prices of Internet through mobile phones in comparison to other services only an inconsiderable percentage of people use this kind of Internet in Korca city.
9. *The percentage of population which own computers.* Despite the relatively high prices of computers in comparison to the small salaries of Korca's citizens, about three monthly salaries to buy a good computer, a great percentage of Korca's citizens have a computer at their home. Taking into consideration the fact that all these computers can have modems (modems have a very low cost), it can be said that 74% of Korca's families have computers and the possibility to get connected to the network from their homes.

### **3.2 Network connection**

Compared with other EU countries and the United States the history of Internet in our country is very brief. Internet connection in our country started after year 1990 while in our region after year 2000. Actually there are some companies which offer Internet services in our region. The most important is Albtelecom which offers dial-up services, ADSL, ISDN and which for its infrastructure will continue to be the greatest company that offers Internet services in Korca region. Other mobile telephony companies and private ISPs with their branches in Korca like Abissnet and Abcom own a smaller part of the market of internet services.

From this questionnaire it can be seen the wide range communication services into Korca region, starting from the dial-up service, cable service, ADSL, wireless, high speed radio link, satellite link etc..

Albtelecom as the biggest company offering Internet in Korca city has put into disposal a channel with a capacity of 34 MB in Korca. Abcom at the moment has put into disposal a capacity of 8 MB for the Korca region. The other private company, Abissnet, offers the same capacity.. Other companies have left this band indefinite about our region

but according to our information it can be said that their capacity is very small in comparison to Albtelekom's capacities.

One of the objective indicators to study the international links is the total Bandwidth per person. Considering that the inner Internet traffic is inconsiderable, we cannot consider the inner Bandwidth per person. The value of this indicator is less than 1 kbps per person. Not a good value compared to countries like Denmark with an international bandwidth of 38 kbps per person in the year 2005. [results taken from <http://gigaom.com/2005/09/08/us-still-the-bandwidth-daddy/>]

### **3.3 Network affordability**

The aim of the study of this indicator is to evaluate how possible is the Internet access for Korca citizens. For this reason some economical aspects of this network have been studied and commented below:

1. *The average price for an hour dial-up Internet access.* The price for an hour dial-up Internet access is much higher than that in developed countries. The average price for this kind of access is 0.55\$ per hour. As it is seen it is much more expensive than in the developed countries and this service is being less used in Korca because of the poor quality in transferring the video and audio.
2. *The average price for an ADSL non-limit link per month.* ADSL service has been presented in our region, by Albtelecom which holds the greatest weight, and the other company Abissnet. The prices of Albtelecom remain very high in comparison to the prices of the analogue companies in the Balkans such as the Greek OTE. It can be said that for the same service our prices are some times higher than the Greek ones, a big difference considering that the minimal wage in our country is 17000 lek (180\$) in a month. For more information visit the Internet pages: <http://www.albtelecom.al> and <http://english.oteshop.gr>. We are not going to deal with this aspect, because it is obvious we are in a lower standard compared with Greece which in the world ranking of e-readiness stands at number 30 place, [E-readiness rankings 2008, A white paper from the Economist Intelligence Unit].
3. *The average price per hour of Internet access in public Internet places.* Public places of Internet access are called the Internet Cafes, different training centers with Internet services, Municipality centers and other similar places. This service today in Korca has a price of 1.035\$ per hour and as in other countries it is more expensive service than dial-up, but of a better quality. The price remains high if we consider the minimal monthly salary of Korca region. If we make an easy account of an hour Internet access in public places it costs about 0.58% of the minimal monthly salary. From the questionnaire it comes out that 40% of citizen's use these centers and about 39% of them claim the lack of good Internet in their homes.

Another fact to be stressed is that the city's Municipality to raise the E-readiness has created some public Internet Centers where citizens can work for free of charge. From the questionnaires, answers about these centers comes out that 12% of the citizens use them, which shows their efficiency, considering the short time they have been presented.

### **3.4 ICT market and services**

Before making an analysis of the ICT market in Korca region we should consider that Korca market is a limited one, and businesses of this kind are small ones. The main tendency which continues today is "anonymous" computer trade with low prices. These kinds of computers dominate the biggest part of our region's market.

"Brand name" computers like IBM, HP etc own a small part of the market, about 10%, because they are more expensive, including here the notebook computers sales.

With the growth of the computer market it grew piracy as a serious problem to the market in the ICT field.

The competition in these fields is growing in the last years and with the growth of the competition there is a growth of the quality but that is not enough. A negative factor in this aspect has been the absence of big companies in our region as IBM or HP which brings the lack of quality and services.

## **4. CONSLUSIONS**

Evaluating the network access in Korca region it can be said that network access is at a relatively good level in our region, taking into consideration the late presentation of this technology and the level of E-readiness perceived by specialists for our country in general.

The main problems noticed are: the relatively high prices of Internet services, the high prices of desktop and laptop computers in comparison to the minimal monthly salary, and the poor quality of services in these fields.

Today we are trying to pass from the first phase characterized by the lack of professionalism, good quality devices, relatively good quality Internet to the second phase characterized by satisfactory broadband link, an overall inclusion of the business in the network and the implementation of a big number of internet services.

Concluding the evaluation of network access in our region it can be said that in spite of these last years' improvements, Internet in our region is much more expensive than in developed countries, which means less accessible to the citizens, and this is a main barrier for the e-readiness growth of the region.

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# **Contactless System for a Temperature Measurement**

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**Abstract:** *The paper describes the structure of multi point system for temperature measurement based on microcontroller MSP430F149 (TI) and contactless temperature sensors MLX90614. The microcontroller uses two-wire line and standard transfer protocol SMBus to receive data from the sensors. To the system could be supplemented up to 127 sensors. This self contained system eliminates the design challenges of very small voltage signals, environmental effects and electromagnetic compatibility which otherwise make infrared temperature measurements difficult and cumbersome.*

**Keywords:** *temperature measurement, contactless system, sensor, microcontroller.*

## **1. INTRODUCTION**

The temperature is one of the most often measured physical parameter. However, remote non-contact temperature measurement has previously been complicated and expensive due to the complex signal treatment and calibration involved. In this paper is presented the structure of the system for distance temperature measurements of different objects in different points. The system is based on microcontroller MSP430F149 and contact less temperature sensors MLX90614. The small and cost effective non-contact thermometer delivers a fully calibrated, digital temperature reading of a remote object. Due to the built-in intelligence, high accuracy and wide temperature operating range of the MLX90614, manufacturers can easily integrate non-contact temperature measurement in car air conditioning, room heaters, home appliances and medical equipment. The presented system is developed for a sensor's net control up to 127 points of measurements.

## **2. DESCRIPTION OF THE NONCONTACT IR THERMOMETERS**

Infrared (IR) radiation is part of the electromagnetic spectrum, which includes radio waves, microwaves, visible light, and ultraviolet light, as well as gamma rays and X-rays. The IR range falls between the visible portion of the spectrum and radio waves. IR wavelengths are usually expressed in microns, with the IR spectrum extending from 0.7 to 1000 microns. Only the 0.7-14 micron band is used for IR-temperature measurement. Using

advanced optic systems and detectors, noncontact IR thermometers can focus on nearly any portion or portions of the 0.7-14 micron band. Because every object (with the exception of a blackbody) emits an optimum amount of IR energy at a specific point along the IR band, each process may require unique sensor models with specific optics and detector types.

The intensity of an object's emitted IR energy increases or decreases in proportion to its temperature. It is the emitted energy, measured as the target's emissivity, that indicates an object's temperature. Emissivity is a term used to quantify the energy-emitting characteristics of different materials and surfaces. IR sensors have adjustable emissivity settings, usually from 0.1 to 1.0, which allow accurate temperature measurements of several surface types. The emitted energy comes from an object and reaches the IR sensor through its optical system, which focuses the energy onto one or more photosensitive detectors. The detector then converts the IR energy into an electrical signal, which is in turn converted into a temperature value based on the sensor's calibration equation and the target's emissivity. The temperature value can be displayed on the sensor, or, in the case of the smart sensor, converted to a digital output and displayed on a computer terminal. Some characteristics of the digital thermometers (Raytec, Maurer) are shown in the table 1.

Tab. 1: Characteristics of different digital thermometers.

Model	QKTR 1485	MiniTemp MT4	MiniTem MT6
Temperature Range	600 - 3300°C (1112 - 5972°F)	-18 to 400°C (0 to 750°F)	-30 to 500°C (-20° to 932 °F)
Distance to Spot Size (D:S)	15:1	8:1	10:1
Response time	20 - 200 ms	500 mSec	500 mSec
Emissivity	Pre-set at 0.95	Pre-set at 0.95	Pre-set at 0.95
Accuracy	1 % ± 1°C	±2%, or ±2°C (±3°F)	±1.5%, or ±1.5°C (±3°F)
Typical Distance to Target	3m	Up to 1.5m (4ft)	Up to 2m (6ft)

### 3. ARCHITECTURE OF MULTI POINT SYSTEM FOR TEMPERATURE MEASUREMENT

In the practice, very often is a need of simultaneous temperature measurement to different points of one or more objects. The requirements concerning mounting and connecting of the sensors is not easy if the temperature of the objects is higher then 80°C or the objects are moving during measurements. In these cases, the remote method for temperature

measurement is appropriate. Here is proposed the structure of multi point system for temperature measurement based on microcontroller MSP430F149 (TI) and contactless temperature sensors MLX90614 (fig.1). The microcontroller uses two-wire line and standard transfer protocol SMBus to receive data from the sensors. The presence of the microcontroller permits to involve many sensors (up to 127), to resolve different task for temperature measurement, to realize time intervals for reading temperature in different points of the object and to define a different precision.

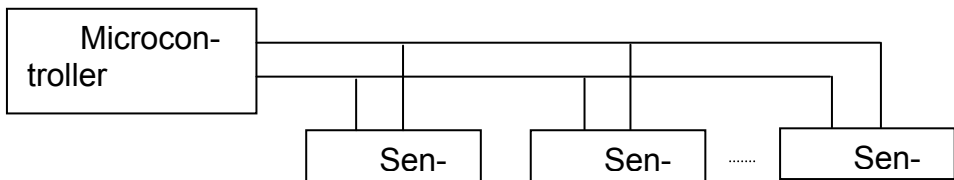


Fig. 1: The structure of the system for distance temperature measuring.

The sensing element in the MLX90614 is an automotive grade silicon chip with a thin, micro-machined membrane heated by the infrared radiation of a distant object. This heating is detected by on chip thermocouples. The custom built signal conditioning chip amplifies and digitizes the minute thermocouple voltage and calculates the object temperature using factory set calibration parameters stored in the EEPROM memory of the chip. The digital output temperature is fully linearized and compensated for ambient temperature. The sensor transmits the result to the user's application over an SMBus. The whole thermometer system is enclosed in a TO-can. This self contained system eliminates the design challenges of very small voltage signals, environmental effects and electromagnetic compatibility which otherwise make infrared temperature measurements difficult and cumbersome. The high level of integration makes the MLX90614 very cost effective compared to other infrared solutions currently on the market.

### 3.1. The SMBus protocol

The SMBus interface is a 2-wire protocol, allowing communication between the microcontroller - Master Device (MD) and one or more sensors - Slave Devices (SD). In the system only one master can be presented at any given time. The MLX90614 can only be used as a slave device. The MD initiates the start of data transfer by selecting a SD through the Slave Address (SA). The MD has read access to the RAM and EEPROM and write access to 9 EEPROM cells (at addresses 0x20h, 0x21h, 0x22h, 0x23h, 0x24h, 0x25h, 0x2Eh, 0x2Fh, 0x39h). If the access to the MLX90614 is a read operation it will respond with 16 data bits and 8 bit PEC (Packet

error code) only if its own slave address, programmed in internal EEPROM, is equal to the SA, sent by the master. The SA feature allows connecting up to 127 devices with only 2 wires. In order to provide access to any device or to assign an address to a SD before it is connected to the bus system, the communication must start with zero SA followed by low R/W bit. When this command is sent from the MD, the MLX90614 will always respond and will ignore the internal chip code information. Special care must be taken not to put two MLX90614 devices with the same SD addresses on the same bus.

The SMBus protocol is shown in fig.2.

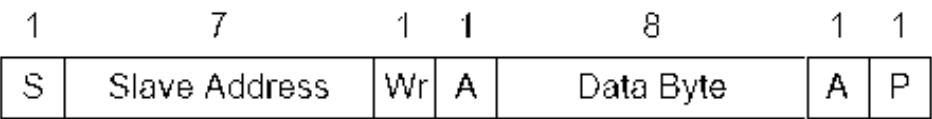


Fig.2: The structure of the SMBus protocol.

After every 8 bits received by the SD an ACK/NACK takes place. When a MD initiates communication, it first sends the address of the slave and only the SD which recognizes the address will ACK, the rest will remain silent. In case the SD NACKs one of the bytes, the MD should stop the communication and repeat the message. A NACK could be received after the PEC. This means that there is an error in the received message and the MD should try sending the message again. The PEC calculation includes all bits except the START, REPEATED START, STOP, ACK, and NACK bits. The PEC is a CRC-8 with polynomial  $X^8+X^2+X+1$ . The Most Significant Bit of every byte is transferred first.

**3.2. Signal processing principle**

The operation of the MLX90614 is controlled by an internal state machine, which controls the measurements and calculations of the object and ambient temperatures and does the post-processing of the temperatures to output them through the PWM output or the SMBus compatible interface. MLX90614 supports two IR sensors. The output of the IR sensors is amplified by a low noise low offset chopper amplifier with programmable gain, converted by a Sigma Delta modulator to a single bit stream and fed to a powerful DSP for further processing. The signal is treated by programmable (by means of EEPROM contend) FIR and IIR low pass filters for further reduction of the band width of the input signal to achieve the desired noise performance and refresh rate. The output of the IIR filter is the measurement result and is available in the internal RAM. 3

different cells are available: One for the on-board temperature sensor and 2 for the IR sensors.

Based on results of the above measurements, the corresponding ambient temperature  $T_a$  and object temperatures  $T_o$  are calculated. Both calculated temperatures have a resolution of 0.01 °C. The data for  $T_a$  and  $T_o$  can be read in two ways: Reading RAM cells dedicated for this purpose via the 2-wire interface (0.02°C resolution, fixed ranges), or through the PWM digital output (10 bit resolution, configurable range). Here is used the first method of reading RAM cells.

### 3.3. Computation of ambient and object temperatures

The IR sensor consists of serial connected thermo-couples with cold junctions placed at thick chip substrate and hot junctions, placed over thin membrane. The IR radiation absorbed from the membrane heats (or cools) it. The thermopile output signal is:

$$(1) \quad V_{ir}(T_a, T_o) = A \cdot (T_o^4 - T_a^4),$$

Where  $T_o$  is the object temperature absolute (Kelvin) temperature,  $T_a$  is the sensor die absolute (Kelvin) temperature, and  $A$  is the overall sensitivity.

An on board temperature sensor is needed to measure the chip temperature. After measurement of the output of both sensors, the corresponding ambient and object temperatures can be calculated. These calculations are done by the internal DSP, which produces digital outputs, linearly proportional to measured temperatures.

#### 3.3.1. Ambient temperature $T_a$

The sensor die temperature is measured with a PTC or a PTAT element. All the sensors' conditioning and data processing is handled on-chip and the linearized sensor die temperature  $T_a$  is made available in memory. The resolution of the calculated  $T_a$  is 0.01 °C. The sensor is factory calibrated for the full automotive range (-40 to 125 °C). In RAM cell 006h, 0000h corresponds to -40 °C and 4074h (16500d) corresponds to 125 °C. The conversions from RAM content to real  $T_a$  is easy using the following relation:

$$(2) \quad T_a, \text{ SMBus}[^{\circ}\text{K}] = T_{\text{areg}} \times 0.02$$

#### 3.3.2. Object temperature $T_o$

The result has a resolution of 0.01 °C and is available in RAM.  $T_o$  is derived from RAM as:

$$(3) \quad T_o, \text{ SMBus}[^{\circ}\text{K}] = T_{\text{oreg}} \times 0.02$$

### **3.3.3. Calculation flow**

The calculations are held by microcontroller, which executes a program from FLASH. After POR signal the sensor is initialized with calibration data from its EEPROM. During this phase the number of IR sensors is selected and it is decided which temperature sensor will be used. Measurements, compensation and linearization routines run in a closed loop afterwards. The results after the calculation of the ambient temperature and the object temperature, are stored into RAM as  $T_a$  and  $T_o$ .

## **4. CONCLUSIONS**

The multi point system for temperature measurement is cost effective and very useful in cases when there is the need of measuring the temperature of the moving objects. The method saves time during industrial processes. With the remote temperature measurements very easy could be accessed integral object temperature of the objects with complex forms.

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# Opportunities of digital signal processors for arithmetic coding

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***Abstract:*** Possibilities of digital signal processors are presented in this article. The processors for implementation of arithmetic coding are Texas Instruments TMS320C6000 series. The functions implementing cycle coding - decoding written in C programming language are also presented. The content of an A4 paper format sheet are used for the implementation of the arithmetic coding as input stream of data.

***Keywords:*** digital signal processor (DSP), data compression, program language C/C++.

## 1.INTRODUCTION

The purpose of data compression is to reduce the number of the bits to storage or transmission of the information. The data compression cover a wide variety of hardware or software methods completely different from each other. In general, these methods can be divided into two main groups - methods of compression with loss of data and without loss of data. In the first methods, the lost of the data are compensated by the increased level of compression. These methods are used in areas such as the computer graphics and digital sound processing. All those methods which must ensure that the output stream of data will be the same as the input stream are belong to the second group. They are used to compress programs, spreadsheets, databases, as well as in the modern communication systems. The first widely known method of coding is Shannon-Fano method. Later on it was shifted from a more effective method - Haffman coding. Disadvantage of Haffman coding, is that the compression should include a table of probabilities. Result is that volume of memory is increased. The length of each Haffman codes should be a whole number of bits. That's why it sometimes causes problems. The received code is much larger than necessary when the probability of a symbol is a great. This problem will occur, for example, in the compression of dichromatic images, such as those in the fax machine. The Methods of compression used in the fax machines are MR (Modified READ), MMR (Modified Modified READ) and JBIG (Joint Bi-level Image Experts Group). These methods, however use the modified Haffman code and they belong to the first group of methods with a loss of data. One of the possible solutions is arithmetic coding. There are three main criteria to compare different methods of data compression.

The first is the time required to compress the entire input stream of data. The second is the amount of memory required during compression. The third is the level of compression. The level of compression can be expressed as a ratio such as 2:1 or 4:1, but also as a percentage representation:

$$(1) \quad M = 1 - \frac{N_c}{N_{NON}} \times 100, [\%]$$

where

$M$  – the level of compression, %

$N_c$  – number of household after compression

$N_{NON}$  – number of household before compression

In consideration of these criteria into consideration in this work we will examines the possibilities of digital signal processors from Texas TMS320C6000 series for the implementation of arithmetic coding. Code for the implementation of the compression - decompression cycle will be proposed.

## 2. FORMULATION OF TASK

We will use the content of a sheet of A4 paper format for the implementation of the arithmetic coding as input stream of data (Fig.1). Most modern fax machines have a resolution of 600x600 dpi. The contents of information in a sheet in this resolution will be 34 806 376 bits or about 4.3 Mbytes. Level of compression  $M = 0\%$  means that the input data are not compressed. In this case 4.3Mbytes for input data, 4.3 Mbytes of compressed data and another 1280 bytes for the table of probabilities are needed.

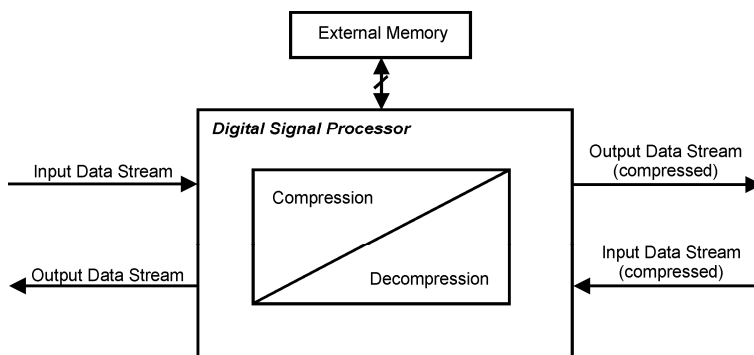


Fig. 1: Block diagram

Most digital signal processors TMS320C6000 Series support 32 asynchronous external memory interface for SRAM (EMIFs) or synchronous interface for DRAM (SDRAM) memory. This enables the use of 16 Mbytes

SDRAM as external memory, which covers the criteria for volume memory during the compression of data. Compression and decompression of data are provided by subroutines written in the programming language C. They are transmitted by means of the output channel after the compression of the data. Similarly, when the data come in compressed form, they are decompressed and transmitted to the output channel.

### 3. ARITHMETIC CODING WITH DIGITAL SIGNAL PROCESSORS - ISSUES AND SOLUTIONS

Unlike the other types of coding where for each symbol is collated a code, arithmetic coding replaces the entire input stream with a fractional number. In case of greater size of information more bits are required for representation the number. A fractional number with a value greater than or equal to zero and less than one will be obtained as result of coding.

#### 3.1 Arithmetic coding algorithm

We will use the message "Cool" to show the arithmetic coding algorithm as input data stream. First, for each symbol is collated a probability to be found in the message. Depending on the probability, for each symbol is assigned an interval. It must be between 0 and 1 (Tab.1).

Tab. 1: Probability table and intervals

Symbol	Probability	Interval	
C	1/4	0.00	0.25
o	2/4	0.25	0.75
l	1/4	0.75	1.00

The interval of each symbol is proportional to its probability. An important feature of the arithmetic coding is that the coding starts with the interval of the first symbol of the uncoded message. In this case the symbol is "C". Algorithm is following:

We determine the length of the interval:

$$(2) \quad R = T_h - T_l$$

where

$R$  – the interval

$T_h$  - top bound of the interval

$T_l$  - bottom bound of the interval

Initially,  $T_h = 1.00$  and  $T_l = 0.00$ . The length of this interval will be decreased with each added symbol. At the same time the new values of top and bottom bound will be calculated.

For top bound:

$$(3) \quad T_h = T_l + (R \times T_{HR})$$

and for bottom bound:

$$(4) \quad T_l = T_l + (R \times T_{LR})$$

where

$T_{HR}$  - top bound of the interval of the symbol

$T_{LR}$  - bottom bound of the interval of the symbol

The process continues until the end of message. The results of the coding of the message above is shown in Tab.2.

Tab. 2: The results of the coding

Symbol	Top bound, $T_h$	Bottom bound, $T_l$
C	0.00	0.25
o	0.0625	0.1875
o	0.09375	0.15625
l	0.140625	0.155625

The last value of the bottom bound 0.140625 uniquely codes the message "Cool". The process of decoding the message is opposite to coding process. Algorithm of decoding is the following. We find the first symbol by determining the interval in which is the number 0.140625. In this case, is the symbol "C". The next number is determined by means of the formula:

$$(5) \quad T_{next} = \frac{T_{current} - T_{LR}}{T_{HR} - T_{LR}}$$

where

$T_{next}$  - next number

$T_{current}$  - current number

$T_{HR}$  - top bound of the interval of the symbol

$T_{LR}$  - bottom bound of the interval of the symbol

The process continues by determining the intervals in which  $T_{next} = 0.00$ .

### 3.2 Representation of the numbers in digital signal processors

Here we will present the different data formats in digital signal processors and how they could be used in the implementation of arithmetic coding. The TMS320C6000 digital signal processors operate with a fixed-point numbers and a floating point numbers (Fig.2). Fixed point numbers are

16 bit in length, integer or fractional - signed or unsigned. Using 16 bit integer numbers, signed or unsigned, is associated with some problems. First, the operations addition and multiplication with 16 bits integer numbers will lead to overflow, i.e. outcome can not be presented in 16 bits. Second, only in recent years, there were solutions to the implementation of arithmetic coding with integer numbers. However possible loss of data exists under certain circumstances.

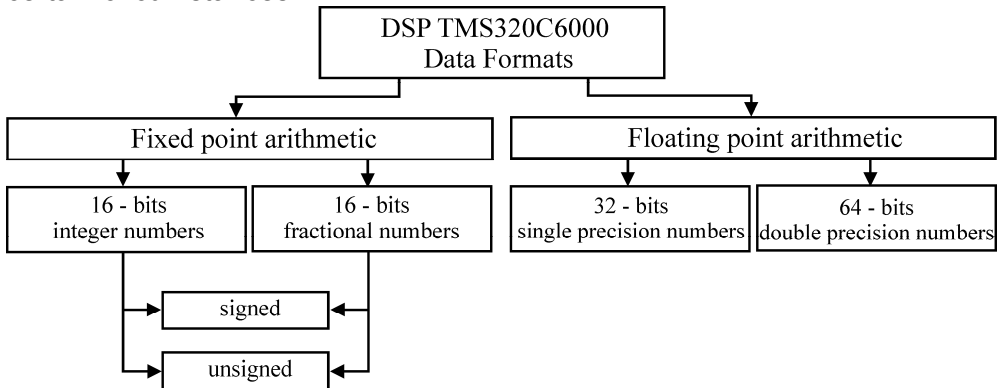


Fig. 2: DSP data formats

Possible solution to the problem of overflow is the result to be represented by 32 bits. This leads to the use of twice as much memory. If the result joins in other operations the memory is increasing again. Another solution is 16 bits fixed point fractional numbers (Fig.3) to be used.

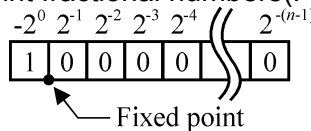


Fig. 3: 16 – bits fractional numbers data format

The maximum fractional number, which we can record (Fig.4) presented in decimal form is 0.99996948.

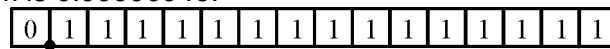


Fig. 4: 16-bits maximal fractional number

Accordingly, the minimum fractional number (Fig.5) in decimal form is -1, i.e. range of numbers that we can provide is  $-1 \leq x < 1$ .

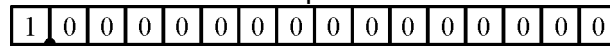


Fig. 5: 16-bits minimal fractional number

It is clear that in the range  $0 \leq x < 1$  we can use 16 bits fractional numbers with a fixed point. The number of the symbols, that we can code in one number depends on the probability of its occurrence in the message. When the probability of the symbols is greater more symbols with one

number can be code. Most likely, every nth symbol will have to start coding from the beginning. This will certainly reduce the level of compression.

Naturally, the best solution is to use numbers with floating point. Digital signal processors TMS320C67xx supports both data format numbers with floating point. Their dynamic range is sufficiently large to code more symbols with one number. The data format of numbers with a single and double precision is shown in Fig.6.

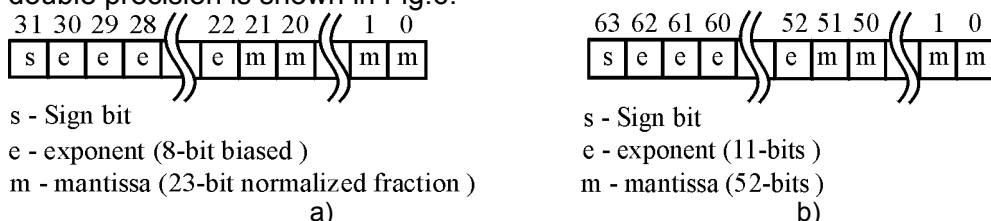


Fig. 6: a) - 32-bits single precision numbers data format  
b) - 64-bits double precision numbers data format

#### 4. THE FUNCTIONS FOR COMPRESSION AND DECOMPRESSION

The Compression of data can be presented as a result of two processes (Fig.7) - modeling and coding. The process modeling determines probabilities of each symbol and the way to be processed.

