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Book 5

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MEAN VALUE THEOREMS IN DISCRETE CALCULUS

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Abstract: *Discrete analogues of some basic theorems of differential calculus such as Rolle's theorem, Lagrange's and Cauchy's Theorems, L'Hospital's rule are presented and proved in the paper. The discrete Lagrange's theorem is applied to an eigenvalue problem for p - difference equations.*

Keywords*: Discrete functions, Rolle's theorem, Cauchy's theorem, Mean value theorem, finite differences, difference calculus.*

INTRODUCTION

In recent years there has been an increasing interest in calculus of finite differences and discrete boundary value problems. There are several reasons for this. The advent of high speed computers and the need of a technique for (approximate) differentiation of functions employing arithmetic operations only have led to a need for fundamental knowledge of difference calculus. The modelling of certain nonlinear problems from biological neural networks, economics, optimal control and other areas of study have led to the rapid development of the theory of difference equations (see the monographs [1], [2]).

There is a remarkable analogy of the theory of finite differences to that of differential and integral calculus and differential equations. Note, however, that quantum results hold in general for functions which are necessarily continuous unlike in discrete calculus. In view of the importance of the Mean Value Theorem (MVT) in numerical methods and theory of critical points we are going to discuss the discrete versions of the basic theorems of differential calculus, such as Rolle's theorem, Cauchy's theorem and L'Hospital's Rule. We present an application of the discrete version of the MVT to p - difference equations.

NOTATIONS AND DEFINITIONS.

We shall use the following notations: $N_0 = \{0,1,2,3...\}$ the set of natural numbers including zero, $[a,\, b] = \{a, a+1, a+2, ..., b-1, b\}$, where $a,\, b \in N_0$. Let $x(t)$ be a discrete real function of the variable $t \in N_0$. The forward difference operator Δ is defined by

$$\Delta x(t) = x(t+1) - x(t),$$

and the backward difference operator ∇ is defined by

$$\nabla x(t) = x(t) - x(t-1) = \Delta x(t-1).$$

We also define the operator $\Delta_p x(t) = \Delta \varphi_p x(t)$, where $\varphi_p(t) = t\,|\,t\,|^{p-2}$, $p > 1$. It is obvious that $\varphi_p(t)$ has the following properties:

1. $\varphi_p(t_1 t_2) = \varphi_p(t_1)\,\varphi_p(t_2)$.
2. $\varphi_p(\lambda\, t) = \varphi_p(\lambda)\,\varphi_p(t) = \begin{cases} \lambda^{p-1}\varphi_p(t), & \lambda > 0 \\ -\mu^{p-1}\varphi_p(t), & \lambda = -\mu < 0. \end{cases}$
3. $\Delta_p x(t) = \Delta \varphi_p x(t) = \varphi_p x(t+1) - \varphi_p x(t)$.

Local extrema. Discrete Analogues of the Mean Value Theorems.

Let $x(t)$ be a discrete real function defined on $[a,\, b] \subset N_0$, $a > b$ and $\{k-1,\, k,\, k+1\} \subset [a+1,\, b-1]$ be three consecutive natural numbers.

Definition 1. The number $k \in [a+1,\, b-1]$ is said to be a *critical point* of $x(t)$ if