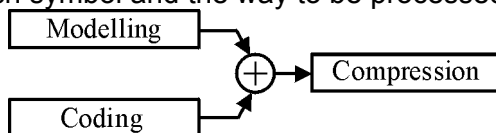


Fig. 7: Data compression

The program that implements arithmetic coding works with zero-order model. Input data stream is stored in external memory. The program reads all input data, then compiles a table probabilities and for each symbol determines the interval. On the basis of this table, the function of coding reads the data and codes them byte by byte. The compressed data and the probability table together are sent to the output channel after finishing the coding function.

The coding function works with floating point numbers with double precision.

```

void compression(unsigned int *inp_data, double *out_data)
{
    double boundLow = 0.00;
    double boundHigh = 1.00;
    double range;
    while((1-boundLow) > scale_factor)
    {
        range = boundHigh - boundLow;
        boundHigh = boundLow + (range * prob_tableHigh[*inp_data]);
    }
}
  
```

```

        boundLow=boundLow+(range * prob_tableLow[*inp_data]);
        inp_data++;
    }
    *(out_data++) = boundLow;
    If(!END_OF_STREAM)
        compression(inp_data, out_data);
}

```

As it can be seen, this is a recursive function. It will continue until all the data has been compressed. It is not clear whether entire flow of data can be compressed with a 64-bits floating point number. That's why the condition is introduced in which every nth - symbol coding starts again. The condition is a scale\_factor constant which represents the smallest number. This number we can record in a 64-bits floating point cell in range  $0 \leq x < 1$ .

The code of the function of the decoding algorithm implement is presented below.

```

void decompression(double *inp_buff, unsigned int *out_buff)
{
    double next;
    next = *inp_buff;
    while(next != 0.0)
    {
        for(int count = 0; count<256; count++)
        {
            if((*inp_buff>prob_tableLow[count])&&(*inp_buff>prob_tableHigh[count]))
            {
                *(out_buff++) = prob_table_simbol[count];
                next=(*inp_buff-prob_tableLow[count])/(prob_tableHigh[count]-
                prob_tableLow[count]);
                break;
            }
        }
        inp_buff++;
        if(!END_OF_STREAM)
            decompression(inp_buff,out_buff);
    }
}

```

## 5. RESULTS, DISCUSSIONS, CONCLUSIONS

Digital signal processor TMS320C6713 was used for implementation of the arithmetic coding. The input data are generated by a function of random numbers. For reporting the results, the output data stream was redirected to the PC. For coding of the data we used a 64 bits floating point numbers. The results showed that level of compression was about  $M = 72\%$  in

different generated data. Of course, this depends on the probability curve of the symbols. Time required for compression, however, was significant because of the huge number of calculations in coding. The time can be reduced through a careful optimization of the code of the program.

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# Reducing the impact of the generated noises by the integral scheme ISD1400 in the process of simulation of transitional magnetization of electrical transformers

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**Abstract:** *The generation of magnetic electricity with defined amplitude time characteristics for simulation of transitional process in the electrical transformers is performed by a standard PC. The Parallel port is connected to a special interface, by which the simulation signal is recording on a specialized integral scheme – ISD1400 Chip Corder.*

*In this project we offer a way to reduce the noise generated by the actual recording on the integral scheme- ISD1400 Chip-Corder.*

**Keywords:** *transformer, magnetic, histerezis cycles, harmonious components*

## 1. INTRODUCTION

For the studying of the magnetic characteristics of current transformers with a ferromagnetic core requires special experimental platforms are required.

The problem is that the presence of a hysteresis loop in the ferromagnetic material creates nonlinearity and ambiguity between the intensity of the magnetic field  $H$  and the magnetic induction  $B \rightarrow B = B(H)$ .

The use of such transformers in a transitional regime leads to the fact that the magnetic induction moves predominantly in private hysteresis loops, and the rules of *Madelung*, which describe these movements are not accurate and may only have tentative character.

## 2. A STANDARD MODELING WITH A NON-LINEAR ELEMENT

In this work the question for registering private hysteresis loops in ferromagnetic materials in transitional magnetization is examined.

Concretely for the core of current transformers (CT) this happens in the experimental treatment of *fig. 1*[4].

The units  $R_1$  and  $R_2$  the active resistances of the primary and the secondary coils with  $w_1$  and  $w_2$  windings, and  $L_{p1}$  and  $L_{p2}$  are the inductions of scattering, which are negligible and are not considered [2].

In the scheme the resistors  $R_{sh1}$  and  $R_{sh2}$  are placed, the voltage over which is proportional to the currents in the two circuits of the transformer.

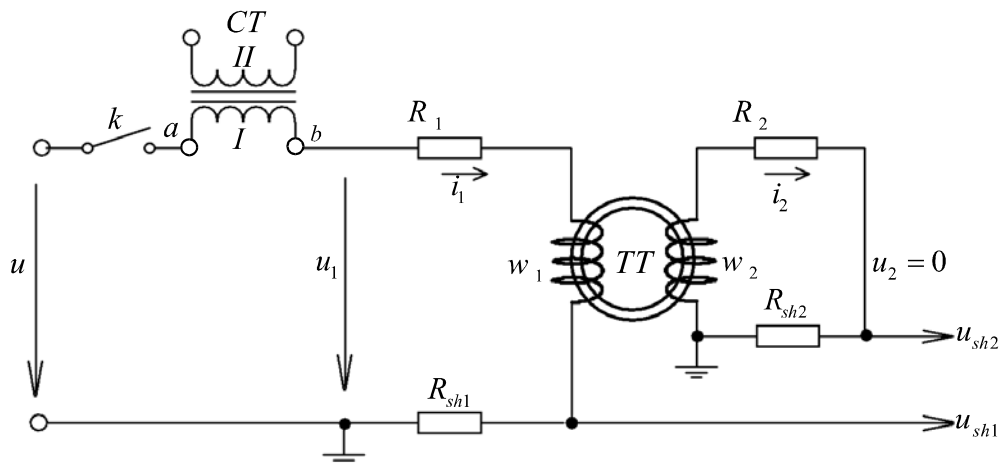


Figure 1 Examining of a CT in the PT circuit

Having in mind that the secondary side of the CT is connected „short-circuit”, then the equations that describe it, received by the second law of Kirchhoff and the full current law are presented in (1).

From the last two equations - from (1) the magnetic field intensity  $H$  is defined and from (2)- the magnetic induction.

$$(1) \quad \begin{cases} u_1 = (R_1 + R_{sh1})i_1 + w_1 S \frac{dB}{dt} \\ 0 = -(R_2 + R_{sh2})i_2 + w_2 S \frac{dB}{dt} \\ i_1 w_1 - i_2 w_2 = lH \end{cases} \quad (2) \quad \begin{cases} B(t) = B_0 + \frac{1}{w_2 S} \left( 1 + \frac{R_2}{R_{sh2}} \right) \int_0^t u_{sh2}(t) dt \\ H(t) = \frac{1}{l} \left[ w_1 \frac{u_{sh1}(t)}{R_{sh1}} - w_2 \frac{u_{sh2}(t)}{R_{sh2}} \right] \end{cases}$$

For simulating a transition process in the electrical circuit, successively to the primary side of the CT, a power transformer is included (PT).

Thus, while commutation of the loop, a transition process arises, which is examined in [4].

The disadvantage of this experimental method is connected with the restricted number of the possible different transitional processes, by which the necessary database with the physico-mathematical model describing the processes in some or other conditions to be created.

### 3. A COMPUTER SIMULATION OF A TRANSITIONAL MAGNETIZATION

To solve this problem in the place of the power transformer a specially designed for this purpose voltage-source converter (VSC) should be included to the parallel port of the PC [1,2].

To avoid the inconvenience and the risk of electrical breakthrough with costly consequences, the signals from the parallel port of the PC should be recorded in a special buffer, which performs the function of a programmable generator [3].

A key element of the buffer is an energy-independent memory, which is the used specialized integrated circuit – *Chip Corder ISD1416* [6].

For including the last block in the entire experimental process requires a change in the VSC, whose work can be seen in the time-graphs on *fig.2*.

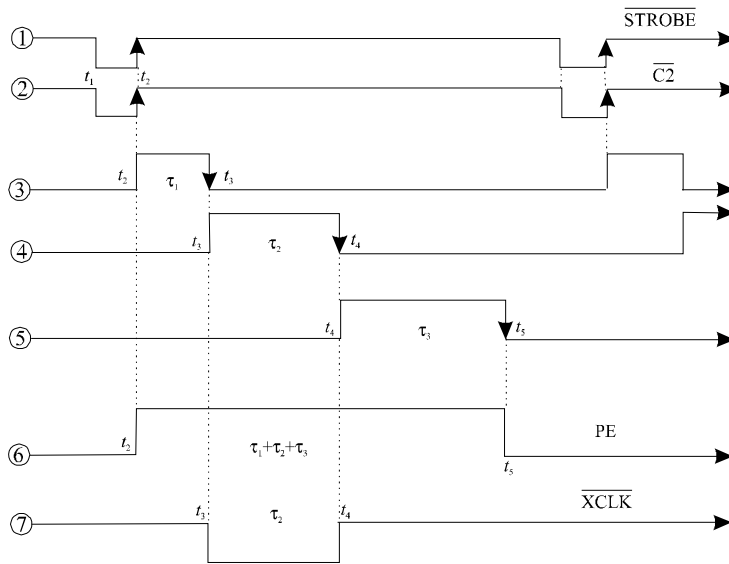


Figure 2 A time-diagram for the signals from the parallel port of a PC.

Signals characterizing the process of the simulation are synchronized by *STROBE* signals from the PC.

These are numeric values and commands codes arranged in a certain order. [1].

The VSC separates the data from the commands, as the data is converted from digital into analog form, and the commands are submitted to the relevant units for implementation or as control signals towards the PC.

The signal  $\overline{C2}$ , which the VST makes, corresponds to the beginning of the numerical series, and  $\overline{LF}$  - to its end. The individual positions on the time-graph are as follows:

- ① - shows the temporary development of the signal  $\overline{STROBE}$ ;
- ② - the synchronized signal  $\overline{C2}$  from the VSC;
- ③ - a signal with a duration  $\tau_1$  is produced to end the work of the digital-analog converter;
- ④ - a signal with a duration  $\tau_2$  is produced, which corresponds to the time during which the stroke generator of the *ISD1416* is blocked;
- ⑤ - represents the duration of time  $\tau_3$ , which is the pause between two adjacent discrete values of the analog signal;
- ⑥ - a signal with a duration  $\tau_1 + \tau_2 + \tau_3$  is produced, in which the *PC* is in *PE (Paper Error)* regime;
- ⑦ - the signal, which is handed over the input  $\overline{XCLK}$  of the *ISD1416*.

#### 4. SOLVING THE PROBLEM WITH THE NOISE OF THE ISD1416

As a result of the experiments which have been carried out with the *ISD1416*, the fact described in the technical documentation, that *Chip Corder* circuits introduce noise in the output signal, is confirmed.

In order to reduce the noise, in the supplements given by the firm-producer [5] a sample topography is shown, in which the power traces towards the analogue and the digital parts, and the ones the grounds of which are staying at a certain remove from each other and they are well filtered one to another with appropriate capacities.

In spite of following this requirement, the noises generated when using the integral scheme *ISD1400* cumber the preliminary plan of the experiment.

The reduction of the noise may partly be done by plugging in the outlet of the *Chip Corder* scheme of the integrating circuit, which smoothes over part of this noise.

Depending on the specificity of the different transitional processes, which should be generated, a change in the  $\tau_a$  time constant of the integrating circuit should be done.

This is often done as an experiment, the process is labour-consuming and takes a lot of time.

In this work another approach has been offered, which is based on passing the noise signal to both entrances of the differential amplifier on *fig.3*.

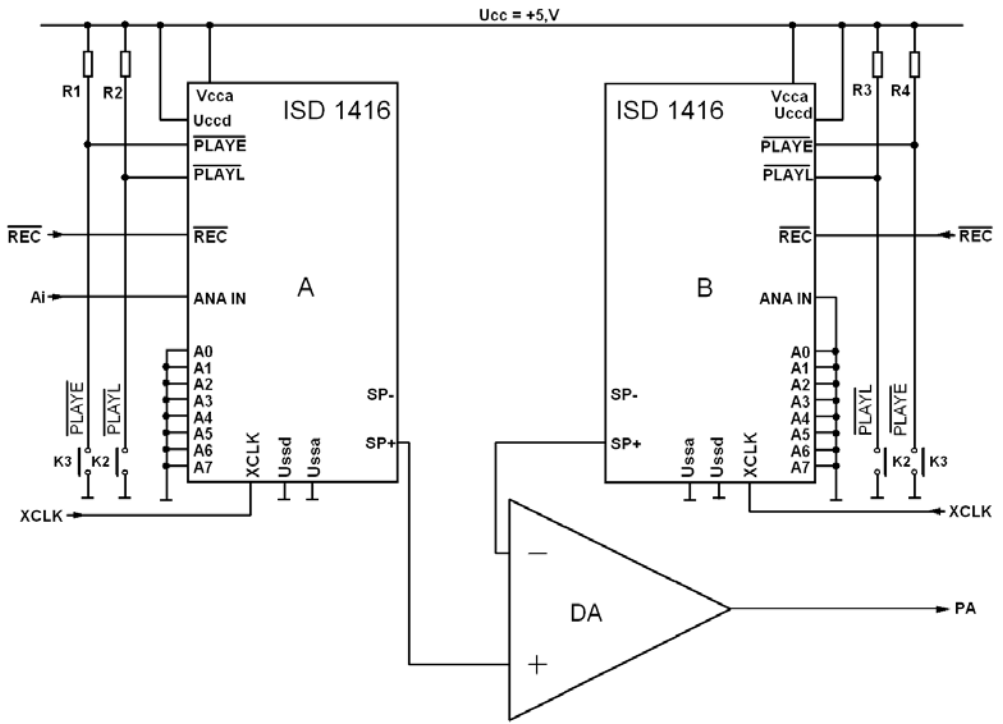


Figure 3 PCB configuration with two schemes ISD 1416

For the purpose two circuits from the *ISD1416* type are used - *A* and *B*. The integral circuit *A* is the basic one and the entrance analog signal is passed to it, and *B* is a secondary one.

Both of the circuits work at the same time in the regimes of recording and reproduction, but an input analog signal is not passed to the second circuit and the exit is connected to ground.

In mode of reproduction from the outputs *SP+* of the two circuits is taken signal for measuring amplifier with differential input. The signals which go out of the terminals *SP+* of both circuits may be presented as follows:

$$(3) \quad \begin{cases} u_0(t)_A = u_0(t)_S + u_0(t)_N \\ u_0(t)_B = 0 + u_0(t)_N \end{cases},$$

where  $u_0(t)_A$  and  $u_0(t)_B$  are the output signals from the circuits *A* and *B*. They consist of the useful signal  $u_0(t)_S$  and a signal of the noise in the circuit -  $u_0(t)_N$ .

It may be accepted that the parameters of both integral circuits ISD1416 are one and the same and the boards are made equal enough to be suggested that both circuits will generate almost the same noise levels. Then on the output of the differential amplifier DA, the analog signal will be:

$$(4) \quad u_0(t)_{DA} = k_{DA} [u_0(t)_A - u_0(t)_B] = k_{DA} u_0(t)_S,$$

where  $k_{DA}$  is the coefficient of amplification - voltage of the amplifier.

## 5. CONCLUSION

The usage of two integral circuits *ISD1416* provides additional reduction of the noise in the regime of reproduction. Besides this, the total price of the device does not become much more, because the integral circuits are comparatively cheap, the boards are easy to be made and contain only a few cheap standard elements.

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# Output Signal of a Transformer Eddy Current Transducer with Rectangular Coils

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**Abstract:** The output signal of transformer eddy current transducers with rectangular excitation and receiver coils is analyzed in this paper. The controlled object is conductive, flat and single layer. Graphic relations of the output signal to the change of the relative velocity between the eddy current transducer and the tested object are shown in the paper.

**Keywords:** Eddy current transducer, rectangular coils, relative velocity.

## 1. INTRODUCTION

The system under consideration comprises a controlled object (CO) and an eddy current transducer (ECT), as in [1-3]. The research object is electroconductive with relative permeability  $\mu_r$  and is seen as a linear, homogeneous and isotropic with specific electrical conductivity  $\gamma = \text{const}$  [3].

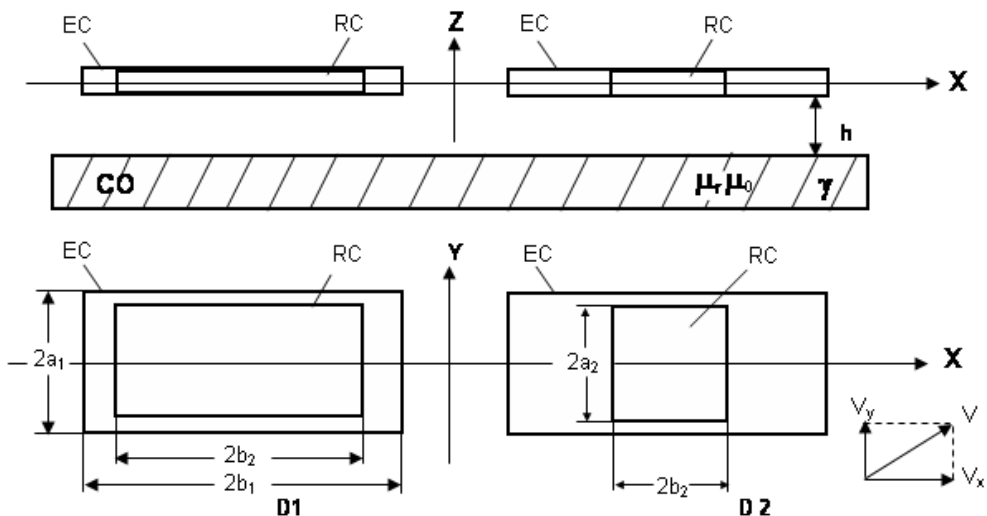


Fig. 1: Different designs of eddy current transducers over flat electroconductive control object.

Eddy current transformer transducers with two rectangular coils, parallel to the surface of the CO and Cartesian coordinate system with axes OX, OY and OZ are used. Two types of ECT design are considered (Fig. 1):

- Design D1 – both the excitative coil (EC) and the receiving coil (RC) are rectangular (Fig. 1 D1)
- Design D2 – the excitative coil (EC) is rectangular, and the receiving coil is square ( Fig. 1 D2)

The quantities, associated with the excitative coil are labeled with index 1 and those associated with the measuring (receiving) coil - with index 2. The excitative coil (EC) is powered by a sinusoidal current with angular frequency  $\omega$  through it.

The output signal of a measuring coil is the induced sinusoidal voltage with an effective value [3]:

$$(1) \quad \dot{U}_2 = \dot{U}_0 + \dot{U}_{in}$$

Where  $\dot{U}_0$  is the voltage in the EC when the CO is not present, and  $\dot{U}_{in}$  is the voltage, introduced by the CO.

Studies have been made in the presence of relative movement between CO and ECT with linear velocity  $\vec{v} = v_x \vec{e}_x + v_y \vec{e}_y$  with  $\vec{v}$  lying in a plane parallel to the CO. Indimensional variables and parameters are usually used in eddy current nondestructive control. All linear dimensions are divided by the half length of the EC  $a_1$  and mean index \* [3, 4].

$$(2) \quad w^* = \frac{w}{a_1}, w = a_2, b_1, b_2, h_1, h_2$$

Here the short and long sides of the EC and the RC are marked by  $a_i, b_i$  ( $i=1,2$ ), and  $h_1 = h_2 = h$  is the lift-off from the contours of the EC and the RC to the CO [2]. Known popularly as generalized parameter  $\beta$  is used [4]:

$$(3) \quad \beta = a_1 \sqrt{\omega \gamma \mu_0}$$

It is assumed that if  $\beta$  is changed, it is due to a change of the specific electrical conductivity  $\gamma$ . Relative linear velocity is normalized as follows [4]:

$$(4) \quad \tau_x = \frac{v_x}{\omega a_1}, \quad \tau_y = \frac{v_y}{\omega a_1}$$

The introduced component of the output signal  $\dot{U}_{in}$  of (1) is normalized in relation to the effective value of this voltage, when there is no relative movement between the ECT and CO ( $\vec{v} = 0$ ) [4].

$$(5) \quad \dot{U}^*(\tau, \beta) = \frac{\dot{U}(\tau, \beta) - \dot{U}(0, \beta)}{U(0, \beta)}$$

Here  $\dot{U}(0, \beta)$  is the complex effective value of the transformer component of the introduced voltage.

The form of the coils and their mutual position is taken into account by means of an input parameter  $\theta$  [3, 4]:

$$(6) \quad \theta_1 = \frac{b_1}{a_1} = b_1^*, \quad \theta_2 = \frac{b_2}{a_2} = \frac{b_2^*}{a_2^*}$$

For D1  $\theta_1 = \theta_2 = 4$ , D2  $\theta_1 = 4, \theta_2 = 1$ .

Studies have been made for the following ECT designs with relevant normalized sizes - table 1.

Table. 1.

Design	$b_1^*$	$a_2^*$	$b_2^*$
D1( $\theta_1 = \theta_2 = 4$ )	4	0.95	3.8
D2( $\theta_1 = 4, \theta_2 = 1$ )	4	0.95	0.95

Investigation of the output signal under different conditions

The normalized output signal of (5) has got two components - real  $\text{Re} \dot{U}^*$  and imaginary  $\text{Im} \dot{U}^*$  part or effective value  $U^*$  and initial phase  $\psi = \arg \dot{U}^*$  [5, 6].

Were investigated following graphic dependencies.

- The plane diagrams of  $\text{Im} \dot{U}^*$  ( $\text{Re} \dot{U}^*$ ) in the modification of relative velocity  $\tau$ ,
- The dependence  $\dot{U}^*(\tau)$
- The dependence  $\dot{U}^*(\alpha)$

## 2. RESULTS OF NUMERICAL EXPERIMENTS

### 2.1. The angle of the direction of the velocity $\tau$ to the axis $OX$ -

$$\alpha = 0$$

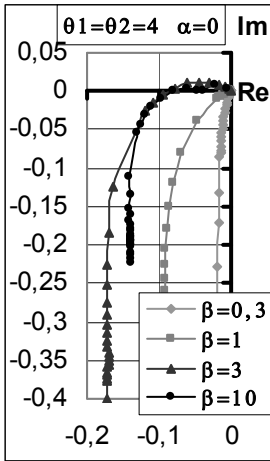


Fig. 2

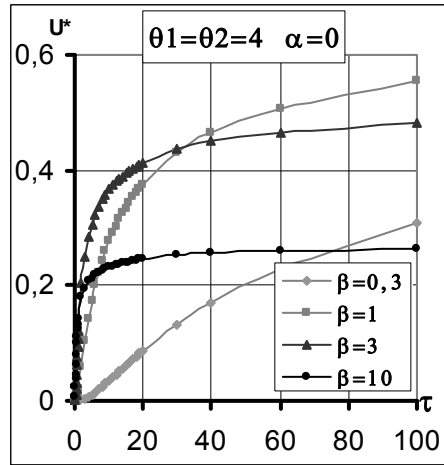


Fig. 3

Fig. 2 and Fig. 4 show the plane diagrams for D1 and D2. There are no significant differences. Fig. 3 and Fig. 5 show the output signals of D1 and D2. For small  $\beta=0.3$  the output signal  $\dot{U}^*$  depends almost linearly on velocity  $\tau$ . For  $\beta=1$  and  $\beta=3$  plots are linear for  $\tau=0 \div 5$ , and for  $\beta=10$  has a linear plot up to  $\tau=2$ , then the output signal  $\dot{U}^*$  does not depend on velocity  $\tau$ -fig. 5.

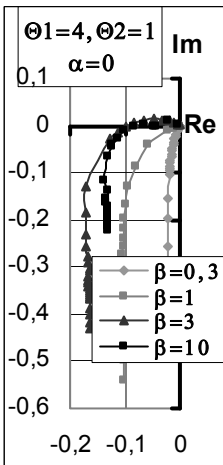


Fig. 4

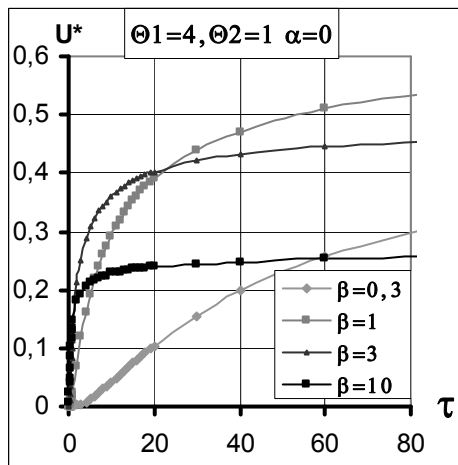


Fig. 5

## 2.2. The angle of the direction of the velocity $\tau$ to the axis $OX$ -

$$\alpha = \frac{\pi}{2}$$

When  $\alpha = \frac{\pi}{2}$  and  $\beta > 3$  the plane diagrams for D1 are nonlinear - Fig.-6, and for D2 they have got a spiral form and are self-intersecting - Fig. 8.

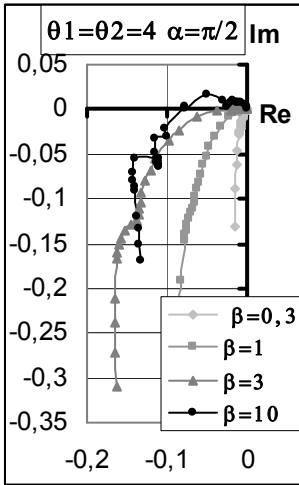


Fig. 6

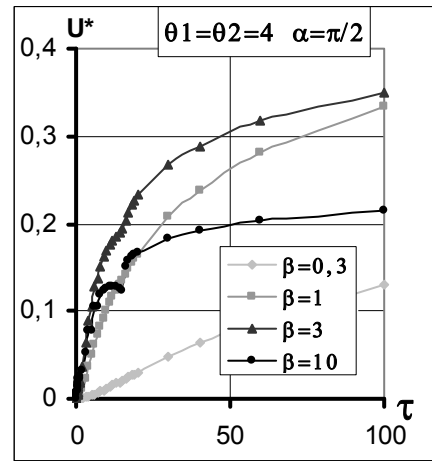


Fig. 7

The output signal of the ECT has got a small linear section for  $\beta = 10$  and large fluctuations are observed for D2, Fig. 9.

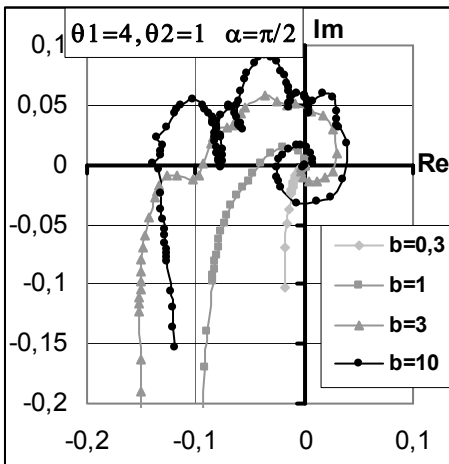


Fig. 8

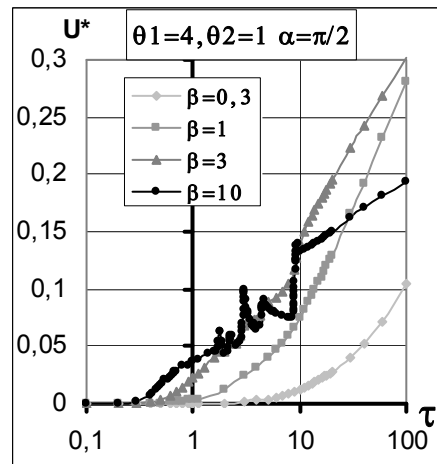


Fig. 9 is in logarithmical scale

### 2.3. Dependence of the output signal of the ECT on the direction of velocity $\dot{U}^*(\alpha)$

The effective value of the output signal has got a maximum, when the velocity is parallel to the axis OX ( $\alpha = 0$  and  $\alpha = \pi$ ) and a minimum, when the velocity is aimed at axis OY ( $\alpha = \frac{\pi}{2}$  and  $\alpha = \frac{3\pi}{2}$ ).

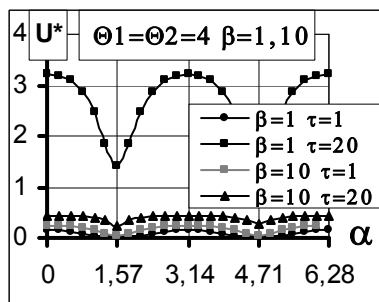


Fig. 10

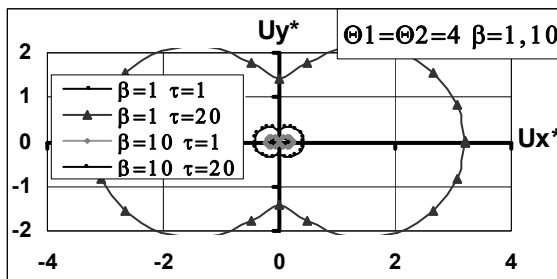


Fig. 11-polar coordinate system

Furthermore the extrema are more pronounced at higher values of velocity  $\tau$ -fig. 10 and fig. 12. The relationship  $\dot{U}^*(\alpha)$ , presented in a polar coordinate system provides useful information as well. For both types of ECT the curve has got an "eight" shape.

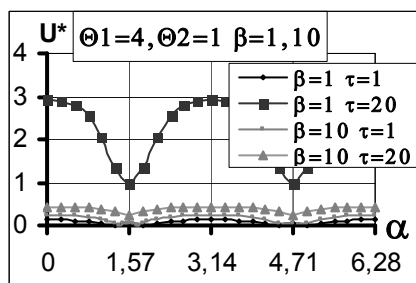


Fig. 12

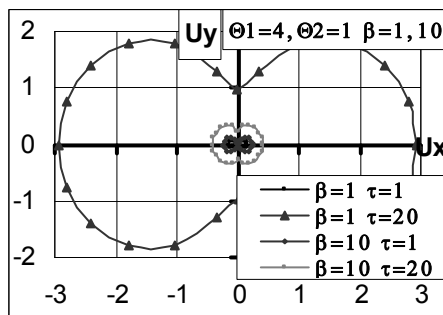


Fig. 13-polar coordinate system

### 3. CONCLUSIONS

- The difference in the form of the coils of both transducers leads in some cases to significant differences of the output signal in relation to the relative velocity. The spiraling plane diagrams are of interest for large  $\beta = 10$  for D2.

- For the effective value of voltage there are large ranges of almost linear dependence on  $\tau$ . Therefore velocity can be measured both by amplitude and phase methods.

- The investigation of self-intersections of the plane diagrams for D2 can be continued.

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# Estimation of the error of the silicon based pressure sensor MPX4115A at room ambient temperatures

**Ivo Angelov**

South West University

**Abstract:** *A digital barometer with USB interface was constructed, using MPX4115 integrated pressure sensor. Although the error of the sensor is 15 hPa according to its data sheet, if the instrument is used at room temperatures and an additional software calibration is made, the error is approximately 0.3 – 0.5 hPa.*

**Keywords:** *pressure sensors, microcontroller, data acquisition systems.*

## 1. INTRODUCTION

The atmospheric pressure is one of the most important meteorological parameters and its exact values have to be taken into account during many physical experiments in which the results are affected by the atmosphere. In this particular case, the continuous measurement of the atmospheric pressure was needed for a barometric correction of cosmic rays (CR) data [1] from the muon telescopes, at the South West University [2] and the basic Ecological Observatory – Moussala [3].

Taking in mind the values of the barometric coefficients, ( $\beta = -0.1248\%/hPa$  for SWU telescope,  $\beta = -0.2889\%/hPa$  for BEO telescope), and the small ( $\sim$  few %) amplitude of the studied variations, we can define the resolution and accuracy of the barometer needed for these corrections – if they are  $\sim 0.1$  hPa, the errors in measuring muon flux due to errors in barometric correction would be in the order of  $0.01 \div 0.02\%$ , negligible compared to the studied variations and statistical uncertainties of the telescopes.

A custom digital barometer had to be developed and built, trying to achieve these parameters at affordable price. The barometer should be interfaced to a data logging PC, and the pressure data written in the file with CR data.

The silicon pressure sensors produced nowadays use piezoresistive technology and can be divided in four groups.

- Non compensated. They include just a piezoresistive bridge. The sensitivity is about  $1\text{--}2\text{ mV / kPa}$  and the temperature coefficients are large. The user has to use own signal conditioning and temperature compensation.

- Compensated. They include the piezoresistive sensing element and a thin film laser trimmed resistor compensation and calibration circuitry. The user has to use a amplifier to interface it to ADC.
- Integrated. They include the sensing element, the compensation and calibration circuitry and a amplifier in one package. Can be interfaced directly to ADC and have good sensitivity.
- Digital. The pressure sensing element, a temperature sensor, an ADC and a microcontroller are included in a single package. The output signal is digital, I2Bus or SPI are used. The calibration is made storing constants in the memory of the microcontroller. The temperature compensation is made by software calculations in the microcontroller. The accuracy, temperature stability and resolution are at highest level compared to the analog sensors.

For our application we chose the MPX4115A (Freescale Semiconductor) integrated silicon pressure sensor. This sensor is available at moderate price and reasonable delivery time at most of the electronic components suppliers. The range of the sensor is 1150 hPa. The full scale output is 4.8V and the sensitivity is  $\approx 46 \text{ mV} / \text{kPa}$ , which make it ideal for 5V microcontroller applications. The sensor is temperature compensated over the temperature range  $-40 \div 125 \text{ }^{\circ}\text{C}$ . According to the data sheet, the maximum error is 15 hPa over  $0 \div 85 \text{ }^{\circ}\text{C}$ .

## **2. THE DEVELOPED INSTRUMENT.**

We have developed and built two digital barometers.

The needed resolution of 0.1 hPa or better could be achieved with 14-16 bit analog to digital converter (ADC). We used 16-bit Sigma-Delta ADC of the microcontroller (MCU) ADuC836 (Analog Devices).

ADuC836 has 2 independent 16-bit ADC, the primary (pri.) ADC is differential and has a programmable gain amplifier, while the auxiliary (aux.) ADC is single ended. The microprocessor core is 8051 compatible. A part of the schematic is presented on fig. 1.

### ***2.1. Temperature drifts.***

Much care was taken to provide minimum temperature drift of the instrument. An external voltage reference (V<sub>ref</sub>) type ADR03C or REF192G with temperature coefficients (TC) 10ppm/C, was used, instead of the internal reference, which has TC 100ppm/C. As the output voltage of the MPX4115 is proportional to its power supply voltage, the sensor was powered via the operational amplifier (OpAmp) U1-B. The OpAmp is connected as non-inverting amplifier with gain  $\approx 2.04$ , and amplifying the 2.5V from V<sub>ref</sub> provides 5.1V power for the pressure sensor. Thus any changes in the V<sub>ref</sub> will result in changes of the sensor power supply

voltage and the sensing is ratiometric. Metal film resistors with tolerance 1% and  $TC=50$  ppm/C were used. (The TC of traditional 5% carbon film resistors is  $\approx 700$  ppm/C.) All the OpAms used are MCP602 (Microchip) with input offset voltage  $\pm 0.7$  mV typical and input offset voltage drift  $\approx 2.5$   $\mu$ V/C.

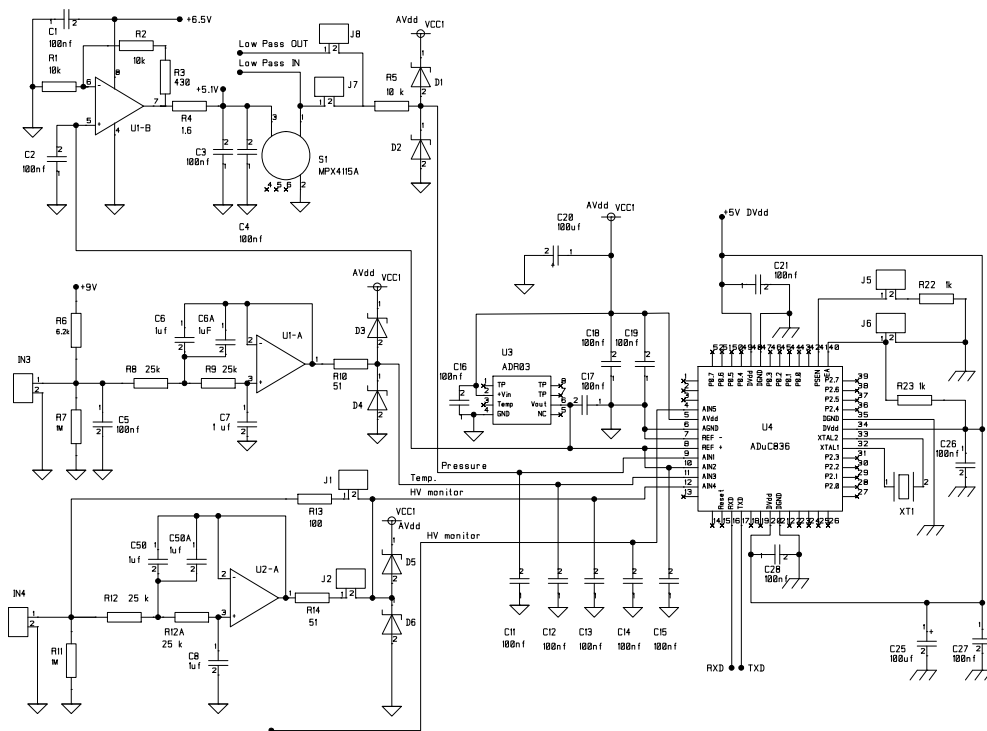


Fig. 1: Part of the barometer schematic.

## 2.2. Resolution and noise considerations.

The differential pri. ADC is used to measure the sensor voltage. (Inputs AIN1 and AIN2 are multiplexed to the ADC by software). The inverting input AIN2 is connected to the  $V_{ref}$  source for additional increase of the resolution. The measured with the ADC voltage range is from  $V_{ref}=2.5$ V to  $2V_{ref}=5$ V, corresponding to pressure range  $\sim 575$ hPa to 1150 hPa. Thus the resolution is  $(575 \text{ hPa}/2^{16})=0.0088$  hPa, which is comparable with the noise of the sensor.

A key for achieving a real high resolution is the reducing and filtering of the sensors noise. According [4], the optimal way is low pass filtering of the analog signal and averaging the digital values. We tried active low pass filter, with the similar design as the one used for temperature sensor (input IN3, U1A) – it can be switched by jumpers J8-closed, J7-open – but the offset and temperature drift were not satisfactory. So a simple RC filter (R5

– C11, jumper J8-open, J7-closed) is used and gives better stability. The digitized values of the sensor voltage are averaged over 16 samples by the application software.

It is important that the high resolution and dynamic range are achieved without external analog amplifiers and do not need to be calibrated using potentiometers, which have large TC and aging effects. All the calibrations can be done by software constants.

### 2.3. Other details. Software.

The instrument measures also (with the aux. ADC) the outdoor temperature (LM335 sensor, input IN3), the indoor temperature (the built-in thermosensor of the MCU), the high voltage power supplies of the telescopes (via resistive voltage divider and inputs IN4, IN5).

The interface to the PC is USB 2.0, realized with the FTDI232RL (Futre Technologies Devices International Ltd.) The RX and TX signal from the MCU UART are optocoupled to FTDI232RL, the MCU and the sensor are powered via DC-DC converter from the USB. Thus the board is galvanically separated from the PC ground.

The software for the MCU was written in Assembler and compiled with Keil A51 compiler. The ADCs work in continuous conversion mode, at pri. ADC driven interrupt, the sensor voltage (pri. ADC) is sent via the UART (ASCII code), the voltage from the aux. ADC is sent via the UART, the input of the aux. ADC is multiplexed to the next input. Thus every 4 measurements of pressure we have a measurement of outdoor and indoor temperature and the 2 high voltages.

The application software for the PC was written in Delphi 7 using virtual com port drivers for Windows XP from FTDI.

## 3. RESULTS

The instruments were used at room temperatures  $\sim 10\div 25^\circ\text{C}$ . The barometer at the SWU was calibrated using data archive from the meteorological station at Kustendil (30 km from Blagoevgrad, 520 m a.s.l.), available at <http://meteo.infospace.ru>. The data were recalculated for 383 m a.s.l. The barometer at BEO was calibrated using data from the automatic weather station Vaisala working at the observatory (<http://beo-db.inrne.bas.bg/moussala/>).

The transfer function of MPX4115, according the data sheet is :

$$P_{MPX4115A} = \frac{(V_{out}/V_s) + 0.095}{0.009} \pm Error \quad (1)$$

where  $V_{out}$  is the output voltage and  $V_s$  is the power supply voltage. The correlation between the measured with our instruments pressure and the data from the meteostations is shown on fig. 2.

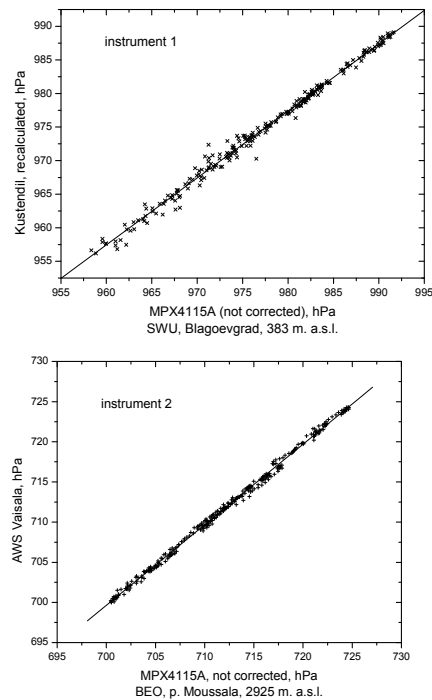


Fig. 2: Correlation of MPX4115A data and meteorological station data.  
Left SWU instrument and meteorological station Kustendil,  
right BEO instrument and AWS Vaisala

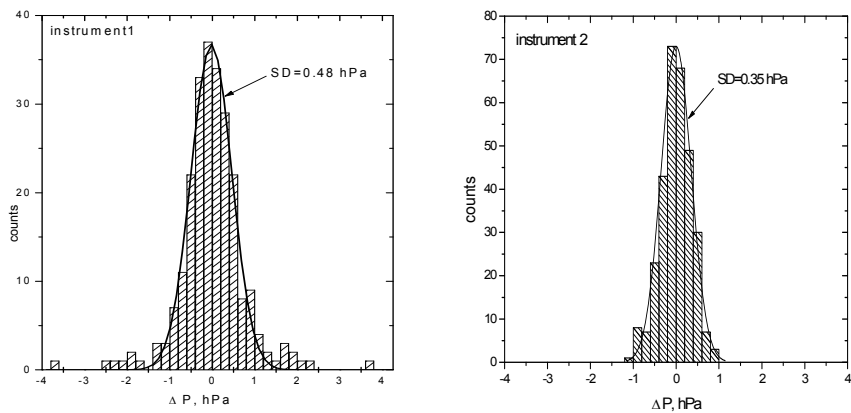


Fig. 3: Distribution of the differences between the corrected data and meteorological station data.  
Left SWU instrument and meteorological station Kustendil,  
right BEO instrument and AWS Vaisala

The actual pressure for the two instruments is calculated, with correction coefficients derived from the above correlations:

$$P_{instrument\ 1} = (P_{MPX415} - 8.40611) / 0.99403 \quad (2)$$

$$P_{instrument2} = (P_{MPX415} \cdot 1.00305) - 2.49374 \quad (3)$$

The distributions of the difference between the meteostations data and the corrected data from the barometers are shown on fig. 3. For the SWU instrument, 240 measurements, from November-December 2007 are used. For the BEO instrument, 300 measurements in 2008 are used. The two histograms can be approximated with normal distributions and the standard deviations are  $SD1=0.48$  and  $SD2=0.35$  hPa.

#### 4. CONCLUSIONS

If the sensors MPX4115A are used at room temperatures ( $10\div 25^{\circ}\text{C}$ ) and additional calibration is made, the error measuring atmospheric pressure in the range 650 – 1000 hPa is approximately  $0.3\div 0.5$  hPa.

The sensor should be connected directly to a  $14 \div 16$  bit ADC to decrease temperature drifts, simple RC low pass filtering and 16 samples averaging of the digital values provides noise free 0.1 hPa resolution.

Additional temperature corrections (for example, like described in [5]) should be made if larger temperature range is needed.

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## TMS320 – simple application

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**Abstract:** *In this article we consider the minimum hardware and software requirements necessary to use digital signal processors (DSP) in the training of students majoring in Computer systems and technologies (CST). Furthermore, through simple examples show the sequence of creation of programs, their setting and implementing policy.*

**Keywords:** Digital Signal Processing (DSP), DSP Starter Kit (DSK), host PC.

### INTRODUCTION

Training course “Signal processors” in CST are subject to laboratory exercises. Acquisition of basic knowledge and skills in digital signal processing is done by simulating programs. They allow testing different algorithms, but can not clarify the entire process of creating, setting and implementing real programs for digital processing.

Best this can be illustrated using the development system, which is a combination of specialized hardware, including signal processor and application software for creating and testing programs. These conditions corresponding DSP Starter's Kit (DSK) of the company Texas Instruments. Within the project “Complex development of systems for monitoring processes in real time” is intended to provide various modifications DSK (different processors and various peripheral circuits). They will be introduced in the training of students in stages, this process can continue a long time.

In order to facilitate the process and reduce the time needed, we set a task to do a test implementation of the DSK. We wanted to verify what initial knowledge is necessary and what problems will arise. The initial conditions were to no have experience working with DSK and to use available sources of information. The ultimate objective is operating system on which to start a simple demo program.

As you aware of the differences between different DSP platforms still hope that the experience gained will help us to seamlessly integrate into the training of new systems.

The first part of the proposed material, consider some features of the DSP and the function of individual elements of the DSK.

The second part, we turn attention to the application software (**assembler, debugger**) and characteristics in dealing with them.

In the third section with a concrete example describe the consistency of working with the system - assembly, loading, execution of the program.

In the discussions, we summarize experience and make conclusions.

## **1. FEATURES OF THE DSP**

With the development of microprocessor techniques it's necessary the need of creating different types of microprocessors, which is intended to solve specific problems. Need of creation processors intended for applications with dominant data processing requires the emergence of so-called processor for digital signal processing (DSP). The first such processor whose architecture is consistent with the specifics of the implementation of digital algorithms appear in the early 80's. The first TMS320 DSP processor is manufactured in 1982 by the company Texas Instruments. They are widely used due to their advantages compared with analogue, these are: high reliability, 100% repeat the result, easily change the parameters of the system by modify the algorithm for management, parameters of the system is not influence of weather factors, lower consumption rates, the possibility for realization of program components, which realization is practically difficult. The main drawback of DSP systems is related to difficulties in synthesizing numerical algorithms and their practical due to the need of a good mathematical and software training.

Architecture of TMS320C3x comprises a central processor unit (CPU), memory, DMA controller, serial port and two timers. Central processor consists of the following modules: multiplication of whole numbers and numbers with floating point, arithmetic logical drive (ALU), 32 bit barrel shifter, internal highways (CPU1, CPU2 and REG1, REG2), devices for arithmetic with the auxiliary registers (ARAUS ), chief of the central file processor.

In specific example used DSP processor TMS320C3x is the so called integrated platform for working with digital signal processor (DSP Starter Kit - DSK). DSK is a simple, inexpensive high-performance system for creation of applications that allows you to experiment and use the TMS320C3x for applications in real time. DSK allows creating software that can be charged accordingly to the DSK - then be started.

Key features of the DSK:

- built-in standard DSP processor TMS320C31;
- 40ns cycle, 50 MFLOPS, 25 MIPS;
- standard or extended printer parallel port for connection to PC, which allows the DSP processor to communicate with host PC;
- acceptance of data in analog interface TLC32040. Variable frequency range of digital to analog converter (DAC) to 20 000 sample per second. Filter output capacitor and switched with an option to bypass the entrance;

- standard RCA connectors for analog input and output, which is provided in direct connection with the microphone and speaker;
- XDS-510 emulator connector;
- connectors, allowing connection of additional TMS320C3x to different platforms.

Main components on DSK are DSP TMS320C31, AIC TLC32040, additional connectors, system clock, a parallel printer interface and led. All signals are out to additional connectors, which include four 32 – pin headers, 11 - drawn conclusions block with jumpers and 12 - pin XDS510 headers.

TLC32040 is connected to the serial port of DSP processor. Block with jumpers allows removing this connection and connecting to the serial port set by other controllers placed by user.

Working principle of the DSK:

- in analog input of the system enters a continuous analog signal, which with the help of TCL32040 (which includes himself an analog to digital converter) is transformed into a discrete set of values;
- digital processing is a key set;
- output of the scheme to be submitted by the transformations of the digital to analog converter TLC32040 a digital signal in its analog equivalent.

DSK will not work alone. The creation of the program, its processing load and start is done in most cases using the PC. Requirements are as follows:

- hardware requirements - to make a link between DSK and PC parallel interface is required;
- software requirements - to work DSK software required operating system Windows 98 or MSDOS;
- more necessary initial knowledge - knowledge of basic commands in MSDOS, and assembly language for DSK.

## **2. THE SEQUENCE OF WORK**

The sequence of work with DSK is the following:

### ***2.1. Creating the program***

To create a DSK assembler source file, you can use almost any ASCII program editor.

DSK assembly language source programs consist of source statements that can contain assembler directives, assembly language instructions, and comments. Source statement lines can be up to 80 characters per line. Your source statement can contain four ordered fields. The general syntax for source statements is as follows:

[label] [:] mnemonic [operand list] [: comment]

Follow these guidelines: All statements must begin with a label, a blank, an asterisk, or a semicolon. - Labels are optional if you use them, they must begin in column 1. - One or more blanks must separate each field. Note that tab characters are equivalent to blanks.

Comments are optional. Comments that begin in column 1 can begin with an asterisk or a semicolon (\* or;), but comments that begin in any other column must begin with a semicolon.

Example of how it looks a part from the code:

```
. title 'PROCESSOR INITIALIZATION'
. mmregs
. ref ISR0, ISR1, ISR2, ISR3, ISR4,
TIME
. ref RCV, XMT, TRX, TXMT, TRP,
NMISR
V_TBL. Sect "vectors"
RESET B INIT                                ; This section will be loaded in program
; memory address 0h.
INT0 B ISR0                                ; INT0 - begins processing here
INT1 B ISR1                                ; INT1 - begins processing here
INT2 B ISR2                                ; INT2 - begins processing here
TINT B TIME                                ; Timer interrupt processing
RINT B RCV                                  ; Serial port receive interrupt
NMI B NMISR
. text
INIT LDP # 0                                ; Initialize data pointer
```

## 2.2. Assembling the program

The **assembler** is a software program that converts source code in assembly language into a machine code. To assemble the program should be called **assembler** and that happens with the following command:

dsk3a filename [options]

- dsk3a - is the command that invokes the **assembler**;
- filename - is the assembly language source file.

Filenames are not case sensitive. If you do not specify an extension, the assembler assumes the default extension .asm.

Options - affect the way the assembler processes input files.

After you assemble the program, **assembler** give notice of whether errors or warnings.

Such a message looks like this:

```
>>>> PASS 1 Complete
>>>> Errors: 0 Warnings: 0
>>>> PASS 2 Complete
>>>> Errors: 0 Warnings: 0
>>>> ENTRY 0x008098a9
```

### **2.3. Starting the program**

To be able to start the program first must call the **debugger**, and this happens with the following command:

dsk3d [options]

- dsk3d - is the command that invokes the debugger;
- options - supply the debugger with additional information.

**Debugger** is a complex program, which can be controlled state of the processor to monitor the contents of the registers, memory and more. Through its program can be started, can passes by a continuous to step mode, etc. **Debugger** program contains a window in which we observe the contents of the memory, disassembly window, the status window for registers and command window

## **3. BRIEF DESCRIPTION OF PROGRAM**

PASS.ASM is a simple program which the information received on the input serial port it passes to the output serial port. PASS is a basic program which is administered in a book of Texas Instruments. On every interrupt the port of the DSK is read into the DSP and is written unmodified to the serial output port. The program also:

- initializes the processor;
- initializes the on-board AIC, setting a sampling rate of 8KHz;
- reads every sample from the serial port to the DSP's accumulator;
- writes the accumulator to the output serial port before the next sample arrives.

The program serves to illustrate the quality of a signal passed through a 16 bit processor and also shows how the board can be initialized. After we created the program and assembled it we can monitor how it works. This program represents a simple DSK program which illustrates the global concepts, software components necessary for proper handling of program. Every DSK program is divided into two main parts, they are: the instructions that are necessary for proper set-up board and instructions for implementing the user algorithm (Fig. 3.1).

First part required for each DSK program, it consists of Settings, Interrupt Settings, Processor initialization and Board initialization. Second

part belongs to the applications and consists of Main program and The Interrupt Service Routine.

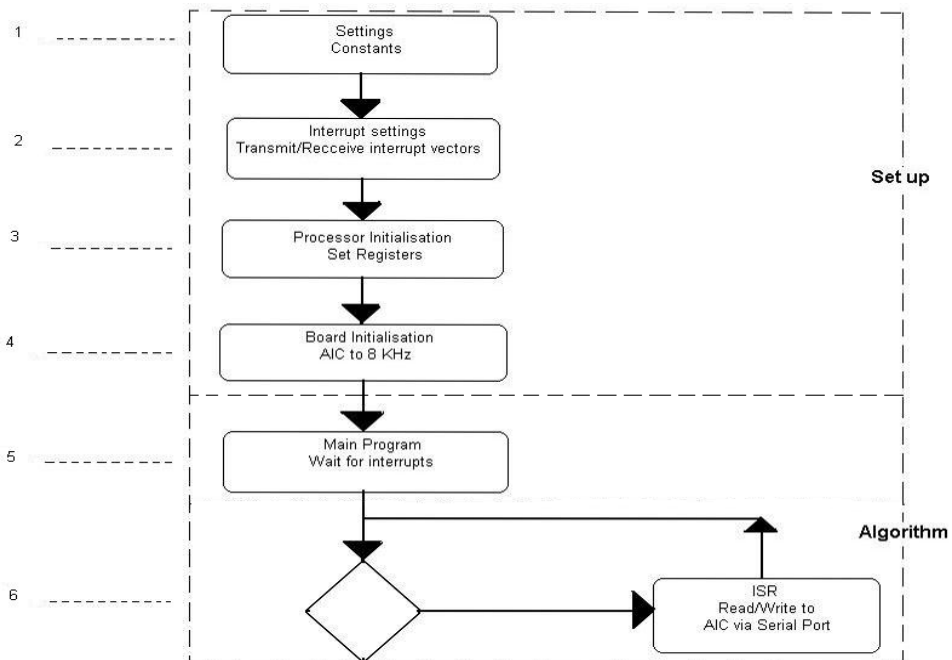


Fig.3.1: Algorithm of the DSK program.