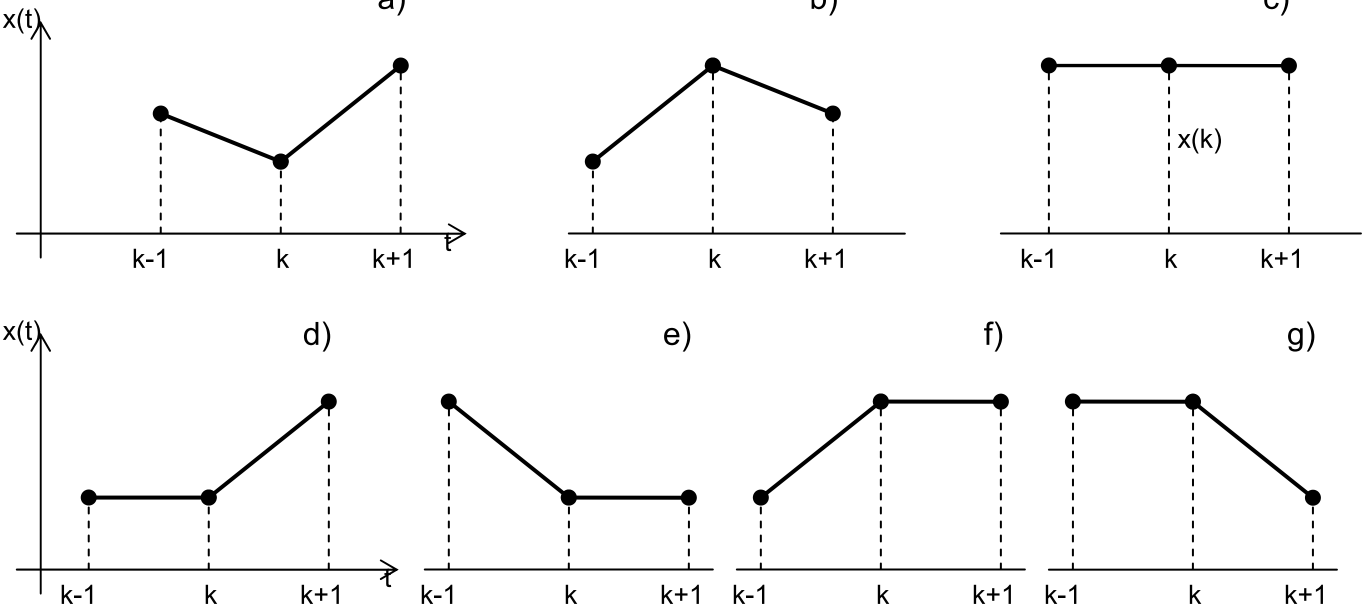
(1) $\Delta x(k)\,\Delta x(k-1) \le 0$, i.e. $\Delta x(k)\nabla x(k) \le 0$.

Definition 2. The number $k \in [k-1,\, k+1] \subset [a+1,\, b-1]$ is said to be a *local maximum (or local minimum)* of the function $x(t)$, defined on $[a,\, b] \subset N_0$ if

(2) $x(k) \ge \max\{x(k-1),\, x(k+1)\}$ (resp. $x(k) \le \min\{x(k-1),\, x(k+1)\}$).

The local maximum (local minimum) is said to be strict, if inequality (2) is strict. Hence, when k is a local extremum, which means local maximum or local minimum, inequality (1) holds, i.e. k is a critical point of $x(t)$.

Figure 1



In the case of:

- strict extremum (figure 1 - a, b), (1) holds with strict inequality;
- local minimum (figure 1 - d, e) and local maximum (figure 1 - f, g) one of the factors of (1) equals zero and in case 1-c both of them are equal to zero.

Theorem 1. Discrete analogue of Rolle's theorem. If $x(a) = x(b)$ and $x(t)$ is a scalar function defined on $[a,\, b] = \{a,\, a+1,\, a+2,\ldots,\, b-1,\, b\} \subset N_0$, then there exists a local extremum point $k \in [a+1,\, b-1]$, where $b-a \ge 2$.

Proof: Let us assume the contrary statement is true, i.e. $x(a) = x(b)$ and there exists no local extremum point $k \in [a+1,\, b-1]$. Then $\Delta x(t)\,\Delta x(t-1) > 0$ for every $t = a+1,\, a+2,\ldots,\, b-1$. Hence, any two consecutive differences have the same sign:

$$\big(x(a+2) - x(a+1)\big)\big(x(a+1) - x(a)\big) > 0,$$
$$\big(x(a+3) - x(a+2)\big)\big(x(a+2) - x(a+1)\big) > 0,$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$\big(x(b) - x(b-1)\big)\big(x(b-1) - x(b-2)\big) > 0.$$

Let $x(a+1) - x(a) > 0$.