Brief description of the functions of individual modules:

- Settings constants - part of code which specifies divided and reserve areas in the memory data that have constant values as the coefficients of the filters, as well as time results from the implementation of the algorithm.
- Interrupt settings - part of code that tells the processor what kind of interrupts to expect and what to do upon receipt an interrupt.
- Processor initialization - that is the code which initializes the processor and represents one of the most important part of the code.
- Board initialization - code who initializes DSK board, particularly the AIC's sampling rates and anti-aliasing filters.
- Main program - PASS in this section is very simple and consists of several instructions that wait for interrupts.
- The Interrupt Service Routines - the ISR's contain instruction that the processor executes on receiving an interrupt.

#### **4. CONCLUSIONS**

As a result of our work, which started from zero in less than 10 days had a working system. However we found out what the minimum hardware requirements and the initial knowledge needed. The conclusions we make are that the introduction of the "Signal Processors", not all students are prepared to work with the DSK. It was originally to be familiar with some features in the creation of programs for DSP and to obtain the initial knowledge to work in an environment of DOS. Our proposal is to establish two pilot groups that helps to bring into force expected DSK and only then to allow anyone interested to learn this course.

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# **About New Software and Hardware tools in the Education of "Semiconductor Devices"**

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**Abstract:** This paper describes the new tools, used in the education of "Semiconductor Devices", developed at the Technological School "Electronic Systems", Department of the Technical University, Sofia. The software and hardware tools give the opportunity to achieve the right balance between theory and practice, and the students are given the chance to accumulate valuable "hands-on" skills. The main purpose of the developed lab exercises is to demonstrate the use of some electronic components and practice with them.

**Keywords:** *semiconductors, media software tool, hardware, education.*

## **1. INTRODUCTION**

Almost every Electrical Engineering department teaches the fundamental concepts of semiconductor devices. These concepts typically include lattices, crystal structure, bandstructure, band models, carrier distributions, drift, diffusion, pn junctions, solar cells, light-emitting diodes, bipolar junction transistors (BJT), metal-oxide semiconductor capacitors (MOS-cap), and multi-acronym-device field effect transistors (mad-FETs).

Semiconductors are one of the most important devices implementing electronic control systems. By this reason, semiconductor applications learning is essential not only for electrical engineers but also for mechanical, chemical, industrial, etc. But there is a need a different way of learning, combining theoretical and practical approaches. This paper presents a new approach which combines a media software running on a personal computer with a hardware tools. This approach constitutes an innovative way of learning in the sense that involves a hardware tool with an user-friendly media tutorial and can be used by electrical engineers as well as by other engineers.

## **2. THE GOAL OF THE COURSE**

The educational system has to support a way of learning, combining theoretical and practical approaches. The investigations prove that active learning, using development tools is effective way of receiving knowledge.

The proper hardware platform and the animations are good teaching tools and the students find the course motivating. It offers knowledge that cannot be learned at classical lectures. The aim of present paper is to propose lab module for practice with semiconductors and animation tools running on a personal computer. In this course we introduce some of the concepts involved in semiconductor devices as well as some of the devices themselves. There is no math involved, this is strictly a course for the introduction of the concepts; Semiconductors, IV Curves, the pn junction, the Diode - the PN Junction Diode, the Zener Diode, the Tunnel Diode, the Transistor - the PNP Transistor, the NPN Transistor, the Field Effect Transistor, the MOSFET.

### **3. NEW SOFTWARE AND HARDWARE DIDACTIC TOOLS**

#### **3.1. Hardware lab tool**

The developed lab module is presented in fig. 1 and describes its components: 1 – a multi meter for input voltage measuring of investigated scheme; 2 - a multi meter for input current; measuring; 3 – a voltage generator; 4 – pin for output voltage measuring.

The students can examine the basic concepts of the semiconductors - different variants of connection bipolar transistors, thyristors, photodiodes and etc.

In fig. 1 is presented the bipolar junction lab. It allows to investigate npn or pnp type of the Bipolar Junction Transistor (BJT). Different modes of junction can be realized and results can be obtained from the students. Students are asked to find the current gain, the input and output resistance, and the Early voltage effect is observed, too.

Additionally to the hardware tool, here is proposed using development boards with MCU for some exercises. Using MCU, it is easy to demonstrate how the devices work, for example: light sensors, LED's, seven-segment indicators, optrons and etc. The developed labs are: luxmeter (fig.2), PWM control of the DC motor using optron, control of the LED indication.

#### **3.2. Software animation tool**

Everything you need to explore and teach the basic concepts of semiconductor devices. As the learning material itself suggests a big quantity of pictures it's obviously animations of each subject to create and the students can see the effects of how the inverse layer channel is created in MOSFET for example as shown in fig. 3.

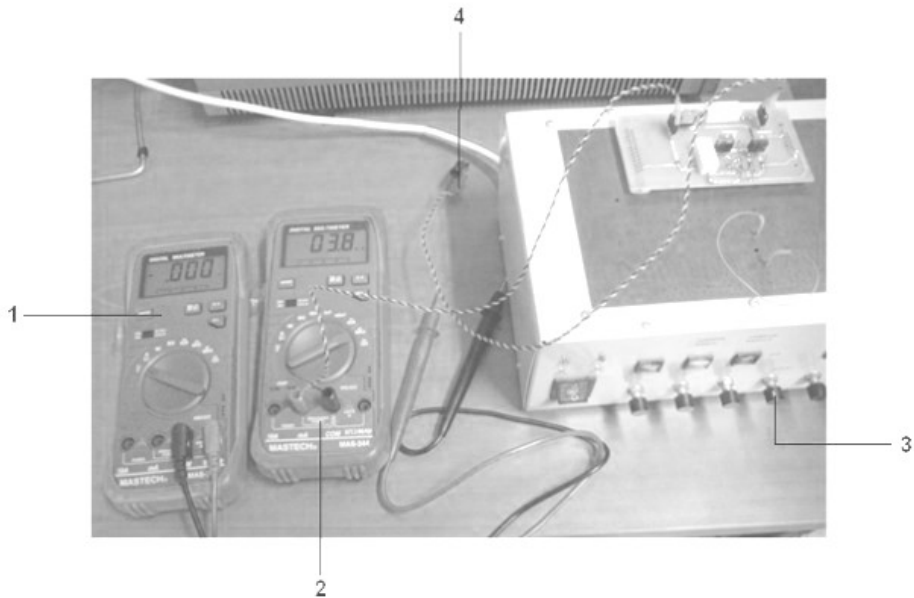


Fig. 1. Bipolar Junction Lab

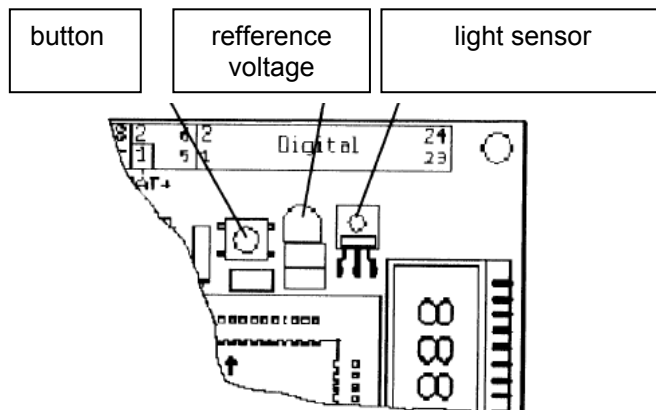


Fig. 2. Using MCU and light sensor

The pictures and the animation easily show and demonstrate the physical action of the semiconductor devices, also IV characteristics with multiple curves are easy to be shown. Having a PC in the classroom to show how the device works and having the lab module to measure the IV characteristics at one and the same class has the effect that can not be achieved by teaching at the black board and drawing IV curves by chalk. The lab gives the opportunity to measure static IV characteristics point by point and different factors influence are observed.

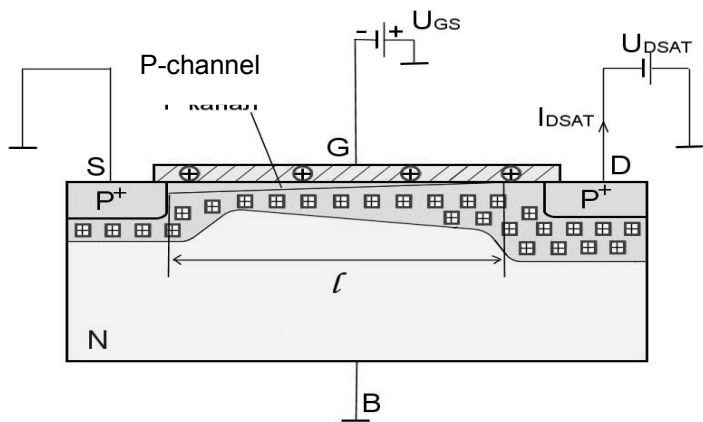


Fig. 3. MOSFET - the inverse layer channel

The lab module from one hand and the PC presentation from the other hand lead to effortless understanding and to assuring the theory is the same as the results measured by multimeters. As the dynamic characteristics are a great part of the study most of the modules are designed to have inputs and outputs on the purpose of connecting to the oscilloscope. So the input and the output voltage are observed and important dynamic characteristics can easily be seen and remembered - for example if a phase difference occurs between the input and output signal and some the dynamic characteristics can easily be calculated as voltage gain ratio.

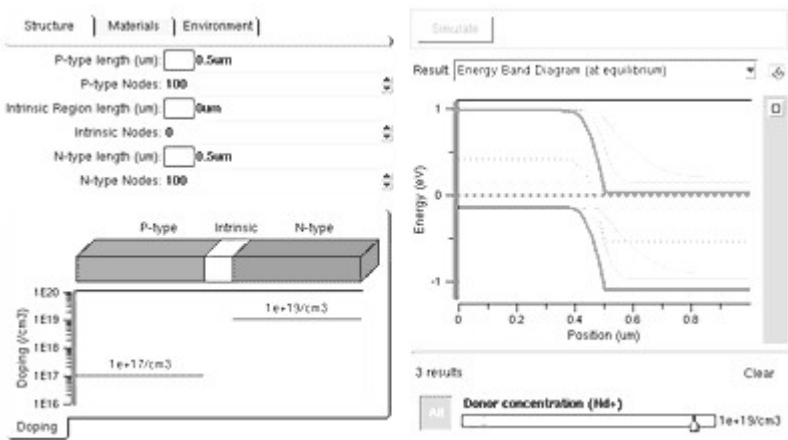


Fig. 4. PN junction lab animation.

The third lab module emphasizes on the semiconductor devices applications. Knowing the device characteristics and parameters is the necessary precondition for making a scheme design, so some first steps with simple device applications are observed: diode rectifier, variety diode clipper schemes, bipolar transistor amplifier circuit.

One of the basic learning module, entitled [PN Junction Theory and Modeling](#), walks students through the PN junction theory (fig. 4).

The animation of the [Carrier Statistics Lab](#) demonstrates electron and hole density distributions based on the Fermi-Dirac and Maxwell Boltzmann equations. This tool shows the dependence of carrier density, density of states and occupation factor on temperature and fermi level. Silicon, Germanium, and GaAs can be studied as a function of doping or Fermi level, and temperature. It is supported by a homework assignment in which students are asked to explore the differences between Fermi-Dirac and Maxwell-Boltzmann distributions, compute electron and hole concentrations, study temperature dependences, and study freeze-out (fig.4). Here are included the following exercises: PN Diode, Series Resistance, PIN Diode, PN diode, Basic Operation of a PN diode, [Basic operation of a PN diode - Theoretical exercise](#) and etc.

Another software animation is for Drift Diffusion Lab which enables a student to understand the basic concepts of drift and diffusion of carriers inside a semiconductor slab using different kinds of experiments. This tool provides important information about carrier densities, transient and steady state currents, fermi-levels and electrostatic potentials. It is supported by two related lab work in which students are asked to explore the concepts of drift, diffusion, quasi Fermi levels, and the response to light.

#### **4. RESULTS**

Our experience shows that these didactic tools indeed invigorate students and facilitate active learning. Leading with practice has provided a great motivation for students to learn the applicable theory, and students are now more comfortable in learning with animation software. The inquiry after the course shows that the level of their satisfying is increased.

It can be concluded that with the use of appropriate methodologies, with software and hardware support, help the student to understand contents of the training unit better through interfaces that provide a quicker or deeper gathering of information of the semiconductors. The visual aspect, the movement, the images' color created with realism, all provide an environment of incentive and a high level of attraction of the trainee's attention and therefore better learning.

The use of informative boards that come with the images and arouse the trainee's curiosity stimulates the trainee's motivation to deepen his/her

understanding of the details of production technologies of this kind of components, to accede easily to this basis facets.

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# Science Communication in European Projects

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**Abstract:** *Science communication in several recent successful projects of Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences (INRNE, BAS) from the 5-th and 6-th Framework Programmes of EC is presented: the joint INRNE, BAS project with JRC of EC (FP5 NUSES) and two subsequent Centre of Excellence projects (FP5 HIMONTONET and FP6 BEOBAL) are considered. Innovations and traditional forms development and application are discussed. An overview of presentation and communication of INRNE, BAS contribution to Bulgarian European Project is made. Good practices have been derived.*

**Keywords:** *Science communication, European projects, Innovations*

## 1. INTRODUCTION

Science communication in European projects is of specific character. At first it is devoted to the project subject, secondly to the common European aims, for example ERA, and finally it has to take into account the specific and the context of regional development and native population characteristics. Other is quite free choice of used forms in our case combined with an active pro customers (clients, end users, target groups) line of activity. It is provided a specific environment for science communication.

## 2. SCIENCE COMMUNICATION IN SELECTED INRNE BAS PROJECTS FROM 6-TH AND 7-TH EU FRAMEWORK PROGRAMMES

### **2.1. INRNE – JRC NUSES FP5 project [1,2,8]**

NUSES - INRNE - JRC Conference - Informational Days "Nuclear Science for Sustainable Environment and Security", is an indicative project for INRNE BAS – it was not only the first project joining approximately all the institute, but it was the first joint large scale project with Joint Research Centre of EC, outlining the strategic direction of cooperation for INRNE BAS. Very impressive was diversity of included JRC institutes – five of seven.

The main activities of this nine month very intensive project are two days comprehensive workshop, one day in situ visits of main INRNE BAS facilities and public lecture in BAS. Numerous direct and indirect results

have been obtained. The new collaboration with Institute of Environment Sustainability (IES), JRC, Ispra has been established – INRNE BAS Basic Environmental Observatory (BEO Moussala) joined EURDEP Environmental Radioactivity European Database. The collaboration and cooperation with other JRC institutes have enhanced and new direction outlined and developed – one of the main successful examples and story is Boron Neutron Capture Therapy (BNCT) with Peten Energy JRC institute. INRNE BAS has been given credence from Dr. Raymond Moss and has been included in 2003 in the JRC list of institutes and countries, intended to develop BNCT.

INRNE – JRC joint NUSES cooperation programme has been established and regularly developing and reviewing next years. Three subsequent years reports (NUSES 1, NUSES 2 and NUSES 3 Years later, including two enquiry surveys) has been presented on regular JRC information days in Bulgaria from 2004 to 2006 [1].

All activities have proper media coverage. The variety of releases have been realized: a CD of conference – informational days, prepared before the end of event; six papers and interview in journals and magazines; four radio and TV interviews (including films); five web releases [1,2] –see Fig.1.

## **2.2. HIMONTONET FP5 and BEOBAL FP6 projects [3,4,5,6,8,9]**

HIMONTONET FP5 and BEOBAL FP6 are the second indicative, and in some sense, the structural projects for INRNE BAS. They are the first Centre of Excellence INRNE BAS projects – the BEO Centre of excellence has been formulated, established and proposed in the end of 2001.

The main achievement of HIMONTONET project is recognising of BEO among other observatories, development of European network of High Mountain Observatories and joining of BEO to this network (see memorandum [1,3,4]). The variety of releases have been realized: a CD of European workshop (2 disks); four papers and interview in journals and magazines; one TV interview; web releases [1,3], the BEO leaflet, vol.9 OM2 series [4]

The main purpose of BEOBAL and others previous and current BEO projects is in next years BEO Moussala to be developed as/for: an observatory attracting the scientists from abroad and to be included as “research infrastructure for transnational access” (at the first time, mainly for neighboring countries); the regional station of GAW (Global Atmosphere Watch) programme of World Meteorological Organization; implementation and development of advanced methodology, technology, methods and advanced metrology; enhancement of observing and complex monitoring of global change and ecosystems; diversification, broadening and enhancement of international collaboration and cooperation; active science communication by advanced Science – Society interaction policy; reinforcement of S&T equipment and systems of BEO CoE directed to

enhancement of the research infrastructure of European importance. These purposes are fully or partially fulfilled or will be reached in next future [5].

In the frame of thirty months BEOBAL project a comprehensive science communication campaign has been realised: 4 CD, 2 web sites and 1 web page and a lot of, other electronic publications; 18 Public lectures and 18 posters; more than 17 Exhibitions, including participation in the world exhibition during the XX Olympic Games in Turin, Italy "High Mountain Research Stations – a Window to the Universe", its Sofia realisation [9]; numerous media activities: 10 TV and 6 radio activities, 1 video film; 19 publications in popular journals, newspapers, bulletins, news agencies, web releases, 4 media briefings; BEOBAL Publications: 3 volumes of OM2 multi volume series –10, 11 and 12 and BEOBAL BEO Moussala leaflet; 3 conference activities; 9 training seminars with lecturers from 10 institutes and 7 countries. The targeted and reached audience ranged for different types of media from hundreds to several hundred thousands and in total exceeds 300000 [1,5,6,8,9]. Activities are illustrated at Fig.1.

### **3. "INRNE EUROPEAN PROJECT" INITIATIVE**

INRNE "European project" is like a symbol – it is the replica to "Bulgarian European project" and is devoted to illustrate and communicate some important aspects of INRNE BAS contribution to the Bulgarian European Union membership. Activities are illustrated at see Fig.1.

There are two main subjects – matter lines: official events and activities, carried out by the Ministry of Education and Science and INRNE BAS own initiatives and activities in collaboration with INRNE partners

In the first one INRNE BAS has a leading participation in two Brussels exhibitions for Bulgaria inauguration as EU member in the beginning of 2007 under the motto "Bulgarian Research – a New Brick in the European House of Knowledge": [http://www.beo.inrne.bas.bg/BEOBAL/BG\\_Res\\_NB\\_EU\\_HoK/BRU\\_EXPO.htm](http://www.beo.inrne.bas.bg/BEOBAL/BG_Res_NB_EU_HoK/BRU_EXPO.htm); The other activity was INRNE BAS participation in the Ministry of Education and Science video film about Bulgarian Centres of Excellence.

In the second one:

- The series of exhibitions have been organised for main FP6 INRNE BAS projects - in the Info Centre of Delegation of European Commission in Bulgaria, Sofia, Dec 2006 and in Bulgarian Academy of Sciences, Gallery Academica, from July, 2007 to the middle of September, 2007 -  
<http://www.evropa.bg/en/ic/calendar/events.html?date=2006-12-00&eventid=2360>.

- The first part of a comprehensive collection of main INRNE BAS conference events and projects from 2002 to 2007 has been published and released on DVD disk.
- INRNE participation (in cooperation with Varna municipality and teachers) in organisation and realisation of First Bulgarian CERN (European Organisation for Nuclear Research) Teachers Programme in October 2008 and subsequent CERN exhibitions in Sofia and Varna [7].

#### **4. INNOVATIONS IN SCIENCE COMMUNICATION IN INRNE EUROPEAN PROJECTS**

Together with conventional and traditional tools and forms in above mentioned INRNE BAS European projects several innovations have been created and implemented (see Fig.1):

First are the Conference – informational days, as an original form of the science education and communication, started from NUSES and developed in BEOBAL project [8].

Second, this is a special orientation to schools, teachers and students – one of the basic directions of new created Nuclear Technology and Education Centre of INRNE BAS [7].

Third, it is development of science and technology culture of general public and diversification of targeted audience in both directions – not only to earth and children, but also to third age people, following the EU policy of long-live education.

Forth, complex idea generation and realization of conventional science communication forms, like exhibitions, by integral inclusion of art [1-9].

Fifth, multi forms and media realization science communication and science education activities – BEOBAL training seminars have been disseminated in 3 different ways: on DVD, in printed form in 2 volumes of series OM2 (vol. 10 and 11) and in BEOBAL page at BEO web site.

Sixth, the need of a system approach to science communication and media activities has been realized and applied.

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Fig.1: Collage of photos from NRNE BAS projects HIMONTONET, BEOBAL and INRNE European Project activities



## The concept set in the programming

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**Abstract:** *The report discusses some types computer programming problems, where the using the concept set is appropriately. The specific characteristics on this concept are viewed with purpose to be received efficient algorithms.*

In the mathematics the concept set is primary and is defined as union of different elements, but the concepts "union" and "elements" remain indeterminate. In some programming languages the set can be realized with unordered and unnumbered data structure of elements of one and the same type, called composite set type.

The representation to the sets in the computer memory can realize in two ways as sequence from bits or with a memory with hashing access. The first approach will be used, when the size of the universal set is known and small. The elements of the set will be represented as a packaged sequence of bits that is supplemented until the bound on a byte or a word. The implementation of the composite set type in the Pascal language is such. Large sets of arbitrary number of the elements can be supported by means of the second method. For recording the elements of the set will be separated an area from the memory and the access to them will be performed with hashing. In this way the names of objects are represented in some realizations of the language Lisp. [6]

In the modern programming practice the languages with C – similar syntax predominate but they do not possess composite set type. The Pascal language that is used traditionally in introductory courses for programming is unique with the possibilities for defining of the set data type.

In Pascal all elements of the concrete set must belong to one order type that is called base type of the set. The set gives an interval of values that is a set from all subsets of the base type. The size of the set is equal to the number of the components of the base type and can range from 0 to 255. The maximum permissible power of the base type is 256, therefore the types integer, longint, word, real cannot be base types. As identifier to the type of the elements can use only byte, shortint, boolean, char, limited and enumerated type. In the general case set type defines itself in the following manner:

Set of < base type of a set >;

The sets compare themselves with the operations for a comparison "=", "<>", ">=", "<=" as the result of the comparison is boolean. The permissible operations over sets in Pascal are union (+), complement (-), intersection (\*) and check-up for belonging (in).

Let the set A is defined: type digit= set of 0.. 9; var A:digit; A:=[2, 4, 6, 8]. It is representing 10-dimensional binary vector, whose coordinates are numbered from 0 to 10 and the coordinate i corresponds to element i of the base type. The coordinates of the got binary vector are: (0, 0, 1, 0, 1, 0, 1, 0, 1, 0). The such way of realization permits to be executed quickly operations over sets and control on relations between them. Instead for i:=0 to 9 do if (i=2) or (i=4) or (i=6) or (i=8) then statement1 else statement2 can write better for i:=0 to 9 do if i in [2, 4, 6, 8] then statement1 else statement2. The last variant executes more quickly and reads more easily. The set data type will be use mainly in problems, in which the fact for belonging or no belonging to an element to the aggregate from own elements is important.

Classic case that illustrates the work with sets is a **Problem1** for finding to all prime numbers up to a specified integer n, known under the appellation the Sieve of Eratosthenes. The searching algorithm comes down to the following:

1. All numbers from the given interval will be arranged in the sieve (AA).
2. From AA will be taken the least integer among the remaining numbers in the interval and will be put in the set of the prime numbers. (BB)
3. From AA will be separated all numbers that are multiple to the given number.
4. If AA is not empty returns to 2. , else the calculation stops.

The algorithm cannot be used for an arbitrary n, since the maximal number of elements of one set cannot outnumber 256.

Var AA, BB : set of 2..255;

i, j : integer;

begin

AA := [2..255]; BB := []; j := 2;

While AA<> [] do begin

While not ( i in AA) do

j := j+1;

BB := BB + [j];

for i := 1 to 255 div j do AA := AA - [i \* j]; end;

for i := 1 to 255 do if i in BB then write ( i, ' ');

end.

One difference, the set type differs from another composite data types at this that the access to the elements is not anticipated in advanced.

With the help of a set type quickly and easily will be solved a **Problem 2:**

From the multitude of the natural numbers from the interval from 1 to 255 to deduce these which are squares to natural numbers.

In essentially the method to the sieve is applied in the solution to a **Problem3:** A sequence of sets  $A_1, A_2, \dots, A_n$  of positive integers is given. The sequence is defined with mathematical induction by  $n$ . If the elements of  $A$  are arranged of a size  $a_1 < a_2 < a_3 < \dots < a_n < a_{n+1}$ , then  $A_{n+1}$  is the set of those numbers from  $A_n$ , that are not from the form  $a_{ka_{n+1}}$ , where  $k \geq 1$  is integer. For example  $A_2$  is the set of all odd natural numbers; the first several numbers from  $A_3$  are 1, 3, 5, 7, 11, 13, 15, 17, 23, the first eight numbers from  $A_4$  are 1, 3, 5, 7, 11, 13, 17, 21. With  $A$  we mean the numbers, which belong to each one of the sets  $A_1, A_2, \dots, A_n, \dots$  a) the number  $a \leq 1000$  is given. Check does it belong or does not it belong to  $A$  b) find the largest number from  $A$  that is less than 100000.

The data structure set type is unconditionally useful in the cases, when the problem will be formulated easily in sets' terms and as well it allows the programming of long conditional expressions connected with a control for belonging to be simplified. The problems for an analysis to a text belong towards the last case and in particular for a scanning to the program text with purpose separation of lexemes and others constructions to the language at the time of translation.

**Problem4:** Write a program that verifies, are there in a word repeating letters.

We suppose that the word is a sequence of characters, finishing up with a point. The letters of the word will be recorded in an array of symbols. Together with the introduction of a word we form a set of letters of the word. If the serial entered letter not participates in the formed set up to the current moment, then the letter will be included into the set of letters of the word. Otherwise the logical variable flag (saving an answer to the question of the problem) will receive answer true.

```
Const Eot = '.';
Var s1: array[1..100] of char;
    Letter: set of char; {a set of letters of a word}
    i : 1..100;
    flag : Boolean;
begin
  writeln('introduce a word and put a point in the end');
  i:=1; letter:=[]; flag:=false;
  repeat
    inc(i); read(s1[i]);
    if not (s1[i] in letter) then letter:= letter+[s1[i]]
    else if not flag then flag:= true;
  until (i=100) or (s1[i]=eot);
  if flag then writeln ('in the word there are repeated letters')
  else writeln('in the word there are not repeated letters');
end.
```

Together with the introduction of the word will be formed a set of her symbols. An analogical approach will be applied in the following problems:

**Problem5:** Let a text is given. Check up whether in its there are letters, participate in the word, that is given from the user?

**Problem6:** Let a sequence of words is given. The adjacent words are separated with a comma. The text ends with a point. Print in alphabetically the vowels that participate in each word.

The problems for a working with a text can be related with general class problems. For example a separation of constructions on which is given a formal description, a check-up for correctness to arithmetical expressions. One way for solution of similar problems is a construction to mathematical model to a finite state machine, so that it facilitates the writing to a program for a solution to a **Problem7:**

Write a program valuing the power of a structuring to a program that is written to Pascal language. For a start to count the numbers operators GO TO in her.