Then

$$x(a+2) - x(a+1) > 0,$$
$$x(a+3) - x(a+2) > 0,$$
$$\ldots\ldots\ldots\ldots\ldots\ldots$$
$$x(b-1) - x(b-2) > 0,$$
$$x(b) - x(b-1) > 0.$$

Summing the above inequalities, we find $x(b)-x(a)>0$, i.e. $x(b)>x(a)$. In a similar way, in case $x(a+1)-x(a)<0$ we obtain $x(b)<x(a)$. We get a contradiction with the condition $x(a)=x(b)$ of the assumption. Thus there exists a local extremum point $k\in[a+1,\,b-1]$.□

Definition 3. The point $k\in[a+1,\,b-1]$ is said to be a *local p-extremum point* of the function $x(t),\ t\in[a,\,b]\subset N_0$ if

$$\Delta_p x(k)\,\Delta_p x(k-1)\le 0.$$

Lemma . Let $x(t)$ be a function defined on $[a,\,b]\subset N_0$. A point $k\in[a+1,\,b-1]$ is a local p-extremum point of the function if and only if k is a local extremum point of $x(t)$.

Proof. Let k be a local p-extremum point of the function $x(t)$ and the inequality $\Delta_p x(k)\,\Delta_p x(k-1)\le 0.$ holds, i.e.

$$(\varphi_p x(k+1)-\varphi_p x(k))\,(\varphi_p x(k)-\varphi_p x(k-1))\le 0.$$

Case 1: Let $\varphi_p x(k+1))-\varphi_p x(k)\ge 0$ and $\varphi_p x(k)-\varphi_p x(k-1)\le 0$. Since φ_p is a strictly increasing function it follows that $x(k+1)\ge x(k)$ and $x(k)\le x(k-1)$. Hence $\Delta x(k)\,\Delta x(k-1)\le 0$.

Case 2: $\varphi_p x(k+1))-\varphi_p x(k)\le 0$ and $\varphi_p x(k)-\varphi_p x(k-1)\ge 0$. Similarly to the first case we get $\Delta x(k)\ \Delta x(k-1)\le 0$.□

Likewise we prove the reversed statement.

Corollary 1. Let $x(t):[a,\,b]\to R$ be a discrete function and $x(a)=x(b)$. Then there exists a p-local extremum point $k\in[a+1,\,b-1]$.

Theorem 2. Mean Value Theorem (Discrete analogue of Lagrange's theorem)
Let $x(t)$ be a discrete valued function, defined on $[a,\,b]\subset N_0$. Then there exists a $k\in[a+1,\,b-1]$, such that

(3) $$\left(\Delta x(k)-\frac{x(b)-x(a)}{b-a}\right)\left(\Delta x(k-1)-\frac{x(b)-x(a)}{b-a}\right)\le 0.$$

Note, that the latter inequality implies that either

$$\Delta x(k)\ge\frac{x(b)-x(a)}{b-a}\ge\Delta x(k-1)\ \text{ or }\ \Delta x(k)\le\frac{x(b)-x(a)}{b-a}\le\Delta x(k-1).$$

Proof. Let

$$v(k)=x(k)-\frac{x(b)-x(a)}{b-a}(k-a).$$

Then $v(a)=v(b)=x(a)$. By Rolle's theorem there exists $k\in[a+1,\,b-1]$, such that $\Delta v(k)\,\Delta v(k-1)\le 0$. Hence result (3) follows.□