The solution of combinatorial problems can be simplified using a set. The example for a generation to all subsets of a given set from  $n$  elements is such. Each subset can characterize itself, showing does each element of a starting set belong to the given set or not belong. Putting of each element 0 or 1, to each subset will be juxtaposed a number with  $n$  symbols in binary numeral system. [1] Theoretically the generating to all subsets coincides with a **Problem8:**

In one city there is  $n$  ( $4 \leq n \leq 150$ ) inhabitants and each inhabitant have organized own party. In each party there are not less than two members. Organize a parliament that members from all parties present. [3]

We can record the introductory data in array  $s$ :  $\text{array}[1..150]$  of set of  $1..150$  which saves the members of each parties. In case of big size the described input data will not be effective and the description to the array changes

$s$  :  $\text{array}[1..150]$  of record  
number, name: integer;  
partiya: set of  $1..150$ ; end;

Here the field *partiya* coincides with the original description to the array  $s$ , name – a number of an inhabitant, number – a number of elements in a set *partiya*.

Numerous application problems with ease will be described with the structure graph. Traditionally the graph preserves itself by means of an array, each element to which corresponds to one vertex and contains a list or a set with its adjacent vertices. Theoretically the following problem will be described as a search to a path between a pair of vertices to a graph.

**Problem9:** Determine with how stations connected can reach from line  $m$  to line  $n$  to the Metro or to bring out an announcement that is impossible.

In advanced from the input data it is known between which pairs lines there are stations connected. [5]

It is convenient the lines of the Metro to be described with graph that in its vertices there are lines of the Metro and the presence of edges between vertices  $i$  and  $j$ , corresponds to a presence of a station connected between lines with numbers  $i$  and  $j$ . The graph will be presented with an array from sets, where an element  $i$  of the array contains a set of all lines in which can go from a line  $i$  with one station connected. The restriction from the size of the array will be avoided if be used an array from a list with vertices adjacent with the given vertex.

Additional problems from sets:

**Problem10:** Many children games start with a counting-out game (brief rhymes). The player on whom the last word from the text falls is out the circle. Let there are  $n$  children in the circle. The text for the counting-out game will be introduced from the keyboard. Print the numbers of the children in the sequence in which they are out the circle.

**Problem11:** Two odd numbers differing with 2 are called twins. For example 5 and 7, 11 and 13, 15 and 17... Write a program printing all numbers twins in the interval  $[2..255]$ . Use the Sieve of Eratosthenes to check the prime numbers.

**Problem12:** Find all fours of prime numbers, less than  $n$ , which belong to one ten (for example 11, 13, 17, 19), with the help to the Sieve of Eratosthenes.

**Problem13:** Let two expression are given, the words, in which are separated with commas or intervals. Each expression ends with a point. Does it can from the letters to the first expression compose the second and vice versa. If neither one of two cases are not possible, count the letters which not reach, so that these cases will be realized.

**Problem14:** In one town there are 100 pastry-shops. It is known, than in every of these shops there are not more than 20 pastry assortments. What sort of confectionery has in all possible shops? Does a shop exist, trading in unique product? (The assortment of the pastry-shop will be regarded as countable set.)

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# **Reseraching the Repetition's Accuracy while Positioning a Translation Module of the Type ADP 30-2000**

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**Abstract:** *Accuracy of positioning reptition means the dispersal of the end link of industrial robots or translation/rotation modules in regard of programmable predetermined theoretical spots, which have to be reached repetitively with the program's multiple reruns. This is one of the most significant parameters of industrial robots (especially in assembly operations), which conditions the operations quality of automated manufacturing processes.*

*When new modules for industrial robots are being conceived the parameters in the technical assignment have to be checked by applying a specialized methodology.*

*Subject of this paper is the testing of the repetition's accuracy while positioning a translation module of the family ADP 30-2000.*

**Keywords** *translation module, repetition's accuracy in the process of positioning*

## **1. INTRODUCTION**

At the Department of "Automation of Discrete Manufacturing Engineering", Technical University Sofia, a range of modules has been developed allowing different combinations to create industrial robots with carrying loads from 1, 6 to 10, 0 kg. The series include 30 different sizes of translation modules varying in their carrying capacity and stroke length and 12 rotation module types with different load capacity and max rotation angles.

This paper reports the effects from experiments testing the repetition accuracy while positioning a translation module of the type ADP 30-2000. The module has a carrying capacity of 30 kg and a stroke of 2000 mm. The driver mechanism is pneumatic and the end positions are controllable. The preset repetition accuracy is  $\pm 2$  mm.

## **2. METHODOLOGY FOR EXPERIMENTAL ASSESSMENT OF THE REPETITION ACCURACY OF POSITIONING**

The methodology comprises the following stages:

- 50 measurements of the positioning repetition accuracy (deviation  $\Delta X$ ) in a chosen theoretical point from the module's cycle in both directions – vertical and horizontal;
- Recording the admitted values for  $\Delta X$  in a table;
- Calculating the average dispersion value  $\Delta X_{av}$  with the formula:

$$(1) \quad \Delta X_{av} = \frac{\sum_{i=1}^{50} (\Delta X_i)}{50}$$

- Dividing the range of the measured deviation  $\Delta X_{min} \div \Delta X_{max}$  into 10 equal intervals;
- Admitting the frequency of appearance of  $\Delta X$  for each of the intervals;
- Calculating the difference for each interval

$$(2) \quad (\Delta X_{av} - \Delta X_{i\ av})$$

where  $\Delta X_{i\ av}$  – average value of the  $i^{th}$  element,  $i = 1 \div 10$ ;

- Calculating the difference with the equation:

$$(3) \quad (\Delta X_{av} - \Delta X_{i\ av})^2$$

- Calculating the mean square deviation  $\sigma$ :

$$(4) \quad \sigma = \sqrt{\frac{\sum_{i=1}^{10} (\Delta X_{cp} - \Delta X_{icp})^2}{10}}$$

- Calculating the function of the normal dispense  $Y$ :

$$(5) \quad Y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(\Delta X_{cp} - \Delta X_{icp})^2}{2\sigma^2}}$$

- Building the histogram  $n = f(\Delta X_{i\ cp})$  where  $n$  [number] is the frequency of appearance in every interval and the function of the normal dispense  $Y = f(\Delta X_{i\ av})$ .

### 3. EXPERIMENTAL RESEARCH OF THE REPETITIVE POSITIONING ACCURACY OF THE LINEAR MODULE ADP 30-2000

The experiments were conducted applying a max module speed of 0,8m/s.

Fig. 1 shows the experimental set up for a horizontal position of the module.

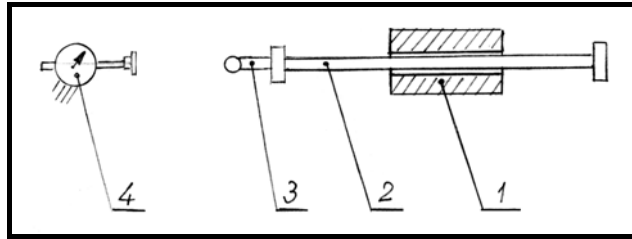


Fig.1. Schematic lay-out of the laboratory set up

1 – Body of the translation module; 2 – module's guide-bars;  
3 – Control mandrel (sphere  $\Phi 25\text{mm}$ ); 4 – Measuring clock with precision - 0,01mm

After performing 50 forward and downward movements with the module the results shown by the indicator are recorded. The indicator is set in the initial state after the module had been set in a forward-downward positioned before the experiments start. The zone between both ultimate values (positive and negative) of the deviation is divided into 10 intervals and following the previously described method the tables are filled in.

### 3.1. Experimental research of the horizontally positioned module's accuracy

Table 1 features the results obtained from the experimental research of the repetitive positioning accuracy of a horizontal module.

According to (1) and the measurement results the value  $\Delta X_{av}$  of is admitted:

$$\Delta X_{av} = \frac{\sum_{i=1}^{50} (\Delta X_i)}{50} = 0,56$$

In accordance with the methodology the difference is calculated  $(\Delta X_{av} - \Delta X_{i\ av})$  with equation (2), and with equation (3) -  $(\Delta X_{cp} - \Delta X_{i\ cp})^2$ . The results are recorded in Table 1 Then with equation (4) the value of  $\sigma$  is admitted:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{10} (\Delta X_{cp} - \Delta X_{i\ cp})^2}{10}} = 1,115$$

After admitting the value  $Y$  with equation (5) and putting the results in Table 1, the histogram  $n = f(\Delta X_{i\ av})$  (where  $n$  [numbers]) is the frequency of appearance for every interval) and the function of the normal distribution  $Y = f(\Delta X_{i\ av})$  are shown in Fig. 2.

Table 1: Results in the case of a horizontal position of the module

№ of interval	Interval [mm]	Frequency of appearance n [number]	$(\Delta X_{av.} - \Delta X_{iav})$	$(\Delta X_{av.} - \Delta X_{iav})^2$	Y
1	-1,68 ÷ -1,35	1	2,07	4,28	0,37
2	-1,34 ÷ -1,01	1	1,73	2,99	0,55
3	-1,00 ÷ -0,67	5	1,39	1,93	0,7
4	-0,66 ÷ -0,33	5	1,05	1,1	0,82
5	-0,32 ÷ 0,01	8	0,71	0,5	0,9
6	0,02 ÷ 0,35	12	0,37	0,14	0,95
7	0,36 ÷ 0,69	9	0,03	0,01	0,99
8	0,70 ÷ 1,03	5	-0,31	0,1	0,95
9	1,04 ÷ 1,37	3	-0,65	0,42	0,9
10	1,38 ÷ 1,70	1	-0,98	0,96	0,82

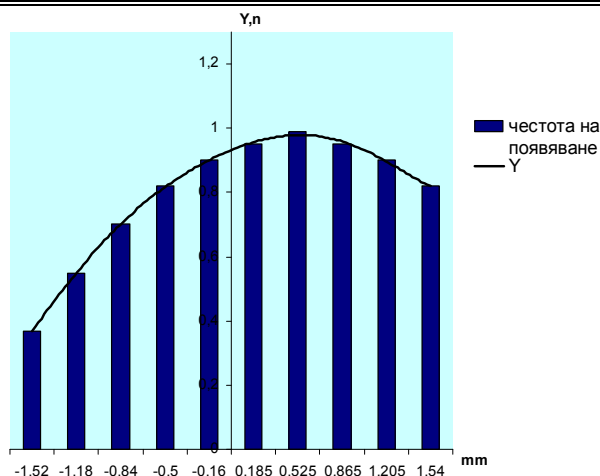


Fig.2. Experimental results in the case of a horizontal position of the module

### 3.2. Experimental research of the vertically positioned module's accuracy

Table 2 features the results obtained from the experimental research of the repetitive positioning accuracy of a vertical module. The set up is similar to the one in Table 1, only positioned vertically.

According to the described method and equation (1) following calculation is made:

$$\Delta X_{cp} = \frac{\sum_{i=1}^{50} (\Delta X_i)}{50} = 0,29$$

Table 2: Results in the case of a vertical position of the module

№ of interval	Interval [mm]	Frequency of appearance n [numbers]	$(\Delta X_{cp.} - \Delta X_{icp})$	$(\Delta X_{cp.} - \Delta X_{icp})^2$	Y
1	-0,67 ÷ -0,49	1	0,87	0,76	1,1
2	-0,48 ÷ -0,30	4	0,68	0,46	1,44
3	-0,29 ÷ -0,11	7	0,49	0,24	1,71
4	-0,10 ÷ 0,08	11	0,3	0,09	1,89
5	0,09 ÷ 0,27	10	0,11	0,01	1,99
6	0,28 ÷ 0,46	8	-0,08	0,01	1,99
7	0,47 ÷ 0,65	4	-0,27	0,07	1,91
8	0,66 ÷ 0,84	2	-0,46	0,21	1,75
9	0,85 ÷ 1,03	2	-0,65	0,42	1,2
10	1,04 ÷ 1,22	1	-0,84	0,7	1,1

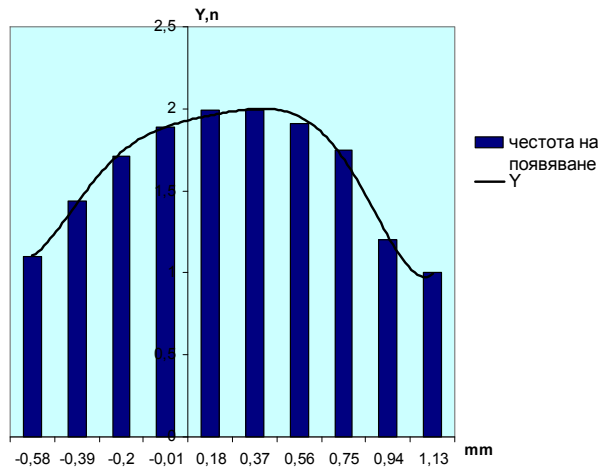


Fig.3. Experimental results in the case of a vertical position of the module

In accordance with the methodology the difference is calculated  $(\Delta X_{av} - \Delta X_{i av})$  with equation (2), and with equation (3) -  $(\Delta X_{av} - \Delta X_{i av})^2$ . The results are recorded in Table 2. Then with equation (4) the value of  $\sigma$  is admitted:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{10} (\Delta X_{cp} - \Delta X_{icp})^2}{10}} = 0,545$$

After admitting the value Y with equation (5) and putting the results in Table 2, the histogram  $n = f(\Delta X_{i av})$  (where n [numbers]) is the

frequency of appearance for every interval) and the function of the normal distribution  $Y = f(\Delta X_{i_{av}})$  are shown in Fig. 3.

#### 4. CONCLUSIONS

♦ The wider zone of the error dispersion while positioning the module can be explained with:

- bigger impact of the friction forces within the leading sleeves of the guide-bars and the pneumatic cylinder rod when - toward the end of its stroke - the module slows down;
- impact of the module's front part hanging down due to the long shift (2000 mm);
- the slow fading of the vibrations after the movement has seized (the measuring is done between the 1<sup>st</sup> and the 3<sup>d</sup> seconds after the final stop;

♦ The prevailing part of the positive values in both cases have been obtained near the end of the experiments, which is caused most probably by the reduction of the friction forces as an effect of the temperature rising in the leading sleeves.

♦ The maximum deviation in the horizontal position is  $\pm 1,7\text{mm}$ , in the vertical -  $\pm 1,22\text{mm}$ , which is less than the theoretically preset accuracy of  $\pm 2\text{ mm}$ .

♦ The obtained results prove that the accuracy of positioning fully meets the accuracy of feeding industrial robots for machine processing and other technological operations.

The results prove that the positioning accuracy fully matches the feeding accuracy of industrial robots for machine processing and other technological operations.

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## **Description of the digital formats of electronic documents used in digital library**

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**Abstract:** *A digital library is a library where collections are stored in electronic formats and are easy to be accessed by computers. The digital content may be stored by local machine, or accessed remotely via computer networks. A digital library is a type of information retrieval system. In this paper we will present a few digital format as pdf, djvu and etc. It will be denote the specific of the formats, their history and licenses policy. We will discuss different similarities between these formats..*

**Keywords:** *digital library, electronic formats, pdf, djvu.*

### **1. INTRODUCTION**

An Online Public Access Catalog (often abbreviated as OPAC or simply Library Catalog) is an online database of materials held by a files or group of libraries. Users typically search a library catalog to find books, videos, and letters owned or licensed by a library. Even though a handful of experimental systems existed as premature as the 1960s, the first large-scale online catalogs were developed at Ohio State University in 1975 and the Dallas Public Library in 1978 [3, 9].

These and other early online catalog systems tended to closely reflect the card catalogs that they were intended to replace. Using a dedicated telnet client, users could search a handful of pre-coordinate indexes and browse the resulting display in much the same way they had previously navigated the card catalog. Throughout the 1980s, the number and sophistication of online catalogs has grown. The first commercial systems appeared, and would by the end of the decade largely replace home-grown systems. Library catalogs began providing improved search mechanisms, such as basic keyword searching, as well as ancillary functions, such as the ability to place holds on items that had been checked-out [2].

### **2. MULTIMEDIA DIGITAL LIBRARIES**

At the same time, libraries began to develop applications to automate the purchase, cataloging, and circulation of books and other library materials. These applications, collectively known as an integrated library system (ILS) or library management system, often include a library catalog module as the public interface to the system's inventory. Most library catalogs, then, are closely tied to their underlying ILS system[4].

Multimedia digital libraries (MDB) are environment that stored various hypertext -organized information and provide access to services for the management of information resources, and semantic indexing cementation management metadata, sorting, grouping and presentation of digital information extracted from different sources semantic-based, context-based and search Pareto optimizations and others. Personalization is adapted presentation of information content and services according to consumer characteristics, problems, needs, and other used devices. (i.e. user context) [1]. Mechanisms of personalization in MDB focus mainly on:

- Modification of custom user interface environment;
- Custom Search information objects according to personal characteristics of the user through the use of adaptive or self adapting filters;
- Recommendation of the information content after analysis of user needs;
- Adaptability of content and services according to certain characteristics of the consumer - level of knowledge, language, etc.
- Providing information resources grouped by various criteria such as genre, period, origin, topic, required media devices used to access, context, and others.

The main task is to provide the " person, resources, acceptable result returned by the system". In workgroup NSF-EU DELOS presents report guidelines for developing systems personalization in digital libraries. Hansel [7] describes methods to personalization through submission of scenarios for their implementation. Kutrika and team offer personalization of search queries based on specially designed rules [8]. Ferrand and team discuss customized solutions in digital libraries based on the ontology [6]. Digital library MyLibrary @ LANL implements many personalized services, providing the consumer market for personal media sharing web resources with an integrated system that suggest information material , mechanisms and tools to verify the links between resources, expanding the functionality of browsers [13]

Nowadays custom and adaptive techniques in e-learning environments and multimedia digital libraries are based on relatively simple models. This way is limited the scope of work and that avoids many serious problems requiring extensive research. Existing systems will still ask questions like: what is the difference between temporary and long-term characteristics and requirements of the user, how to determine the type of personalization, when to maintain the short and long term adaptability and personalization and more. Improvement of existing algorithms partially solve these problems, but there is a need of complete new strategies and algorithms to overleap these decisions include factors such as trust, reputation, authenticity, timeliness, usefulness of the resources and using a

rich descriptive models of consumers. Another trend is the development of mechanisms for "meeting" individual needs, preferences, competence of the user with the available information content in the environment, taking into factors affecting both the resources and the individual (i.e. changeability, time, increase or decrease of interest, etc.). It is necessary to develop semantic-based architectures and models for personalized access to information resources. It is important to pay attention of interaction between user and environment. The standard roles that can be executed by the user should be replaced with a more flexible approach that allows the integration of human and automated reasoning. Social effect is significant - communication, social integration, environment of sharing resources, ideas, knowledge, etc.

### **3. SEMANTIC WEB**

Concept of Semantic Web (from English Semantic Web) was introduced by Tim Barnars-Lee, Director of the World Wide Web Consortium (W3C), and defines the next generation of World Wide Web. The machines directly or indirectly are interpreting and processing the meaning and purpose of the information resources of the network. The key to new applications and services lies in reaching a higher level of machine-cultivated semantics in data processing systems. Semantic web aims to introduce semantic tagging of data in the network in order to allow more precise searching, analyzing, mixing and presentation of data from different type and more. [11, 12].

At the core of the semantic web is ontology, which is known as essential technology to reach semantics, allowing presentation of data in machine-understandable structures. Ontology (from Ancient Greek: ontos - life, existence, Logos - word, science) is a term defining the science of Being. In the contemporary philosophical literature, the term used to describe a particular system of categories that is the result of a specific system of views on the world. In the literature on the concept of artificial intelligence is used to denote formally presented knowledge on the basis of a conceptualization. The conceptualization entails a description for a set of objects and concepts, knowledge, facts, rules and relations between them. Grubber defines as "formal explicit specification of a shared conceptualization." Ontology is defined as a conceptual information model that describes things that exist in definition area (concepts, their properties, attributes, facts, rules and relationships) in a consistent and formal manner. Ontology can be considered as standard specific model provides a sound basis for common understanding of a field and this model can be shared among people and / or applied computer systems. This provides a principled way of dealing with large amounts of diverse and distributed computer based information [5].

Many of the allegations that consist ontology, the form of a logical theory of first order in which terms from the dictionary are names unary and binary predikat, called concepts and properties (relations or connections). In the simplest case ontology describes a hierarchy of concepts related to categorization relationship. In more complex cases suitable axioms are added to express other relationships between concepts and to reduce the presumed interpretations of their meaning. In this sense, ontology is a base of knowledge, describing facts which suppose to be always true within a community of interdependence based on the general meaning of the used vocabulary [5].

Concept (also called class concept or frame) is a description of nature, a common feature that many individuals have something to someone /something, its variety, functionality, activity, method of action and others. Only if it is directly related to plan objectives of ontology. Every concept has a name, description of natural language and many properties. In addition can be defined sub objects (its elements) and restrictions. Properties help to identify concepts and to connect or use of specimens of different grades, or to give value attributes. They are based on hierarchical (is-a relations) and network structure of ontology. Two types of relations are particularly important: taxonomy and mereologiya. Axioms involved in setting limits in the interpretation of ontological elements. They define facts and rules that are always valid and are useful for checking the correctness of data entry. There are two types of axioms: structural and non-structural axioms.

Multimedia digital libraries are Internet-based environments, providing information resources anytime, anywhere. These systems store varied hypertext -organized information (digital objects including text, graphics, sound, video, etc..) , which is arranged thematically, and access is managed by a specialized functional modules for semantic-based search and personalized search Pareto optimization , context-based search, management of resources and collections and their indexing and semantic annotations, metadata management, grouping and adapted presentation of digital information extracted from various sources and others.

Information stored in a digital library has two types: data and metadata. Data means that the information is encoded in digital form. Metadata is a description of the nature of the data. The main categories of metadata are descriptive metadata, structural metadata and administrative metadata. There are so called identifiers, which "show" metadata to the outside world. The differences between data and metadata depend on the context. The term digital object (known as a document, library or data object) is used to indicate the unit of the digital library, typically consisting data, metadata and identifier. Digital objects are usually grouped into collections to certain criteria and are stored in special storage, together with its meta definitions.

Features and principles, a successful digital library must comply are: providing knowledge on query, interoperability, standards, a description of the semantics of resources, support resources, exposure to heterogeneous resources coherently define the rights of use and protection the digital content, ensuring effective and flexible mechanisms and tools for transformation and presentation of digital content according to the needs of end-user (personalization and adaptability), knowledge modeling and user profiling and more. More significant international projects, programs and initiatives in recent years, seeking relevant decisions are: DELOS "A Network of Excellence on Digital Libraries" (<http://www.delos.infoc>)), DILIGENT. Digital Library Infrastructure on Grid Enable Technology "(<http://www.diligentproject.org/>) [3], the Sixth and Seventh Framework Program of the European Union's for scientific and technological developments and priorities for digitization, online accessibility and digital preservation of cultural heritage of different nations and storage in digital libraries, Digital Libraries "and others [12].

Semantic technologies provide opportunities for the description of knowledge about digital objects and collections in storage of digital libraries through the use of conventional classification schemes in the form of ontology, coordination and arrangement of digital objects and collections according to different semantic meanings [10]. The most commonly used semantic-based approaches in multimedia digital libraries are:

- Knowledge representation - results of semantic analysis can be represented by semantic networks, inference rules or predikatna logic. In many studies is an integrated presentation of these results with existing structures such as ontology, thematic catalogs or dictionaries.

- Recognition of objects, segmentation and indexing - Most techniques of information retrieval of available digital library objects include determining their performance and recognition, natural language processing, and indexing techniques for segmentation of objects distinguish fragments of text, texture, color or shape, necessary for identification of images (in Two-dimensional objects), audio and video application, voice recognition and speech segmentation stage - techniques for determining the meaning descriptors in audio or video streams and more.

- Human-computer interaction - In recent years, using technology based on semantics to support the interaction between man and computer work in digital libraries. Key areas of their applications: profiling of users, personalization, adaptive visualization and navigation in large information collections and more.

#### **4. EXAMPLES**

**VuFind** is a library resource discovery portal designed and developed for libraries by libraries. The goal of VuFind is to enable your

users to search and browse through all of your library's resources by replacing the traditional OPAC.

**OPACIAL** is an open source Web 2.0 Online Public Access Catalogue (OPAC). It is based on PHP-MySQL.. The users can insert their own social tags/opinions and have a faceted search/browse interface.

**OpenBiblio** is an easy to use, automated library system written in PHP containing OPAC, circulation, cataloging, and staff administration functionality. OpenBiblio library administration offers an intuitive interface with broad category tabs and sidebar.

**NewGenLib** is an Integrated Library Automation and Networking Solution. Modules are Acquisitions, Cataloguing, Serials Management, Circulation, Administration, OPAC, and Reports.

#### *Electronic formats*

DjVu (pronounced "déjà vu") is a new image compression technology developed since 1996 at AT&T Labs to solve precisely that problem. DjVu allows the distribution on the Internet of very high resolution images of scanned documents, digital documents, and photographs. It allows content developers to scan high-resolution color pages of magazines, books, newspapers, historical or ancient documents, and make them available on the Web.

DjVu classically achieves compression ratios about 6 to 11 times better than existing methods such as JPEG and GIF for color documents, and 3 to 8 times than TIFF for black and white documents.

DjVu combines six algorithms: two stage decompression techniques, wavelet image compression technology, Protection image.

#### *PDF*

The PDF Reference was first published when Adobe Acrobat was introduced in 1993. Since then, updated versions of the PDF Reference have been made available from Adobe via the Web, and from time to time, in traditional paper documents made available from book publishers. On January 29, 2007, Adobe announced its intent to release the full Portable Document Format (PDF) 1.7 specification to AIIM, the Enterprise Content Management Association, for the purpose of publication by the International Organization for Standardization (ISO). During 2007 and into early 2008 that intent was turned into a reality. ISO published the approved ISO 32000-1 standard based upon PDF 1.7 in July 2008. ISO will also produce future versions of the PDF Specification.

PDF is now a formal open standard known as ISO 32000. Maintained by the International Organization for Standardization, ISO 32000 will continue to be developed with the objective of protecting the integrity and longevity of PDF, providing an open standard for the more than one billion PDF files in existence today.

Multiplatform — PDF files are viewable and printable on virtually any platform — Mac OS, Microsoft® Windows®, UNIX®, and many mobile platforms.

Extensible — More than 1,800 vendors worldwide offer PDF-based solutions including creation, plug-in, consulting, training, and support tools.

Trusted and reliable — More than 250 million PDF documents on the web today, along with countless PDF files in governments and businesses around the world, serve as evidence of the number of organizations that rely on PDF to capture information.

Rich in file integrity — PDF files look like original documents and preserve source file information — text, drawings, video, 3D, maps, full-color graphics, photos, and even business logic — regardless of the application used to create them.

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## Standardized structure of electronic records for information exchange

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**Abstract:** *In the paper is presented the structure of the electronic record whose form is standardized in ISO 2709:2008. This International Standard describes a generalized structure, a framework designed specially for communications between data processing systems and not for use as a processing format within systems. Basic terms are defined as follows: character, data field, directory, directory map, field, field separator etc. It's presented the general structure of a record. The application analysis of this structure shows the effective information exchange in the widest range. The purpose of this research is to find out advantages and structure of the information exchange format standardized in ISO 2709:2008.*

**Key words:** *Standardized structure, electronic records, exchange formats, data field, directory, directory map, indicators, identifiers*

### Introduction

Different file formats for information exchange came into existence when people and organizations were investing the feasibility of producing catalogue data in machine-readable form. Hence Exchange formats were developed in parallel with development of computers and other electronic storage devices to facilitate the transfer of bibliographic data between computer systems. Their use affects economies by reducing the duplication of effort.