Corollary 2. Let $x(t)$ be a discrete function, defined on $[a,\,b]\subset N_0$ and $M=\max\{|\,\Delta x(k)\,|\}$, where $k\in[a,\,b-1]$. Then,

$$\left|\frac{x(b)-x(a)}{b-a}\right|\le M.$$

Theorem 3. Discrete analogue of Cauchy's theorem. Let $x(t),\ y(t),\ t\in[a,\,b]$ be two discrete functions, and $y(t)$ be strictly monotonous for any $t\in[a,\,b-1]$, ($\Delta y(t)>0$ for any *t* or $\Delta y(t)<0$). Then there exists $k\in[a+1,\,b-1]$, such that

$$\left(\frac{\Delta x(k)}{\Delta y(k)}-\frac{x(b)-x(a)}{y(b)-y(a)}\right)\left(\frac{\Delta x(k-1)}{\Delta y(k-1)}-\frac{x(b)-x(a)}{y(b)-y(a)}\right)\le 0, \text{ i.e.}$$

$$\frac{\Delta x(k-1)}{\Delta y(k-1)}\le\frac{x(b)-x(a)}{y(b)-y(a)}\le\frac{\Delta x(k)}{\Delta y(k)},$$

or

$$\frac{\Delta x(k-1)}{\Delta y(k-1)}\ge\frac{x(b)-x(a)}{y(b)-y(a)}\ge\frac{\Delta x(k)}{\Delta y(k)}.$$

Proof. Let us denote $A=\frac{x(b)-x(a)}{y(b)-y(a)}$ and define an additional function

$$w(t)=x(t)-A(y(t)-y(a)).$$

Then $w(a)=w(b)=x(a)$. By Rolle's theorem there exists $k\in[a+1,\ b-1]$, such that

$$\left(\Delta x(k)-A\Delta y(k)\right)\left(\Delta x(k-1)-A\Delta y(k-1)\right)\le 0.$$

Dividing both sides by $\Delta y(k)\Delta y(k-1)>0$ we get

$$\left(\frac{\Delta x(k)}{\Delta y(k)}-A\right)\left(\frac{\Delta x(k-1)}{\Delta y(k-1)}-A\right)\le 0.$$

Thus,

$$\left(\frac{\Delta x(k)}{\Delta y(k)}-\frac{x(b)-x(a)}{y(b)-y(a)}\right)\left(\frac{\Delta x(k-1)}{\Delta y(k-1)}-\frac{x(b)-x(a)}{y(b)-y(a)}\right)\le 0.$$

Theorem 4. Discrete L'Hospital's Rule.

Let $x(k),\ y(t),\ t\in[1,\infty)$ be two discrete functions, such that

$$\lim_{t\to\infty}x(t)=\lim_{t\to\infty}y(t)=0$$

and assume there exists a number n_0, such that for any $n\ge n_0$

(4) $$\Delta y(n)<0,\quad \mathrm{y}(n)>0.$$

Then, if the limit $\lim\limits_{t\to\infty}\frac{\Delta x(t)}{\Delta y(t)}=c$ exists, it follows that $c=\lim\limits_{t\to\infty}\frac{x(t)}{y(t)}$.

Proof. Let $\varepsilon>0$ and $n\in N$. Take $n_\varepsilon>n$ such that $|x(n_\varepsilon)|<\varepsilon$ and $|y(n_\varepsilon)|<\varepsilon$ $n\in N$. By Cauchy's theorem there exists $k_n\in[n+1,\ n_\varepsilon-1]$:

$$\left(\frac{\Delta x(k_n)}{\Delta y(k_n)}-\frac{x(n)-x(n_\varepsilon)}{y(n)-y(n_\varepsilon)}\right)\left(\frac{\Delta x(k_n-1)}{\Delta y(k_n-1)}-\frac{x(n)-x(n_\varepsilon)}{y(n)-y(n_\varepsilon)}\right)\le 0.$$

By $|x(n_\varepsilon)|<\varepsilon$, $|y(n_\varepsilon)|<\varepsilon$, inequalities (4) and because $k_n\to\infty$ as $n\to\infty$, we have that

$$\frac{x(n)-\varepsilon}{y(n)+\varepsilon}\le\frac{x(n)-x(n_\varepsilon)}{y(n)-y(n_\varepsilon)}\le\frac{\Delta x(k_n)}{\Delta y(k_n)}\to c,\ \text{as}\ n\to\infty.$$

Since $\varepsilon>0$ is arbitrary small, we get

(5) $$\overline{\lim_{n\to\infty}}\frac{x(n)}{y(n)}\le c.$$

Similarly,

$$\frac{x(n)+\varepsilon}{y(n)-\varepsilon}\ge\frac{x(n)-x(n_\varepsilon)}{y(n)+y(n_\varepsilon)}\ge\frac{\Delta x(k_n-1)}{\Delta y(k_n-1)}\to c,\ \text{as}\ n\to\infty.$$

Hence,

(6) $$\underline{\lim_{n\to\infty}}\frac{x(n)}{y(n)}\ge c.$$

Thus, using inequalities (5) and (6) we obtain

$$c \le \underline{\lim}_{n\to\infty} \frac{x(n)}{y(n)} \le \overline{\lim}_{n\to\infty} \frac{x(n)}{y(n)} \le c \quad \Rightarrow \quad \lim_{n\to\infty} \frac{u(n)}{v(n)} = c.$$

AN APPLICATION OF MEAN VALUE THEOREM TO p- DIFFERENCE EQUATION.

We apply the discrete version of the Mean Value Theorem to an eigenvalue problem of a p- difference equation. The second order quasilinear difference equation for $p+1$ is studied in [3].

Consider the eigenvalue problem

(7) $$\Delta\left(\varphi_p\left(\Delta x(n-1)\right)\right) + \lambda\,\varphi_p\left(\Delta x(n)\right) = 0,$$

where $a, b \in N$, $n \in [a-1, b]$, $\varphi_p(t) = t\,|t|^{p-2}$, $p > 1$.

Our main result is

Theorem 5. Suppose that $\lambda > 0$ is an eigenvalue of the difference equation (7), with the corresponding nontrivial solution $\{x(n)\}$, $x(n) > 0$ for any $n \in [a, b-1]$, and either

(a) $\Delta x(a-1) \ge 0, \quad \Delta x(a) < 0$ and $x(b-1) > 0, \quad x(b) = 0,$ or

(b) $x(a-1) = 0, \quad x(a) > 0$ and $\Delta x(b-2) > 0, \ \Delta x(b-1) \le 0.$

Then,

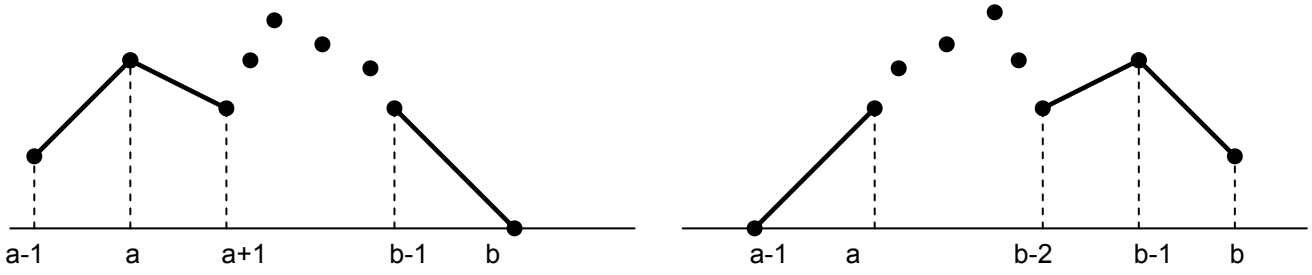
$$\lambda > \frac{1}{(b-a)^p}.$$

Proof. Suppose case (a) holds (Figure 2– a) and let

$$r = \max\{s: \ \Delta x(s-1) \ge 0, \ \Delta x(s) < 0, \ s \in [a, b-1]\}.$$

Figure 2

a) b)