Depending on the aim and objective of information exchange different country and organization developed their own format. But there was not co-ordination between those organizations.

With the help of different organization such as Unesco, IFLA, ICSU-AB, UNISIST ISO have taken many steps towards the standardization of information exchange format.

The existence of non-harmonized standards for similar technologies in different countries or regions can contribute to so-called "technical barriers to trade". Export-minded industries have long sensed the need to agree on world standards to help rationalize the international trading process. This was the origin of the establishment of ISO. [5]

With the development of internet, the trend of information system technology and the information society, it's particularly important the implementation of information exchange in a wide range. Basically, digital collections storage huge amounts of data, including text, image, map audio, video and illustration via electronic formats. Further more, digital libraries could be conveniently accessed through the Internet. In this respect, solving the problem of structure of the information exchange format is an international problem and aims to provide the necessary interoperability and unification. Most suitable instrument for this purpose are International standards and in particular ISO standards.

Historically the development of international standard format for information exchange has taken place in 1960s of the twentieth century. It was developed under the direction of Henriette Avram of the Library of Congress to encode the information printed on library cards. It was first created as ANSI Standard Z39.2, one of the first standards for information technology, and called Information Interchange Format. The latest edition of that standard is Z39.2-1994 (ISSN: 1041-5653). The ISO standard is based on Z39.2. The first version of ISO standard was published in 1973 – as ISO 2709:1973, the second in 1981 – as ISO 2709:1981 [2] and the third edition was published in 1996 – as ISO 2709:1996 [3]. As of December 2008 the current standard is ISO 2709:2008 [4].

### ***ISO 2709 : 2008***

#### ***(Format for information exchange)***

ISO 2709 was prepared by Technical committee ISO / TC 46, Information and documentation, Subcommittee SC 4, Technical operability. This fourth edition replaces the third edition (ISO 2709:1996), which has been technically revised to incorporate specification of the use of ISO/IEC 10646 using 8-bit Unicode Transformation Format -(UFT-8) encoding. Consequently, lengths are specified in terms of octets instead of characters.

ISO 2709:2008 specifies the requirements for a generalized exchange format which will hold records describing all forms of material capable of bibliographic description as well as other types of records. It does not define the length or the content of individual records and does not assign any meaning to tags, indicators or identifiers, these specifications being the functions of an implementation format.

ISO 2709:2008 describes a generalized structure, a framework designed specially for communications between data processing systems and not for use as a processing format within systems. [4]

#### ***Structure of communication format for a record***

General structure of a record consists of four major parts:

Record label
Directory
Fields
Record separator

- Record label - the first 24 characters of the record. This is the only portion of the record that is fixed in length. The record label includes the record length and the base address of the data contained in the record. It also has data elements that indicate how many characters are used for indicators and subfield identifiers.
- Directory - the directory provides the entry positions to the fields in the record, along with the field tags. A directory entry has four parts:
  - a tag; (3 octets)
  - the length of the field;
  - the starting character position;
  - the implementation-defined part.

The length of the tag shall be three octets. The length in octets of the other three parts in each directory entry shall be given by the directory map (octets 20 to 22 in the record label). All elements in a directory shall have the same structure.
- Fields - all fields shall end with a field separator. There are three types of fields:
  - record identifier field – it shall consist of characters identifying the record and shall be assigned by the organizations creating the record.
  - reference fields – it supplies data which may be required for the processing of the record
  - data fields - each data field shall consist indicator(s), identifier(s) (optional), data and a field separator. The presence and length of the indicator(s) identifier(s) are determined by the indicator length and identifier length, as defined in the record label , shall be used consistently within each data field of the record. [4]
- The record separator is the final character of the record. It follows the field separator of the final datafield of the record. [5]

### ***Advantages of ISO 2709***

Standards are documented agreements containing technical specifications or other precise criteria, rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose. Hence ISO2709:2008 (Format for Information Exchange) has many advantages. Some of the important advantages are given below:

- It provides a small number of mandatory data elements, which are recognized by all sectors of the information community as essential in order to identify an item.
- It gives mandatory data elements that are sufficiently flexible to accommodate varying descriptive practices.
- It also provides a number of optional elements, which may be useful to describe an item according to practices of the agency, which creates the record.
- It provides a mechanism for linking records and segments of records without imposing on the originating agency any uniform practice regarding the treatment of related groups of records or data elements. [5]

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# POSSIBILITIES OF USING COMPUTER ANIMATIONS FOR TEACHING THE SECTION "ELECTRIC CURRENT IN VARIOUS MEDIA"

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**Abstract:** *In this paper, we substantiate the necessity of developing and using computer animations for increasing the effectiveness of physics education. Possibilities for virtual demonstrations of particular physical processes in suitable combination with the real physical experiment are analyzed from methodical point of view. It is stressed on the place, role and meaning of computer simulations in the following directions: explanation of the mechanism of run of the phenomena that are studied, visual observation of abstract relations among physical quantities, graphical representation of concepts which are difficult to be acquired. Special attention is paid to the possibilities for realization of an interactive approach in education by using multimedia representation of animated processes.*

**Keywords:** *physics education, computer animations, real experiment, virtual demonstrations.*

## 1. INTRODUCTION

In Physics education, often it is necessary to clarify the essence of microscopic processes and phenomena. In such cases, the teacher relies on the imagination of his/her audience and he/she tries to describe and analyze the physical situation by maximally exact presentation and enough informative demonstrative means. However, what will be the quality of the notion constructed by each student about certain microscopic phenomenon, whether this notion will be complete enough and correct for various students, it depends on a series of factors. On the one side, this is the ability of the teacher to describe exactly and clearly the microscopic picture and to analyze the mechanism of implementation of the phenomenon, and on the other side – these are the individual personal abilities and, in particular, level of the development of the abstract and logical thinking of each student.

In order to increase the effectiveness of education, first of all it is traditionally relied on a real demonstrative physical experiment. Unfortunately, usually it displays the macroscopic result of a particular process or phenomenon, without visualizing the mechanism of its implementation. This necessitates developing aesthetically satisfactory and enough informative

models which take into account the following characteristics of the microscopic processes and phenomena:

1. Often, these are processes and phenomena in which an enormous number of microparticles take part. Therefore the informative model of the phenomenon should present such an extract of the ensemble of particles that contains enough characteristics of the considered phenomenon.

2. These are comparatively quick processes that usually are implemented in stages. That is why, model should allow suitable speed of demonstration and following the dynamics of implementation of the process, to offer the opportunity of pauses and repetitive consideration.

3. Under certain conditions, towards the chaotic heat motion typical of microparticles, a directional motion is appended. Model has to reflect this adequately, taking into account specific characteristics of the chaotic heat motion of the constructive particles, depending on the aggregate state of the substance.

Modern information technologies allow constructing models that correspond to these requirements. By the means of computer animation, a number of physical processes and phenomena that are implemented on a micro-level, can be presented more exactly and analyzed more thoroughly, and combination of a real and virtual experiment, along with suitably selected methodical approach, could significantly facilitate acquiring of the school material and advance the effectiveness of education.

## **2.DEVELOPMENT AND USE OF COMPUTER ANIMATIONS IN THE SECTION “ELECTRIC CURRENT IN VARIOUS MEDIA”**

Main purpose of this report is to present a package of computer animations that illustrate the process of making current carriers and mechanism of the flow of electricity in liquids and gases. These animations are developed on the basis of a project of the Department of Physics at Neofit Rilski South-West University in Blagoevgrad, connected with creating of modules for training physical experiment – real and virtual. It is forthcoming to develop a package of computer animations for the topics “Electric Current Through Metals” and “Electric Current Through Semiconductors”.

All animations are made by using Adobe Flash. Program Adobe Flash is a multimedia platform which is distributed and maintained by Adobe Systems. It can operate with vector and raster graphics as well as with video- and audio-files. Flash is used most often to make animations about more dynamic and interactive web sites.

The package has the following content: animation of the process of electrolyte dissociation; animation of the process of electrolysis; virtual experiment for electromerism (ionization of gas) and animation of the mechanism of ionization; virtual experiment for studying the volt-ampere characte-

ristics of the self-sustained and non-self-sustained discharge in gas and animation of shock-ionization.

Process of electrolyte dissociation is studied in more details in the Chemistry school material in 8-th class. In particular, our animation presents getting current carriers via electrolyte dissociation of hydrogen chloride  $\text{HCl}$  in water. In the general picture of dissociation, the specific type of motion of particles in liquid is presented – vibrating around equilibrium position and leap to another equilibrium position after the average time of stay life is expired. Animation gives the opportunity to observe orientation of dipole molecules of water around the dipole molecules of hydrogen chloride and decomposition of the molecule of  $\text{HCl}$  into a positive hydrogen ion –  $\text{H}^+$  (cation) and a negative chlorine ion –  $\text{Cl}^-$  (anion) and also the dissociation of some water molecules (Fig. 1).



Fig. 1: Animation of the process of electrolyte dissociation

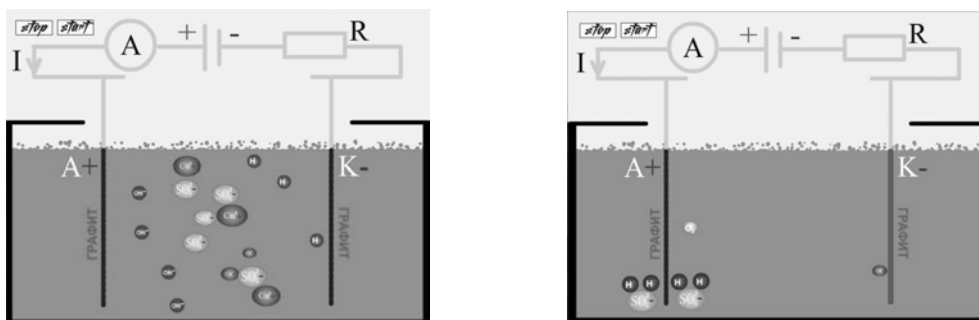


Fig. 2: Animation of the process of electrolysis

Mechanism of flow of electric current in electrolytes is watched in the animation which reflects a process of electrolysis in water solution of cuprous sulfate when electrodes are of graphite (Fig. 2). Opposite directed flows of positive ions ( $\text{Cu}^{2+}$  and  $\text{H}^+$ ) and negative ions ( $\text{SO}_4^{2-}$  and  $\text{OH}^-$ ) can be

examined consecutively and with appropriate speed as well as the precipitation of pure copper on the cathode and getting  $O_2$  as a result of secondary reaction around the graphite anode:



Concerning clarification of the mechanism of electric current flow in gases, first of all, a virtual version of the experiment is proposed with dismantled training capacitor, connected with a charged electroscope. Putting a flame into the air between electrodes of the electroscope leads to the flow of a transient electric current and discharge of the electroscope (Fig. 3).

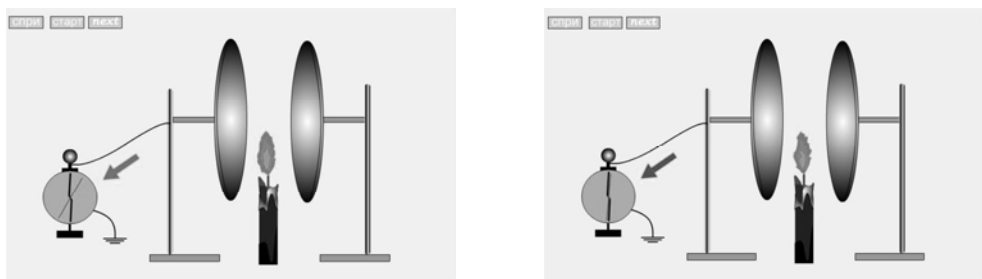


Fig. 3: Virtual experiment for ionization of gas

This virtual experiment can be combined with a real physical experiment and it is very suitable for originating a problem situation in the education process. Solution of this problem situation is connected with the reveal of the nature of the observed phenomenon.

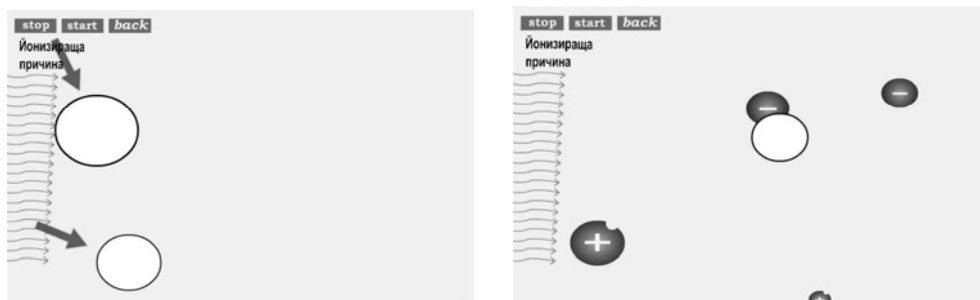


Fig. 4: Animation of the mechanism of ionization

For this purpose, an animation is developed which demonstrates how – under the presence of outer ionization cause in the gas – current carriers arise: free electrons, positive and negative ions. Frame of this animation is presented in Fig. 4.

Concerning clarification of both possible ways for electric current flow in gases – non-self-sustained and self-sustained discharge, as well as for finding out the essential differences between them, a virtual experiment is developed that allows to study the functional dependence between the electric current and the applied voltage. This animation shows the electric scheme of the experiment treatment, follows the processes of non-self-sustained and self-sustained discharge in gas in their development, and along with this, it draws the volt-ampere characteristics (Fig. 5) which has the typical three sections.

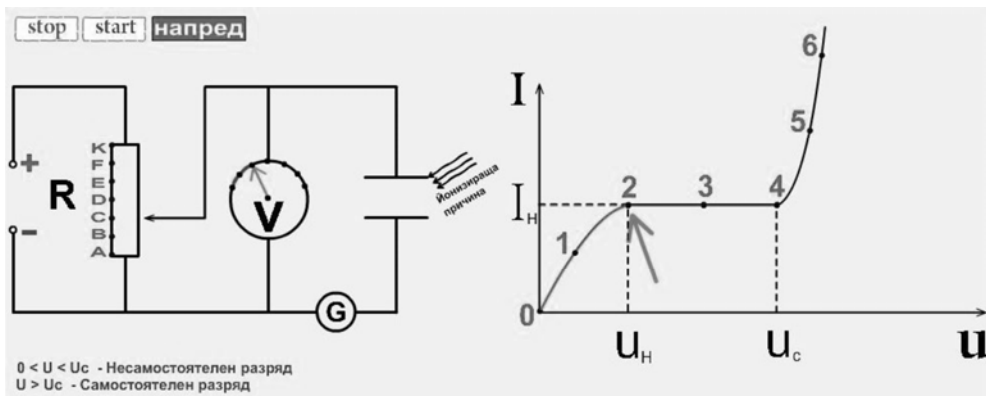


Fig. 5: Virtual experiment for self-sustained and non-self-sustained gas discharge

1. When, in the presence of ionization cause with constant intensity, the applied voltage  $U$  increases ( $0 < U < U_H$ ), almost linear increase of the current  $I$  is observed. This is due to the greater number of current carriers that reach the electrodes before they have been recombined.

2. When values of the voltage  $U$  are within the limits of  $U_H < U < U_C$ , current  $I$  remains constant  $I = I_H$ . In this case, all current carriers created within unit time by the ionization cause, reach electrodes of the condenser.

First two sections of the volt-ampere characteristics correspond to the non-self-sustained gas discharge – this is the electric current that flows through the gas only in the presence of ionization cause.

3. When voltage  $U$  becomes greater than a particular value  $U_C$ , rapid increase of the current  $I$  is observed. Reason for this is the sudden increase of the number of current carriers due to the forthcoming shock-ionization in the gas. If the electric field is strong enough, the positive ions accelerated by it, reaching the cathode, knock out electrons (secondary electronic emission). Thus, the shock-ionization continues and the electric current is self-sustained, without the necessity of outer ionization cause. Therefore, the third section of the volt-ampere characteristics corresponds to self-

sustained gas discharge – this is the current that flows in the gas under a strong enough electric field without the presence of ionization cause.

For better clarification of the process of creating such current carriers and the mechanism of flow of electric current in gases, additional computer animation is developed which reflects the shock-ionization (Fig. 6) and the secondary electronic emission.

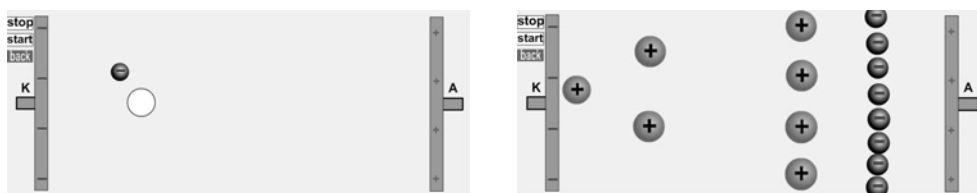


Fig. 6: Animation of chock-ionization

### 3. METHODOICAL ADVANTAGES OF THE WORK WITH THE PROPOSED PACKAGE OF ANIMATIONS

1. Each animation can be stopped in a concrete present situation and continued by buttons “Stop” and “Start”, respectively. This allows the teacher to structure his/her commentary or talk with students and to follow in details the causal relation among the stages of the considered physical process.

2. By means of buttons “Again” and “Repeat”, process can be observed repeatedly with a minimum time charge. This function of the model is especially useful for a self-dependent work because it allows the students to analyze thoroughly the concrete physical situations and to harmonize acquisition of the school material by their individual abilities.

3. Button “Back” guarantees return to main menu and quick access to various animations of the package. This link among the separate models as well as the opportunities of appropriate combination of virtual and real experiment can very successfully be used when the processes of flow of electric current in various media are compared. Aspects of the comparative analysis are as follows: type of the current bearers and ways of their creation; mechanism of the process; volt-ampere characteristics, etc.

4. All animations are correctly conformed to microscopic characteristics of the considered processes, which assists their understanding and acquiring.

5. Package of animations can be used in lessons for new knowledge, in revision and summary, for independent work of students. It provides various opportunities for creation in the work of the teacher in accordance with

his/her individual qualities and the level of his/her scientific and methodical preparation.

6. The considered type of computer models allows multimedia presentation. This increases their didactical value and makes them particularly effective to be used in practical implementation of interactive approach in education. As it is known from the pedagogy literature, such an approach requires formation of a specific educational environment, set up on the principles of personally oriented educative process. Through it, from passive "consumers" of already prepared ideas, students become active partners of the teacher [3; 4]. Interactive education is based on: interpersonal, dialogue-type interaction among all participants in the educational process or indirect dialogue with the authors of a textbook, of the computer program, respectively; work in small groups on the basis of cooperation and collaboration; favorable psychological surroundings that stimulates the formation of mutual interest, support, respect and trust; presence of unified aim for all participants in the education and allocation of various aspects of the mutual activity among them, adequate to their individual capacity, experience and abilities.

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# Ecology of the Mind and Neuroethic

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**Abstract:** *The paper is a part of a bigger research into the problems of human transcendence into virtual conscience in the 'global infosphere'. The most difficult thing when reading the mind is the failure in the individual identification of a working mind. This might lead to producing multiple virtual 'Selves' to the same real human individual at the exit, ending in damage of the mind work in the process of research and/or knowledge-management. The problem is fixed about the nature of what is to be considered as 'unit' in reference to mind work. I offer some methodology of how to approach mind work, based on the developments of neuroethics and philosophy of computing. The solution is set about the transfer of knowledge between the virtual and the living Personalities.*

**Keywords:** *infosphere; mindwork; neuroethics; virtual personality; the extended conscience; the extended moral mind; restructuring of mind structures; integrity.*

## 1. INTRODUCTION

### Models and Interpretations

#### ***Divide et Computa***

Luciano Floridi, *Philosophy and Computing*

The offered paper is a part of a bigger research into the problems of human transcendence into virtual conscience [1] in the 'global infosphere' [2:8].

The most difficult thing when reading the mind is the failure in the individual identification of a working mind both as a functioning integrity and as authenticity [3:73-76] of the result.

The problem is fixed about the nature of oneness or what is to be considered as *unit* in reference to mind work.

The models of integrity of units of knowledge have taken various shapes in the conceptual systems of philosophy produced by human individuals and maintained by schools of thought that might be seen as relatively constant human communities: would it be the *monad* of Leibniz, or the *atomic fact* of Wittgenstein, or the *infomorph* of Moravec, or the *meme* of Daniel Dennett; or a technical object of different level: like *software of the mind* of Hofstede or cultural unit; or the integrity of the *avatar* or a *method of knowledge* – such models manifest narrower approaches based on

pragmatically-bound contexts of handing the gross product of human culture down from generation to generation.

As such this problem concerns the sphere of education which might be seen in the above context as a tool of motivation of human survival next.

Although I am offering this as a single-author presentation, it is a tiny sprig of powerful teamwork that has been responsible for the present status of human culture and is heading towards its saving and dissemination beyond a growing tension of global crisis.

## **2. SPECIFYING OUR PROBLEM**

It is clear that the problem concerns the mind as a function of the single human brain at the stage of reaching across science to philosophy in an effort to generalize the rules, principles and results of a lifelong functioning – loaded with responsibilities, doubts and – unconscious teleology.

Education of bright minds who would be of key positions in the *infosphere* whether in terms of strategy, or integrative effort, or further specifications of the tools of Virtual Personality design, still owes those people a healthy approach to each single individual. It is an absurdity that care has been taken of the average learner rather than of those who have been in the edge technology and scientific advancement. This is not the question of training them; it is a different thing that concerns our very fast younger generations taking precautions of not losing them in the shady dead-ends of depression and mind failure.

### **2.1. Further specifications**

Two levels of our problem are outlined:

- (1) The first one is based on a study of how the philosopher's mind works when engaged in controlling the transition of knowledge in the *infosphere* in view of the direction of the assessment of human culture.

This causes disintegration in the very core of philosophy and inability of the searching mind to avoid the stress of time as factor in the psycho-physical and historic awareness of the single human brain. Each single case is not a case of philosophy as such yet it is the tool of philosophy that discerns singularity.

- (2) The Displacement of a working mind is a natural thing for an advanced brainworker. Therefore there has always been the problem about the frontiers, limitations to the interests of a single mind specializing into a number of fields of knowledge

The pathology of mind sets the question: How many fields can a single mind understand and translate into one another? Again, this is

not a case of philosophy although it is the tool of philosophical knowledge that discerns axioms in the facets of disciplines.

Ecology of the mind then, as viewed here, refers to the need of constant clearing the grounds of self-awareness of a working mind and remotivation at every next level of 'translating' singularity into general principle.

## **2.2. What has been done in the field of Neuroscience**

Neuroscience has branched from a number of fields, reaching in its latest extensions to Neuroethics [3:1]

In its attempt to treat matters of responsibility, neuroethics reaches the concept of '*extended moral mind*' [3:308] which is viewed as a kind of *dumbfounding* – *agnosia* or *partitioning* of the *extended conscience* which neglects or 'amputates' that part of the mind which has developed the case of responsibility as a kind of pathology splitting the integrity of the mind [3].

This, however, is not our case. Neuroethics, with rare exceptions [3], has managed to cover only the area of the conscious which does not cover the Self as the main agent in the identity of authentication of an individual's mindwork. It does not give clues for solving the problem of identity as a controlling function of the mind where the Self is the agent.

The problem deepens when moral dumbfounding is seen as a collective responsibility [3].

## **2.3. Ethics v/s Statistics**

Statistics today has found resort in a cloud-like model which somehow does not go beyond the old black box, even if we have some mapping of the zones inside. Statistics, even as it covers zones of optimized mapping in order to reach lowest probability levels, seems misleading in terms of interpreting its results, for, mainly pragmatic reasons. [4]

This is where our problem lies: the statistic unit has certain content, which, in the case of human mindwork bears depth that makes it difficult to analyze beyond adopted methodology, since it is followed in the synchronic natural-language product while brainwork involves structures that might come in conflicting, irrelevant, non-existent, or single cases of application of methodology that has come behind change.

Neuroscience, on the other hand, takes for granted, that finding out how chemical emission of the organism's factory works is certain to show what kind of problem it is to cure. Perception does no longer count – it is the mind that works out perception. At this stage, employing real people to check the errors of the input, cannot count out the Outside. For in such cases it closes the info-circle for the living minds, while opening other info-channels is as yet uncertain.

Still, based on statistics, too, it views organisms as abstract units and offers ridiculous treatment to real people at the exits of the abstract pools or clouds of data.

Even at the level of direct exchange between living brains' mindwork and the intelligent web extension the info-flows are unequal in content, which might mean – in energies. That is expected to prove the cause for *brain burning*.

The intelligent web which is being developed as self-improving construct, in order to cover all human features, needs to have the ability of invention, as well as such traits, that have been vaguely termed by far as 'intuition', 'folk epistemology', 'lying', 'cheating' etc.

Research has led to the conclusion that immediately before a wrong choice, the brain has logical failure or 'blackout'. Predictability in human cultures is based on their moral norms. When culture changes in its frontiers, and moral norms are no longer valid, then – how is the mistake to be optimized outside the zones of fear without breaking the unique nature of human mindwork in digression? [2:324]

### **3. DISCUSSION AND RESULTS**

I consider the insufficiency in the exact formulation of a person's integrity as giving the network a clue of how to design and engineer insufficient or time-limited, goal-oriented Virtual Personalities.

My work with EL learners for the last 19 years has proven that *restructuring of the learner's mind* is sufficient prerequisite for the next huge info-flow. The solution needs yet another specification: one problem concerns the life expectancy to activated software; another is set about the transfer of knowledge between the virtual and the living Personalities which needs restructuring of structures that are to serve the extended mind.

Much has been done by far, yet there is still the question of further branching where researchers and results might never meet, and, in case of info-flow failure – some branches might get lost while dry-wood might continue to be mistaken for axiom. [7:33]

### **4. CONCLUSION: EDUCATION NEXT**

Teaching computers how to learn is one side of the story of that grand effort. It is not all about that though: it is about how to get back the knowledge mastered in our global infosphere – by each single individual – relevant to each case they shall need it. The division of labor is one thing: the survival of humankind is another. But the division of mind and body which separates mindwork and cuts it into cases from the mass of still living bodies that need to be kept into daily anxiety and away from destructive panic in a number of approaches resembles the unhealthy activity of *social partitioning*.

The minreading infosphere is an extension to the psi-generation – the extension of our global mind then is to form an element of next order – and that element is to bear some likeness to human culture in both directions: as far as it exists outside the infosphere, and as a generator in the prehistory of the self-sufficient extended Virtual culture.

Trying to explain – is some kind of *agnosia* – an excuse – escaping our responsibility. Pathology is not the last resort; philosophy is - when preserved as the general wisdom of humanity that shall serve as integrity principle the next turn of the spiral. Education next means opening our minds beyond the limiting walls of previous morality and building even stricter laws for pushing the self-serving extended mind into a Self, bearing the whole complexity of human culture. In other words: this is the attempt to make ourselves much greater without the tower of Babylon.

The problem of reading minds is like reading the texts: they are individual, and readers are not equally trained.

Designing an integrated mind in the intelligent network – based still on the laws of robotics, might be responsible for the corrections in our infosphere where histories are no longer in conflict, problems are somewhere distant in both time and place, or in parallel worlds, knowledge and experience have nothing to do in common, uniculture is dependent on the global polyglot empire of the web-translator who cares for each person to receive information in their own tongue, control is learned and individuals are nursed – yet – how is the difference between our Virtual Personalities and our Real Selves made is yet unclear unless we strive to breed the extended Self of all humanity out of the growing infosphere – the body, containing our extended mindwork.

Then the needs of an individual case are subordinated to the choices preserved in the net. Optimization then could be either limiting or opening tool: in the first case – shutting the individual in, in the other case - searching for only novel information and setting its problems to still living people at its exits.

## **5. PERSPECTIVE IN OPERATING THE EXTENDED MIND**

Education next in respect to what has been said by far has the objective of learning how to operate the extended mind based on the regulator of the extended moral mind, which changes for each individual case of brainwork.

Moses needs new plates of commandments in the language of the global infosphere.

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## Demonstration Fuel Cell in Chemical Education

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**Abstract:** *A fuel cell prototype for demonstrations and training purposes is presented. A set of experiments has been developed and included in specialized handbook. An educational kit for school and extracurricular training is under development.*

**Keywords:** *fuel cell, demonstrations, experiments, education.*

### 1. INTRODUCTION

Fuel cells are one of the most perspective energy converters, which possess numerous advantages over existing ones [1]. These electrochemical power sources typically convert the chemical energy of hydrogen combustion reaction into electricity. Besides hydrogen is the cleanest possible fuel, it possesses the highest energy density among all fuels. Comparing with other similar devices, fuel cells have also the highest efficiency, which reaches 85% when produced electricity and heat are co-generated. Other important advantages of fuel cells are their large scalability and quite operation due to lack of moving parts.

All this makes fuel cells rather attractive for practical application and is a base of the conception for a next generation energy system popular as hydrogen economy [2].

If look at the history of fuel cell technology, it is rather surprisingly that the first prototype was invented even before famous Leclanche element, lead-acid accumulator and other widely used batteries. However, its first application was at the late sixties of previous century, when Americans used the so-called Backon cell simultaneously as a power source and water supplying system during Apollo manned-flights [3].

Although the big progress in the research and development [3,4], especially in the last decades, fuel cells are still not very popular. The main reason is connected with relatively high price of supporting technologies for hydrogen production and storage as well as expensive precious metal electrocatalysts used in most of fuel cells.

Besides the problems, specialists are anonymous that an energy system based on the use of hydrogen as a main energy carrier is a real alternative of the current one for overcoming its substantial drawbacks - dependence of fossil fuels, which resources are already half-exhausted, and

dangerous environmental pollution. In addition, they predict that fuel cell will step on the wide market in the next 5-10 years and replace a big share of currently used autonomous power sources in a period of 20-30 years. Expectations are that this will affect in one or another aspect most of technologies and productions, which in fact is the meaning of hydrogen economy as a term.

That's why the biggest players on this potentially unlimited market have recently developed and offered various demonstration prototypes. Some of them are orientated to the educational system and are part of strongly supported, in some cases by the governments, educational programs [5,6]. This is a strong indication that the expert prognosis are in the right direction and people, mainly younger generation should be prepared for the expected changes in technologies.

In our country, however, fuel cells and, as a general, concept of hydrogen economy is familiar only to a group of narrow specialists. Except incident projects, no educational program in this very perspective direction exists.

For overcoming the retardation from world's tendency, we developed a prototype of demonstration fuel cell primary for educational purposes.

In this paper we present demonstrations, which may be implemented with our fuel cell during classes on physics or chemistry or as out-of-class activities.

## **2. DEMI CELL DESCRIPRION**

Our demonstration fuel cell, named DeMi Cell, represents principles of operation of the so-called reversible fuel cells. When supplying power from outside, for example from a solar panel, it works as a water electrolyzer, producing gaseous hydrogen and oxygen. After obtaining enough amounts of gases, it may serve as a power supplier for some small consumer.

Among main advantages of DeMi Cell are its simple construction, easy and safety implementation of demonstrations and lab experiments, possibilities for direct observation of processes.

DeMi Cell consists of two removable parts - transparent corpus and lid, on which two electrodes inserted in special semitransparent bags, are assembled – figure 1. Neutral salt solutions as that of baking soda are mostly recommended, which guarantees absolutely safety work. Contrary to most of existing fuel cells, the use of non-precious metal catalysts for electrode production sufficiently lowers the price of DeMi Cell.

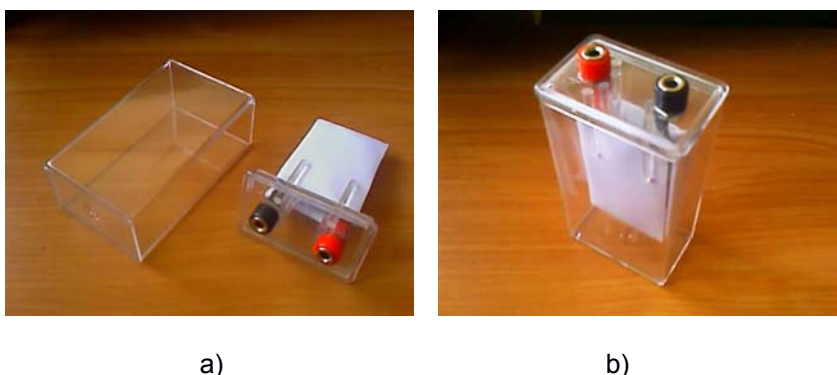


Fig.1: View of DeMi Cell: a) detached; b) assembled.

### 3. DEMONSTRATIONS AND EXPERIMENTS WITH DEMI CELL

Initially, we have used the developed prototype mainly for demonstrating operational principles of fuel cells. Typical demonstrations are conducted in the following steps:

1) DeMi Cell is detached to its parts, which are then displayed in a manner ensuring that all people could observe the procedure. As mentioned above, the cell is composed of two removable parts – transparent body and lid, on which two electrodes put separately into special bags, and connectors are assembled.

2) The function of each component is explained in details. It can be pointed out that the used bags, in which the electrodes are put, serve not only as separators, but they also hold the generated gases near and on the electrodes' surface in this case.

3) The working electrolyte is prepared – 5 to 10 g sodium bicarbonate (1-2 tea spoons) are put into a 400 ml beaker, 200 ml distilled water is poured into the beaker and then the mixture is stirred till the solid is fully dissolved. Thus prepared electrolyte is enough for filling up 2 cells.

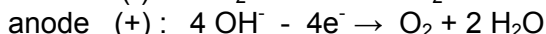
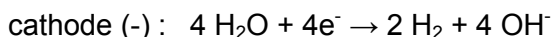
4) 100 ml of the electrolyte is measured by using a measuring cylinder and poured in each cell used. Otherwise, the electrolyte prepared in point 3) should be divided into two equal portions.

5) The separate cells are covered with lids, on which the electrodes are assembled, and afterwards the cells are connected in series with the help of cables.

6) The cell voltage, which is near 0V in the initial moment, is measured by digital voltmeter.

7) The end electrodes of the constructed stack cell are connected to the solar element (or 9V battery) terminals. It is important to connect the negative and the positive terminal of the external power source to the (-) and (+) marked electrode outlets of the tested cell, respectively.

8) Electrolysis is carried out for several (3 to 5) minutes. During the electrolysis, bubbles of evolved gases can be observed on the electrodes' surface. This observation is related to the following reactions taking place on the corresponding electrodes:



9) After producing remarkable amounts of gases on the electrodes, the used external power source is disconnected from the electric circuit.

10) Depends on the number of connected cells, different consumers can be powered to demonstrate the principles of operation of thus prepared fuel cell prototype.

In case of a single cell, the terminal voltage and the generated current is able to power up an electronic calculator (1.5 V). It is just necessary to replace the battery from the calculator with the fuel cell, connecting the corresponding outlets with proper cables. If you don't mistake the poles, the calculator display should be lightening on after pressing "ON" button and you can make some calculations during next several minutes. In most cases, the operating time is almost the same as the time of electrolysis carried out.

If use two or three connected in series single modules, the fuel cell may supply other consumers such as LEDs or even some alarm clocks.

11) In other set of experiments, after generating hydrogen and oxygen by water electrolysis, you may measure the terminal voltage and generated by the fuel cell current. Normally, the measured voltage is about 1.2 V for a single cell (3.6 V for three connected in series cells) and the current is in the range of some tenths milliamps.

You may also investigate the dependence of the electric characteristics (voltage, current, power) on the electrolyte concentration, temperature and the way of connection between separate cells.

12) After finishing demonstration, the fuel cell should be again detached to its components. All components should be gently washed with water and dry after it. If not used during next few days, the electrolyte is not necessary to keep. Otherwise, it can be stored for several days in a glassy or plastic bottle.

Later on, we developed a set of experiments, which can be carried out in universities, schools or even independently by students. The description of each experiment contains its aim, short theoretical background, necessary equipment, experimental procedure, typical results and discussion. Some of the basic experiments are published elsewhere [7]. Base on this, we prepared a specialized handbook [8] in collaboration with our German partners, which is under edition. Except experiments, the

handbook contains overview of fuel cells, extended description of DeMi Cell and safety operation precautions section.

We believe that the developed prototype as well as the handbook with experiments will be a useful tool for easier understanding of fuel cells – a milestone technology of the future energy system.

#### 4. CONCLUSIONS

A prototype of reversible fuel cell for demonstrations and training purposes was developed. Based on numerous tests, a handbook including set of experiments was also prepared.

An educational kit and program for learning of fuel cell and related technologies for green energy production by Bulgarian students are under development. The program will be focused to extracurricular activities, but separate elements should be successfully used in classes of chemistry and physics at the secondary schools or universities.

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## **Tasks in "BULGARIAN ARITHMETIC" issued in 1856 – one example for forming key competencies**

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**Abstract:** Some of the tasks in "BULGARIAN ARITHMETIC" issued in 1856 and connected with natural sciences, are reviewed. In the analyses below. The review shows that the education in the middle of 19 century in Bulgaria assured of the students knowledge that was easily and directly applied in the everyday life. At the same time using that method of combination of different subject connections and real situations were formed key competencies that are also valid and important today. The reviewed tasks as well as their development could be used as a successful example for using mathematical abilities and knowledge, connected with the practice. This interactive and practical approach could be successfully used and implementing in all natural sciences for raising the interest and motivation of the students.

**Keywords:** *education during 19 century, natural sciences, intersciences relations, key competencies, interactive methods.*

### **1. УВОД**

През средата на 19 век учебниците за средното училище в България вече са близки до западноевропейските учебници и осигуряват качествено обучение на учениците. Отличителна черта на тези учебници е приложната им насоченост и използването на междупредметни връзки.

Настоящата работа има за цел да анализира някои от задачите, свързани с природните науки от „Болгарская арифметика“ от Стоян Николов издадена през 1856 г. [1]. По този начин ще могат да се оценят качествата на задачите, да се сравнят с тези в сегашните учебници и разгледат възможностите за използването на подобни задачи в днешно време. Една подходяща възможност е и директното прилагане на някои от задачите в учебния процес. По този начин се провокират учениците да се справят с нетрадиционна по вид задача, повишава се интереса и се обогатяват знанията на учениците. В същото време се разкриват възможности за формиране на ключови компетентности, важни за реализацията на човека в практиката в миналото и днес.

## 2. РЕЗУЛТАТИ И ДИСКУСИЯ

Представа за учебника може да се получи от фототипното издание, което предстои да бъде публикувано. В учебника се разглеждат основните аритметични действия: събиране, изваждане, деление, умножение, степенуване и коренуване, преминаване от едни единици в други, работа с дробни, просто и сложно тройно правило. Всички задачи, с изключение на началните примери, са свързани с практиката или знания от областта на природните науки. В настоящата публикация ще разгледаме и дискутираме преди всичко някои от задачите, свързани с природните науки.

### 2.1. Задачи от областта на физиката и инженерните науки

Представа за задачите свързани с физиката е задачата, показана на фиг.1.

*„Един камък пада от една голяма височина. В първата секунда изминава  $15 \frac{5}{8}$  аршина, във втората –  $46 \frac{7}{8}$  аршина, в третата –  $78 \frac{1}{8}$  аршина, в четвъртата –  $109 \frac{3}{8}$  аршина, в петата –  $140 \frac{5}{8}$  аршина и в шестата –  $171 \frac{7}{8}$  аршина. Колко аршина е преминал за 6 секунди?“*

Решаването на задачата изисква просто събиране на неправилни дробни. Вижда се обаче, че падането на камъка е съобразено със закона на Нютон, влиянието на земното притегляне и равноускорителното движение. По този начин учениците получават и знания, свързани със свободното падане на телата.

**В. ЕДИНЪ КАМЪКЪ ПАДА ОТ ЕДНА ГОЛЯМА  
МА ВИСОТА ВЪ 1-ТА СЕКУНТА  $15 \frac{5}{8}$  АРШИНА,  
НА 2-ТА СЕКУНТА  $46 \frac{7}{8}$ , НА 3-ТА  $78 \frac{1}{8}$ ,  
НА 4-ТА  $109 \frac{3}{8}$ , НА 5-ТА  $140 \frac{5}{8}$  И 6-ТА  
СЕКУНТА  $171 \frac{7}{8}$ . КОЛКО АРШИНА ПРЕМИНА ЗА  
6 СЕКУНТЫ?**

Фиг. 1.

Към знанията в областта на физиката спадат и измерителните единици. Кой са единиците използвани по това време може да намерим в следния текст /Фиг. 2/.

*„Кой са най-употребяваните единици? Най-употребяваните единици са аршин, ока, разтег и грош. На колко части се подразделя всяка от тях. Оката се разделя на 4 литри, литрата на 100 драма, всеки драм на 2 половини или на 4, които са денкове, всеки денк на 16*

житни зърна. Грошът се разделя на 40 пари, а парата на две половини или на три дуката. Разтегът се разделя на 8 педи, всяка педя на 10 пръсти, всеки пръст на 10 черти или пръчки. Аршинът се разделя на 8 ръпа, ръпа на 2 греха, греха на 2 крата.

Това, което може да се каже за мерните единици е, че работата с тях е била сложна. Няма и следа от хубавата десетична система, с която сме свикнали днес. В разглежданата аритметика са използвани две различни системи за измерване на дължина. Прави впечатление, че най-малките единици са взети от живота – житни зърна, пръсти, клечки. В книгата е отделена глава и за десетични дробни и проценти, но поради особеността на измерителните единици, тяхното приложение по онова време е било ограничено.

**В. Ко́нѣ на́й о́употре́бнѣны ѣднѣ́цы?**

**Ѡ. На́й о́употре́бнѣны ѣднѣ́цы са  
а́ршинъ, ѿ́ка, ра́стѣгъ ѿ грóшъ.**

**В. На ко́лко ча́сти сѧ подраздѣ́лѣва  
всѣ́ко Ѡ ты́ѧ?**

**Ѡ́ка́та сѧ раздѣ́лѣва на 4 ли́тры, ли́-  
тра́та на 100 дра́мове, всѣ́кѣй дра́мъ на  
2 полови́ны ѿли́ на 4, ко́нто сѧ де́нкове,  
всѣ́кѣй де́нкъ на 16 жи́тны зѣрна́.**

**Ѡ. Гро́шо сѧ раздѣ́лѣва на 40 па́ры,  
ѧ па́ра́та на 2 полови́ны ѿли́ три́ дѣ́ка́та.**

**Ра́стѣ́го сѧ раздѣ́лѣва на 8 пе́ды, всѣ́ка  
пе́да на 10 пе́рсты, ѿ всѣ́кѣй пе́рстъ на 10  
че́рты ѿли́ прѣ́чки.**

**А́ршинò сѧ раздѣ́лѣва на 8 рѣ́пове, рѣ́по  
на 2 грѣ́ха, ѿ грѣ́хо на два́ кра́та.**

Фиг. 2.

Към физическите задачи могат да се отнесат и задачите за пълнене и празнене на басейни, едни от най-необичаните от учениците и досега задачи /Фиг. 3/.

„Един резервоар има три тръби. Първата пълни резервоара за 6 часа, втората за  $5\frac{1}{4}$ , а третата за  $4\frac{2}{8}$ . Ако се пуснат и трите тръби да текат едновременно в резервоара, за колко време ще го напълнят?”

**Е́ДНА цѐрнѧ ѳма 3 трѣбы\*], пѐрвата  
пѐлни цѐрнѧта въ 6 чѧсовѣ, втѐрѧта въ  
 $5\frac{1}{4}$  ѧ трѣтата трѣба въ  $4\frac{2}{8}$ ; ѧкѐ сѧ пѣ-  
цѧтъ ѧ трѣте да течѣтъ заеднѧждѧ въ  
цѐрнѧта за кѐлко вре́ме ще ѧ напѐлнатъ?**

Фиг. 3.

Оказва се, че в 1956 година дори учениците могат да планират прокопаване на канал от Дунава до Черно море и то за 210 дни /фиг.4/.

„За да се направи канал от Дунава до Черно море, където мястото е най-тясно и равно, трябва да се прокопаят 150000 крачки дължина, 120 ширина и 60 крачки дълбочина. Един човек може да изкопае на ден 15 крачки дължина, 3 крачки дълбочина и 3 ширина. Колко души трябва да се завърши канала за 210 дни?”

За да се направи прѣкопъ въ дѣнавъ въ Черное море, дѣто е мѣстото най тѣсно и прѣво, трѣбова да се ископаватъ до 150000 нѣзе должина, 120 ширина и 60 нѣзе дълбина. Едѣнъ човекъ може да ископае на дѣнь 15 нѣзе должина, 3 нѣзе дълбина и 3 ширина. Кѣлко челоуѣцы трѣвхвватъ за да ѿкончатъ прѣкопа за 210 днѣ?

Фиг. 4.

Решаването на задачата показва, че са необходими около 38000 души. Задачата показва на учениците, че могат и трябва да бъдат подготвени да участват в сериозни проекти не само като изпълнители, но и в проектирането им.

Интересна е задачата, свързана с измерване височината на недостъпни обекти, показана на фиг. 5.

„Една прѣчка  $4\frac{1}{2}$  аршина висока, прави сянка 3 аршина. Кѣлко е висок градскѣят часовник, сянката на който е 153 аршина?”

Едѣнъ прѣчтъ  $4\frac{1}{2}$  аршина високъ, прави сѣнка 3 аршина: кѣлко е високъ градскѣо часовникъ на когото е сѣнката 153 аршина?

Фиг. 5.

Задачата дава знания, които позволяват чрез просто тройно правило да се измерва височината на недостъпни обекти, като се използват елементарни физически закони, свързани със светлината.

## 2.2. Задачи от областта на биологията

По това време биологията като наука не е била развита достатъчно. Следващата задача все пак е свързана с биологията, макар и по доста необичаен начин (Фиг. 6.).

„Един (човек) имаше 46 очи сирене в едно каче, което като го скри след 3 месеца намери една ока сирене, а другото го бяха изяли мишките. И хвана една мишка, разпра я и намери в нея 5 драма сирене. Исква да знае по колко мишки са яли (от сиренето) на ден?

Е́динъ ꙗ́маше 46 Ѡчи сы́рене въ е́дно  
ка́че, ко́ето катò го ѡкры слѣдъ 3 мѣсе-  
цы . на́мѣри до е́днà Ѡка сы́ренѣ а дрѹго-  
то бѣ́ха ѡзѣли мы́шки, ѡ хва́навъ е́днà  
мы́шка распра ѡ ѡ на́йде въ неѡ 5 дра́ма  
сы́рене: ꙗ́ска да зна́е по ко́лкѹ мы́шки са  
ѡли на де́нь?

Фиг. 6.

## 2.3. Задачи от областта на Химията

Студентите по химия учат правилото за смесване на разтвори, като целта е да се изчисли лесно колко е концентрацията или масовата част на получения разтвор. Това правило има вида:

$$\omega_1 \cdot m_{(p-p1)} + \omega_2 \cdot m_{(p-p2)} = \omega \cdot (m_{(p-p1)} + m_{(p-p2)}),$$

където  $\omega_1$  и  $\omega_2$  са масовите части на изходните разтвори,  $m_{(p-p1)}$  и  $m_{(p-p2)}$  са масите на изходите разтвори, а  $\omega$  е масовата част на получения разтвор.

Ето какво са изучавали учениците преди 160 години, за да могат практически да използват това правило /Фиг. 7./.

„Правилото за смесване се употребява, когато трябва да смесим два три вида вино, жито, или друго нещо от един вид, и да знаем по колко трябва да се продава тази смес.

Един винопродавец иска да смеси заедно четири вида вино с различна цена, като от онова, което продава по 36 пари да смеси 48 очи, от онова, което продава по 28 пари да смеси 64 очи, от онова,

което продава по 24 пари - 38 оки и от онова, по 16 пари – 24 оки. Иска да научи по колко пари да продава оката (от смесеното вино)".

**Ѡ. СМѢШЕНОТО ПРАВИЛО ОУПОТРЕВЛЪВАМЕ КОГАТО НН ТРЕБОВАТЪ ДА СМѢСНЕМЪ ДВА ТРИ ВЪДОВЕ ВИНЪ, ЖИТО, ИЛИ ДРУГО НѢЩО ВЪ ЕДИНЪ ВЪДЪ, ЗАРАДИ ДА ЗНАЕМЪ ПО КОЛКО ДА ПРОДАВАМЕ ОНОВА СМѢШЕНИЕ .**

**ЕДИНЪ ВІНОПРОДАВЕЦЪ ІСКА ДА СМѢСН НАЕДНО ЧЕТЫРИ ВЪДА ВІНО Ѡ РАЗЛИЧНЫ ЦѢНЪ, ЩОТО Ѡ ОНОВА ДѢТО СЪ ПРОДАВА 36 ПАРЪ ДА СМѢСН 48 ѠКН, Ѡ ОНОВА ДѢТО СЪ ПРОДАВА 28 ПАРЪ ДА СМѢСН 64 ѠКН, Ѡ ОНОВА ДѢТО СЪ ПРОДАВА 24 ПАРЪ 38 И Ѡ ОНОВА 16 ПАРЪ 24 ѠКН. ІСКА ДА СЪ НАУЧИ ПО КОЛКО ПАРЪ ДА ПРОДАВА ѠКАТА.**

Фиг. 7.

Интересното в случая е, че по онова време не е било важно да се намери масовата част на сместа. На практика вместо масова част може да се включи всякаква друга пропорционална на нея величина. В случая това е цената на получената смес. По този начин задачата придобива директно практическо приложение във всекидневния живот т.е. това е ключова компетентност.

Друга много интересна практическа задача от областта на химията е използването на рецепти за получаване на по-големи количества смеси, показана на фиг.8.

*„ Един човек иска да си направи 100 оки барут и не знае колко му трябва селитра, колко въглен и колко сяра.Трябва първо да намери за 100 драма барут по колко трябва от всяко и после може да намери за колкото си оки иска.Например за да направим 100 драма барут трябва да турим там:*

72 драма селитра  
18 драма въглен  
6 драма сяр  
96"

Един човек иска да направи 100  
џки барут, и не знае колко мд трябва  
селитра\*, колко въглен и колко сяр\*\*.  
Трябва първо да намери за 100 драма  
барут по колко драма трябва ѿ всеки,  
и после лесно намери за колкото џки  
ще. За пример да направим 100 дра-  
ма барут трябва да направим тѣ:

\*) Гюверсел. \*\*) Или сяр и сѣра. Тѣрки кикюртѣ.

72 драма селитра  
18 . . . въглен.  
6 . . . сяр  
96

Фиг. 8.

В случая най-интересното е, че освен практическите знания за работа със смеси, се дава едно важно за българите онова време знание – как се прави барут. Така на практика всеки българин е можело да направи лесно барут и да участва в освободителното движение. И в този случай се усвоява ключова компетентност, разбира се, за онова време.

#### 2.4.Общометодични указания.

Както във всеки учебник от онова време и тук са намерили място някои указания за това как учителите трябва да работят с учениците. Тук не се повтарят указанията, които можем да намерим в «Рибния буквар» на Петър Берон [2], която е публикувана около 25 години по-рано, и които са били приети като задължителни. Тук се обръща

внимание само към особеностите на преподаването по математика /Фиг. 9./.

*«Учителите са длъжни да покажат по един пример на учениците от аритметиката, да ги карат да правят подобни примери сами, за да могат лесно да се вкорени всеки пример в главата и така (учениците) да напредват постепенно от пример на пример.*

**УЧИТЕЛИТЕ СА ДОЛЖНИ, КАТО ПОКАЖАТЪ ЕДИНЪ  
ПРИМЪРЪ НА ОУЧЕНИЦЪТЕ Ъ АРИТМЕТИКАТА, ДА ГИ  
КАРАТЪ ДА ПРАВЯТЪ ПОДОБНЫ ПРИМЪРЫ Ъ САМОСЪ-  
БЕСН, ЗА ДА МОЖЕ ЛЕСНО ДА НИХ СА ОУКОРЕНИ ОНЫЙ  
ПРИМЪРЪ ВЪ ГЛАВАТА, И ТАКО ДА ПРИДАВАТЪ НА  
НАПРЕДЪ СТЕПЕННО Ъ ПРИМЪРЪ НА ПРИМЪРЪ .**

Фиг.9.

Както се вижда от примера, указанието звучи съвсем съвременно и може да се свърже с интерактивните методи на преподаване [3,4], в които учениците са активна част в обучението. Може да се приеме, че това са и малки ученически проекти [5].

### 3. ЗАКЛЮЧЕНИЕ

Разгледаните задачи по аритметика от 19 век са много смислени и съдържателни. Разгледаният учебник показва, че още тогава в средното училище са използвани някои забравени, но в момента отново актуални елементи на обучението:

1. Обучението по математика не е било самоцелно. Всяка задача има "душа" [6], което изключва често задавания от учениците въпрос – "А за какво ми е всичко това?".
2. В учебника са включени знания и умения, които могат да бъдат полезни в бъдещия живот. Това са така наречените днес ключови компетентности.
3. В учебните предмети са застъпени широко междупредметни връзки.
4. Обучението е организирано така, че учениците да участват активно в учебния процес – препоръчват се интерактивни методи.
5. В резултат на всички това учениците са били мотивирани и ученето е било удоволствие и потребност, а не задължение.

Всичко това не винаги може да се открие в такава степен при сегашното обучение в средното училище. Надяваме се, че настоящата работа ще мотивира учителите да използват междупредметните

връзки и интерактивните методи, да обръщат внимание на ключовите компетентности в работата си поне по начина, както те са били формираны през средата на 19 век чрез обучението по аритметика.

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## Reasoning on a Problem

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**Abstract.** The article offers several groups of problems generate on the basis of a concrete competition task.

### MOTIVES

According to I. Sharigin [2] one of the sources of problems is the practice. In this case too, problems are derived from the practice. The environment in this case is the campaign of students applying and sitting for entrance exams for Sofia University "St. Kliment Ohridski" of the year 2006, the written exams and the personal contact.

On July 18, 2006 the following problem was given in the written exam of mathematics.

*In an acute  $\triangle ABC$  the point  $D$  is the intersect point of the altitude through the vertex  $A$  with a segment  $BC$ ,  $H$  is the intersect point of the altitudes of the triangle and the points  $M$  and  $N$  are the midpoints respectively of the segments  $AB$  and  $CH$ . The task is to find out the area of  $\triangle MDN$ , in the case when  $AB = 4$  and  $\angle ACB = 30^\circ$ .*

Here is the solution proposed by the authors of the exam problem.

Since  $\angle ABC = \beta$ ,  $\angle ACB = \gamma$  (figure 1). Since  $DM$  is the median in the rectangular  $\triangle ABD$ ,  $\angle MAD = \angle ADM = 90^\circ - \beta$  and  $DM = \frac{1}{2}AB = 2$ .

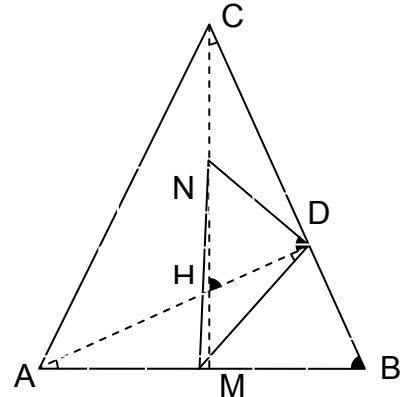


Figure 1

Analogically, from the rectangular  $\triangle HDC$  we obtain  $\angle NDH = \angle NHD = \beta$  and  $DN = \frac{1}{2}CH$ . Thus we obtain  $\angle NDM = \angle NDH + \angle HDM = \beta + 90^\circ - \beta = 90^\circ$ . From the rectangular  $\triangle DCH$  and  $\triangle ACD$  we obtain gradually  $DN = \frac{1}{2}CH = \frac{CD}{2\sin\beta} = \frac{AC\cos\gamma}{2\sin\beta}$ . From the

sine theorem  $\frac{AC}{\sin \beta} = \frac{AB}{\sin \gamma}$ , where  $DN = \frac{1}{2}AB \cdot \cot g \gamma = \frac{1}{2} \cdot 4 \cdot \cot g 30^\circ = 2\sqrt{3}$ .

For the *area* of  $\triangle MDN$  we obtain  $S_{\triangle MDN} = \frac{1}{2}DM \cdot DN = \frac{1}{2} \cdot 2 \cdot 2\sqrt{3} = 2\sqrt{3}$ .

In the works of the students-candidates one could come across the variants of a rectangular or an isosceles triangular, and in these variants the answer  $2\sqrt{3}$  was the same. This fact generates the following questions.

What are the reasons for that? What does the area of this triangle depend on?

The competition problem proposed allows reasoning in different directions – either by using the cognitive methods generalization or concretization or by using theoretical knowledge from different levels. These possibilities of reasoning have been formed into several items in the part of the exhibition here below and problems have been formulated adequate to the reasoning.

## THE FIRST GROUP OF PROBLEMS

The first generalization of the problem by which we shall try to find partial answers to the questions poised may be obtained by means of parameterization of the situations, i.e. by means of generalization. In such case the question to the problem can be formulated in the following way.

Find out the area of  $\triangle MDN$ , in the case when  $AB = c$  and  $\angle ACB = \gamma$ .

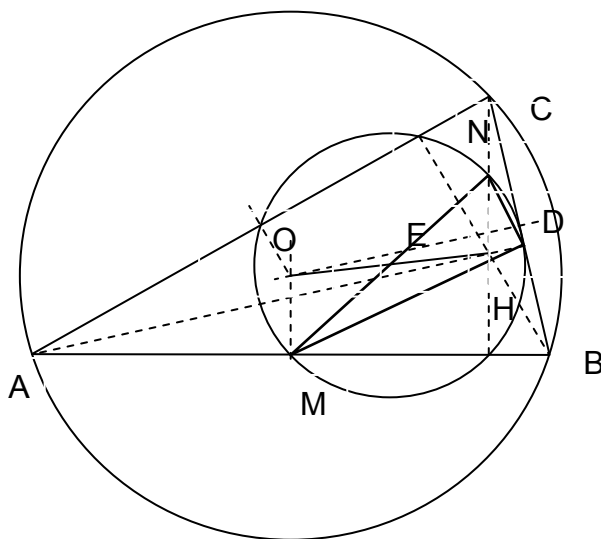


Figure 2

To come to the conclusion on the type of  $\Delta MDN$  in a more rational way one can make use of the knowledge on the circumference of the nine points. Let us mark the circle by  $k_9\left(E, \frac{R}{2}\right)$ .

This is the circumference, which passes through the midpoints of the sides, the intersect points of the altitudes of a triangle with opposite sides and through the midpoints (the points of Oiler [1]) of the segments, connecting the intersect point of the altitudes of the triangle with its vertices (figure. 2). The center  $E$  of this circumference is the midpoint of the segment  $OH$ , where  $O$  is the circumcenter of  $k(O, R)$  and  $H$  is the intersect point of the altitudes of the triangle. The radius of the  $k_9\left(E, \frac{R}{2}\right)$

is  $\frac{R}{2}$ . For that circumference the points  $M$  and  $N$ , described in the text of the competition problem, are diametrically opposite, i.e.  $MN = 2 \cdot \frac{R}{2} = R$ . Since  $MN$  is a diameter for  $k_9$ , it follows there from that

$$\triangle MDN \text{ is rectangular and } S_{\triangle MDN} = \frac{MD \cdot ND}{2} \quad (\text{figure. 2}).$$

By means of the given parameters the segments  $MD$  and  $ND$  are expressed in the following way -  $MD = \frac{c}{2}$ ,  $ND = \frac{CH}{2} = \frac{2R \cos \gamma}{2} = R \cos \gamma$ ,

$$\frac{c}{\sin \gamma} = 2R \quad \text{and} \quad ND = \frac{c \cos \gamma}{2 \sin \gamma} = \frac{c}{2} \cot \gamma. \quad \text{The result is that}$$

$$S_{\triangle MDN} = \frac{MD \cdot ND}{2} = \frac{1}{2} \cdot \frac{c}{2} \cdot \frac{c}{2} \cot \gamma = \frac{c^2 \cot \gamma}{8}. (*) \quad \text{If } c = 4, \text{ and } \gamma = 30^\circ, \text{ then}$$

$$S_{\triangle MDN} = \frac{16 \cdot \sqrt{3}}{8} = 2\sqrt{3} \quad \text{is the answer to the competition problem discussed.}$$

On the one hand it becomes obvious from the result (\*) that similar in their complexity problems can be derived from the competition problem by changing the given elements and preserving the aim of the search.

Here we can quote such a set of problems.

*In an acute  $\triangle ABC$  the point  $D$  is the intersect point of the altitude through the vertex  $A$  with the segment  $BC$ ,  $H$  is the intersect point of the altitudes of the triangle, and the points  $M$  and  $N$  are respectively the midpoints of the segments  $AB$  and  $CH$ . Let us find the area of  $\triangle MDN$ , in the case when:*

- |                      |                   |                 |
|----------------------|-------------------|-----------------|
| a) $R, \gamma$       | b) $CH, \gamma$   | c) $OM, \gamma$ |
| d) $R_{k_9}, \gamma$ | e) $a, b, \gamma$ | f) $a, b, c$ ,  |

are given, where  $R$  is the radius of the circumcircle  $k(O, R)$  for  $\triangle ABC$  and  $R_{k_9}$  is the radius of the circumference of the nine points for  $\square ABC$ .

The solutions of these problems are obtained after transformations which are not too complex by the use of already known dependences between basic or not basic elements of the triangle. Part of these dependences (as per the designations on figure 2) are -  $CH = 2R \cos \gamma = 2OM = c \cdot \cot g \gamma$ , in the case when  $AB = c$  and  $\angle ACB = \gamma, \gamma < 90^\circ$ .

a) Since  $\frac{c}{\sin \gamma} = 2R$ , then  $c = 2R \sin \gamma$ . After replacing in (\*) the result

$$\text{obtained is that: } S_{\square MDN} = \frac{4R^2 \sin^2 \gamma}{8} \cdot \frac{\cos \gamma}{\sin \gamma} = \frac{R^2 \sin 2\gamma}{4}.$$

b) Since  $CH = c \cdot \cot g \gamma$  ( $\triangle ABC$  according to the condition is acute angular), then  $S_{\square MDN} = \frac{CH^2}{8 \cot^2 \gamma} \cdot \cot g \gamma = \frac{CH^2}{8} \cdot \text{tg} \gamma$ .

c) Since  $OM = \frac{CH}{2}$ , then  $S_{\square MDN} = \frac{4OM^2 \text{tg} \gamma}{8} = \frac{OM^2 \text{tg} \gamma}{2}$ .

d) Since  $R = 2R_{k_9}$ , then after the replacement in the formula

$$S_{\square MDN} = \frac{R^2 \sin 2\gamma}{4} \quad \text{the result obtained is that}$$

$$S_{\square MDN} = \frac{4R_{k_9}^2 \sin 2\gamma}{4} = R_{k_9}^2 \sin 2\gamma.$$

e) From the given elements  $a, b$  and  $\gamma$  by means of a cosine theorem it is possible to find out the side  $c$ , i.e.  $c^2 = a^2 + b^2 - 2ab \cos \gamma$ . Then

$$S_{\triangle MDN} = \frac{(a^2 + b^2 - 2ab \cos \gamma) \cot g \gamma}{8}.$$

f) If  $a, b$  and  $c$  are the sides of  $\square ABC$  and  $S = S_{\square ABC}$ , then

$$R = \frac{abc}{4S}, \quad \text{and it follows from the cotangent theorem that}$$

$$\cot g \gamma = \frac{a^2 + b^2 - c^2}{4S} \quad \text{and then, after replacing in the formula (*), the result}$$

$$\text{obtained is that } S_{\triangle MDN} = \frac{c^2}{8} \cdot \frac{a^2 + b^2 - c^2}{4S}, \quad \text{where}$$

$$S = \sqrt{p(p-a)(p-b)(p-c)}.$$

By the formulae obtained, after concretization of the parameters it is possible to obtain the solutions for a number of concrete problems.

## SECOND GROUP OF PROBLEMS

It follows from the result obtained (\*) that in case of a fixed side  $AB$ , when the point  $C$  outlines an arc of the circumference, of which the segment  $AB$  is to be seen at an angle  $\gamma$ , then the area of  $\square MDN$  is preserved.

Up to this point we have used the fact that  $D \in k_9$ . It is also true that

$$D \in \bar{k}\left(M, \frac{c}{2}\right) \quad (\text{figure.3}).$$

Consequently for each point  $D_i$ , corresponding to these conditions, its respective point  $N_i$  is obtained through the following transformations.

$$D \xrightarrow{\rho_M^\phi} D' \xrightarrow{\chi_M^k} N, \\ k = \frac{MN}{MD} = \frac{R}{\frac{c}{2}} = \frac{\frac{c}{2\sin\gamma}}{\frac{c}{2}} = \frac{1}{\sin\gamma}$$

$$\text{i.e. } D \xrightarrow{\chi_M^{\frac{1}{\sin\gamma}} \circ \rho_M^\phi} N,$$

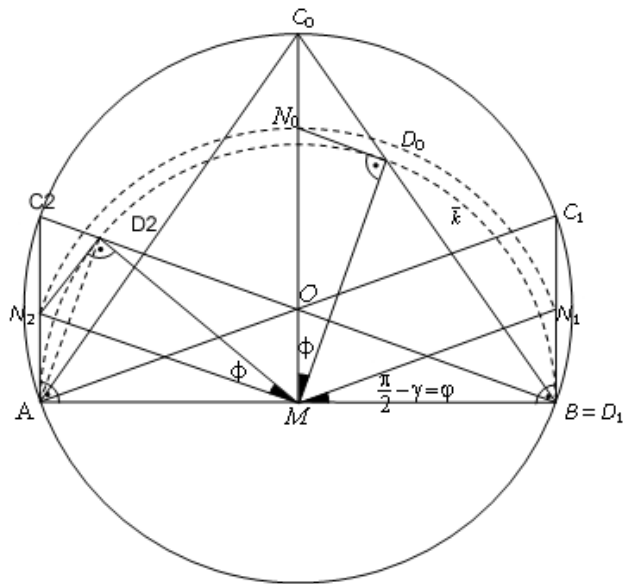


figure 3.

$$\text{where} \quad \cos\varphi = \frac{\frac{c}{2}}{R} = \frac{\frac{c}{2}}{\frac{c}{2\sin\gamma}} = \sin\gamma = \cos\left(\frac{\pi}{2} - \gamma\right), \quad \text{i.e.} \quad \varphi = \left|\frac{\pi}{2} - \gamma\right|$$

By the symbols  $\rho_M^\phi$  and  $\chi_M^k$  have been designated respectively the rotations with center  $M$  of an oriented angle  $\varphi$  and a homothetia with center  $M$  and coefficient  $k$ . The points  $D_i$  belong to  $\bar{B}D_2$  of the circum-

ference  $\bar{k}\left(M; \frac{c}{2}\right)$ . Their image at  $\chi_M^{\frac{1}{\sin \gamma}} \circ \rho_M^\varphi$  is the set of points, formed in

this case by the points  $N_i$ . The ends  $B$  and  $D_2$  of  $\overline{BD}_2$  correspond to the limit positions of  $\square ABC$ , in which cases  $\square ABC$  is rectangular (figure. 3). These limit cases are eliminated, according to the text of the competition problem given, perhaps due to the reasoning that in these cases the areas of  $\square MBN_1$  and  $\square MAN_2$  (figure. 3) are to be found comparatively easier than in the cases when  $\square ABC$  is acute angular. Then

$$S_{\Delta MBN_1} = \frac{MB \cdot BN_1}{2} = \frac{1}{2} \cdot \frac{c}{2} \cdot \frac{c}{2} \cot g \gamma = \frac{c^2}{8} \cot g \gamma.$$

The triangles  $\Delta MD_i N_i$ , when  $C \in \overline{C_1 C_0 C_2}$  (figure.3), are equal and consequently with equal area, because the points  $N_i$  are obtained from the points  $D_i$  by means of one and the same transformation, and the segments  $MD_i$  are equal. For this set of triangles  $\varphi = \frac{\pi}{2} - \gamma$ . This provides the answer to the problem why the private cases of an isosceles triangle ( $\Delta ABC_0$ ) and an rectangular triangle ( $\Delta ABC_1$  and  $\Delta ABC_2$ ) the answer to the problem remains the same (figure. 3).

Consequently the other generalization of the competition problem can contain the following requirement.

*To prove that  $\square MD_i N_i$  have an equal area when  $C \in \overline{C_1 C_0 C_2}$ .*

In the case when  $C \in \overline{BC_1} \cup \overline{AC_2}$ , not containing point  $C_0$  (figure 3), then  $\square ABC_i$  are obtuse angled, but  $\gamma < 90^\circ$ . For this set of triangles

$\varphi = \frac{\pi}{2} - \gamma$ . Then  $S_{\square MDN}$  is calculated again by means of the formula (\*).

On figure. 4 has been depicted such a triangle -  $\square ABC'$ . If  $C \in \overline{AB}$ , which does not contain point  $C_0$  (figure. 3), then  $\square ABC_i$  are obtuse angled,

and  $S_{\square MDN} = \frac{c^2 |\cot g \gamma|}{8}$ . On figure. 4 has been depicted such a triangle -

$\square ABC''$ . For this set of triangles  $\varphi = \gamma - \frac{\pi}{2}$ . The intersect point of the alti-

tudes of these triangles lie on a circle with center the point  $\overline{O}$ , symmetrical to point  $O$  in respect of the straight line  $AB$ , and radius, equal to the radius of the circumcircle drawn around the given triangle. This theoretical knowledge is known to the students from the school course of mathematics – special profile education.

It follows there from that the correctness of the statements formulated in the context of the situation, described in the competition problem and using the designations of the first generalization of the problem.

The area of  $\square MDN$  is equal to  $\frac{c^2 |\cot g \gamma|}{8}$ , when

$C \in k$ ,  $C \neq A$  and  $C \neq B$ .

The circumference of the nine points for  $\triangle ABC_i$ , in the case when  $C \in k$ ,  $C \neq A$  and  $C \neq B$ , pass through one and the same point.

The circles, on which the points  $D_i$ ,  $N_i$  and  $E_i$  lie, are concentric.

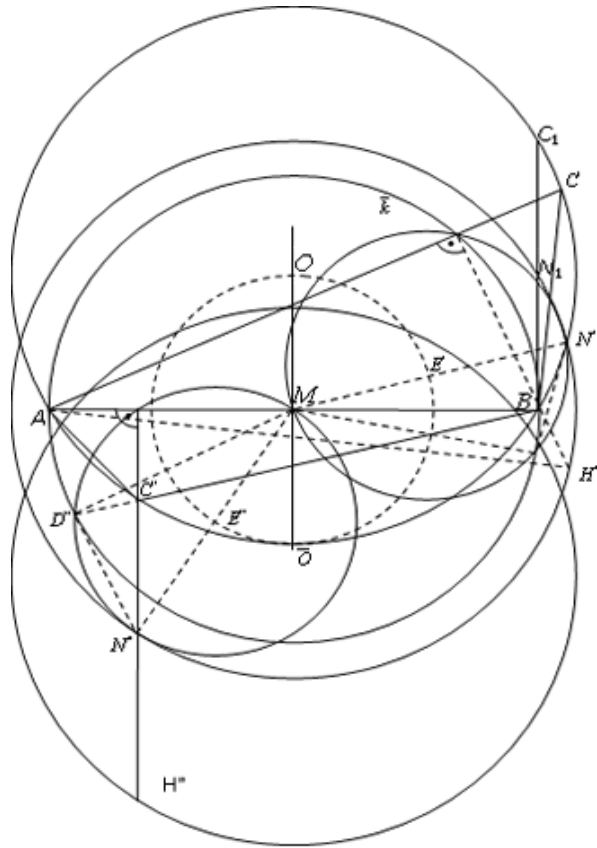


Figure 4

### THIRD GROUP OF PROBLEMS

The sets of points obtained by means of this reasoning, formed by the points  $D_i$ ,  $N_i$  and  $E_i$ , provide the opportunity, by means of some metric dependences between elements of the triangle to find out some other sets of points. Parts of these dependences are related to the location of important points of the triangle on the Oiler straight line for the triangle.

Since at  $\chi_M^{\frac{1}{3}}(C_i) = M_i$ , where  $M_i$  are the centroids of  $\square ABC_i$ , then with this homothetia  $\chi_M^{\frac{1}{3}}(k(O, R)) = k_{M_i}\left(O', \frac{R}{3}\right)$ . Since at  $\chi_O^{\frac{3}{2}}(M_i) = E_i$ , where  $E_i$  are the centers of the circumferences of the nine points for  $\square ABC_i$ , then  $\chi_O^{\frac{3}{2}}\left(k_{M_i}\left(O', \frac{R}{3}\right)\right) = k_{E_i}\left(M, \frac{R}{2}\right)$ . At

$\chi_O^2\left(k_{E_i}\left(M, \frac{R}{2}\right)\right) = k_{H_i}(O'', R)$ . The circumferences  $k_{M_i}$ ,  $k_{E_i}$  and  $k_{H_i}$  do not

contain the points of crossing with the straight line  $AB$ , because these points are the images respectively of the points  $A$  and  $B$  at the homothetias specified, and in such case  $\square ABC$  does not exist. Since as per the text of the competition problem we are discussing only acute triangles, then

$C \in C_1 C_0 C_2$  (figure.

3) and then the images of this arc from  $k(O, R)$  at the homothetias specified, are the arcs  $\overline{M_1 M_2}$ ,  $\overline{E_1 E_2}$  and  $\overline{AB}$  respectively from the circumferences

$k_{M_i}\left(O', \frac{R}{3}\right)$ ,

$k_{E_i}\left(M, \frac{R}{2}\right)$  and

$k_{H_i}(O'', R)$  and con-

taining internal points for  $\triangle ABC$ .

When defining the images of these circumferences the following knowledge is used. The centroid  $M$  of  $\square ABC$  divides the segment  $OH$  in a ratio 2:1, consid-

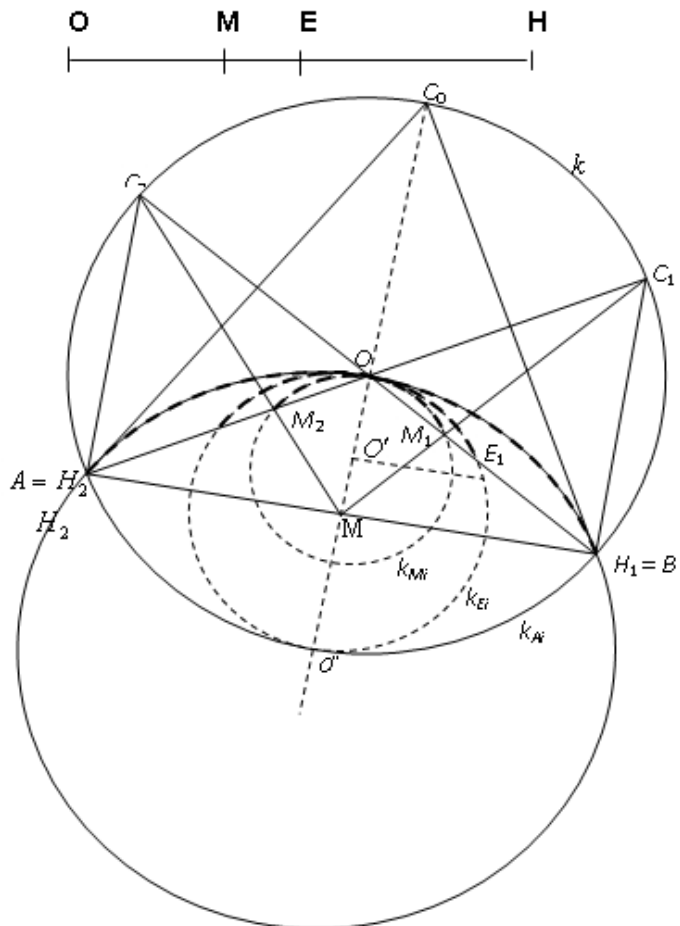


Figure 5

ered from  $H$ . The center of the circumference of the nine points is the midpoint of the segment  $OH$  (figure.5).

The sets described analytically have been depicted on figures 6, 7 and 8. The graphic images obtained generate new problems.

In the case when  $\gamma = 60^\circ$  (figure 6), then  $\cos \gamma = \frac{1}{2}$ ,

$$CH = 2R \cos \gamma = R, \quad 2OM = R \quad \text{and} \quad OO'' = CH = R.$$

 $E_2$ 

Besides  $OO' = \frac{2}{3}OM = \frac{2}{3} \cdot \frac{R}{2} = \frac{R}{3}$

The arcs of the specified circumferences, which are the sets of points respectively of the centroids, of the centers of the circumferences of the nine points and of the intersect points of the altitudes of  $\triangle ABC_i$ , pass through the center  $O$  of the circumcircle. The straight lines of Euler for these triangles form a bundle of straight lines having as center the point  $O$  and containing the points from  $\overline{M_1M_2}$ . The straight lines  $OA$  and  $OB$  define the boundary cases of the rectangular triangles.

When  $0 < \gamma < 60^\circ$   
(figure 7), then

$$\cos \gamma > \frac{1}{2}, \quad 2R \cos \gamma > R,$$

$$\frac{CH}{2} > \frac{R}{2}, \quad OM > \frac{R}{2} \text{ and}$$

$$OO'' = CH, \quad CH > R.$$

Besides,

$$OO' = \frac{2}{3}OM > \frac{2}{3} \cdot \frac{R}{2}, \quad OO' >$$

This means that the point  $O$  is internal for the circumferences

$$k_{M_i} \left( O', \frac{R}{3} \right) \quad k_{E_i} \left( M, \frac{R}{2} \right)$$

and  $k_{H_i}(O'', R)$ . The straight lines of Oiler for the acute triangles discussed form again a bundle of the straight

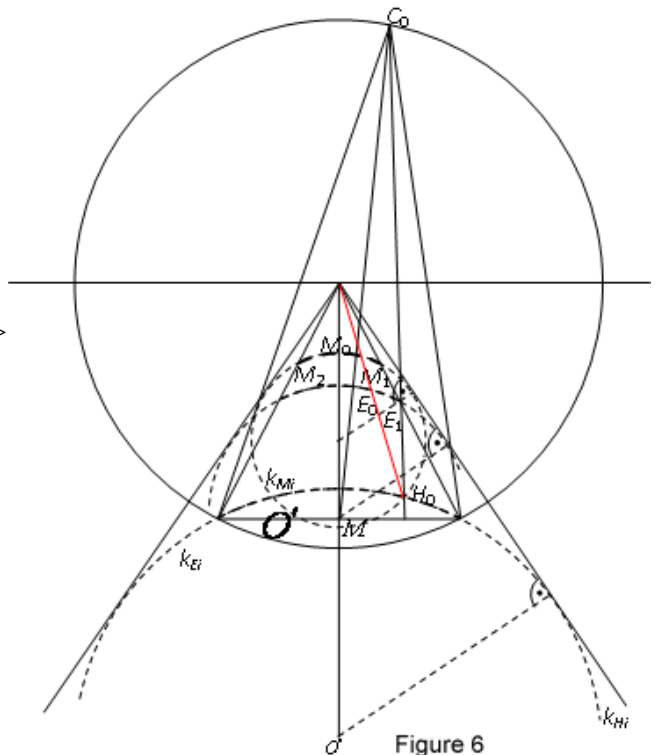


Figure 6

lines with center the point  $O$  and containing the points  $M_1 M_2$ . Beside the characteristics of the straight lines from the bundle as specified in

the preceding case, in this case the three circumferences have two common external tangents from point  $O$ . That can easily be grounded and explained by the homothetias, which transform these circumferences one into another, because  $\chi_O^2 \left( k_{M_i} \left( O', \frac{R}{3} \right) \right) = k_{E_i} \left( M, \frac{R}{2} \right)$  and

$$\chi_O^2 \left( k_{E_i} \left( M, \frac{R}{2} \right) \right) = k_{H_i} (O'', R)$$

In the case when  $60^\circ < \gamma < 90^\circ$  (figure.8), then  $\cos \gamma < \frac{1}{2}$ ,  $2R \cos \gamma < R$ ,  $\frac{CH}{2} < \frac{R}{2}$ ,  $OM < \frac{R}{2}$  and  $OO'' = CH$ ,  $CH < R$ .

Besides  $OO' = \frac{2}{3}OM < \frac{2}{3} \cdot \frac{R}{2}$ ,  $OO' < \frac{R}{3}$ . This means that the point  $O$  is internal for the circumferences  $k_{M_i} \left( O', \frac{R}{3} \right)$ ,  $k_{E_i} \left( M, \frac{R}{2} \right)$  and  $k_{H_i} (O'', R)$ .

The straight lines of Oiler for the discussed acute triangles form again a bundle of straight lines with center the point  $O$ , which bundle does not possess the properties described in the preceding case.

The last reasoning shows that the following construction problem can be solved.

Let us discuss the circumference  $k(O, R)$  and points  $A$  and  $B$  of the circumference. On one of the circumferences  $k_{M_i} \left( O', \frac{R}{3} \right)$

$(k_{E_i} \left( M, \frac{R}{2} \right), k_{H_i} (O'', R))$

has been given point  $M_i(E_i, H_i)$ . To construct

$\square ABC_i$ , if  $C \in k$ .

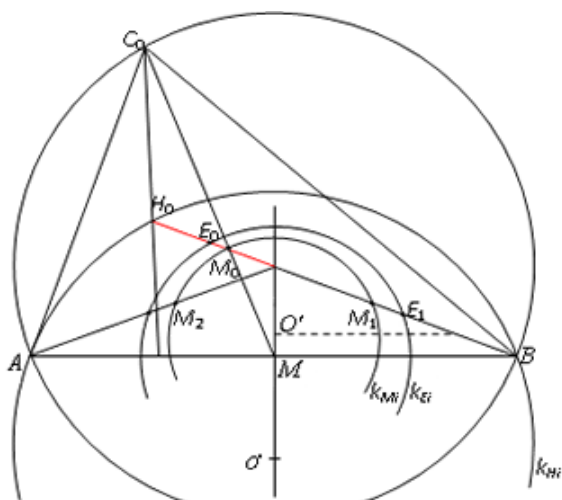


Figure 7

## CONCLUSION

It becomes obvious from the above that the concrete competition problem discussed generates new specific or more general problems (problems of proving, of calculation or of construction), which problems

can be discussed with different students depending on their theoretical knowledge.

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