Hence, $\Delta x(n-1) < 0$ for $n \in [r+1, b]$, and $x(n) \ge 0$ for any $n \in [a, b]$. Then

(8) $$\Delta\left(\varphi_p\left(\Delta x(n-1)\right)\right) = -\lambda\,\varphi_p\left(\Delta x(n)\right) \le 0.$$

Since $\Delta\left(\varphi_p\left(\Delta x(n-1)\right)\right) = \varphi_p\left(\Delta x(n)\right) - \varphi_p\left(\Delta x(n-1)\right) \le 0$, it follows that $\Delta x(n) \le \Delta x(n-1)$ or $-\Delta x(n) \ge -\Delta x(n-1)$ and the sequence $\{\Delta x(n)\}$ is non-increasing. Since $\Delta x(n-1) < 0$, $x(n)$ is decreasing for $n \in [r, b]$.

By Lagrange's theorem there exists a $k \in [r+1, b]$,

$$\frac{-x(r)}{b-r} = \frac{x(b)-x(r)}{b-r} \ge \Delta x(k-1) \ge \Delta x(b-1),$$

which implies

$$\frac{x(r)}{b-r} \le -\Delta x(b-1).$$

Therefore

(9) $$\frac{(x(r))^{p-1}}{(b-r)^{p-1}} \le \left(-\Delta x(b-1)\right)^{p-1} = -\varphi_p\left(x(b-1)\right).$$

From (8) for any $n \in [r, b]$ and $x(n) \ge 0$, we have

$$\Delta\varphi_p\left(\Delta x(r-1)\right) = -\lambda\,\varphi_p\left(x(r)\right) = -\lambda\left(x(r)\right)^{p-1}$$

.....

$$\Delta\varphi_p\left(\Delta x(b-2)\right) = -\lambda\,\varphi_p\left(x(b-1)\right) = -\lambda\left(x(b-1)\right)^{p-1}$$

Summing the equalities above we obtain

$$\varphi_p\left(\Delta x(b-1)\right) - \varphi_p\left(\Delta x(r-1)\right) = -\lambda\sum_{k=r}^{b-1}\left(x(k)\right)^{p-1}, \text{ i.e.}$$

$$\varphi_p\left(\Delta x(r-1)\right) - \varphi_p\left(\Delta x(b-1)\right) = \lambda\sum_{k=r}^{b-1}\left(x(k)\right)^{p-1}.$$

Since $\Delta x(r-1) \ge 0$ and $\varphi_p(\Delta x(r-1)) = \Delta x(r-1)\left|\Delta x(r-1)\right|^{p-2} \ge 0$, we have

$$-\varphi_p\left(\Delta x(b-1)\right) < \lambda\sum_{k=r}^{b-1}\left(x(r)\right)^{p-1} = \lambda\left(x(r)\right)^{p-1}\sum_{k=r}^{b-1}1$$

$$= \lambda\left(x(r)\right)^{p-1}(b-1-r+1)$$

$$= \lambda\left(x(r)\right)^{p-1}(b-r),$$

(10) $$-\varphi_p\left(\Delta x(b-1)\right) < \lambda\left(x(r)\right)^{p-1}(b-r).$$

Now, by (9) and (10), we get

$$\frac{\left(x(r)\right)^{p-1}}{\left(b-r\right)^{p-1}} < -\varphi_p\left(\Delta x(b-1)\right) < \lambda\left(x(r)\right)^{p-1}(b-r).$$

Thus, we conclude that

$$\frac{1}{(b-a)^p} < \frac{1}{(b-r)^p} < \lambda. \square$$

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ТЕОРЕМИ ЗА СРЕДНИТЕ СТОЙНОСТИ В ДИФЕРЕНЧНОТО СМЯТАНЕ

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Резюме: *В тази статия са представени и доказани дискретни аналози на някои основни теореми на диференциалното смятане - теоремите на Рол, Лагранж, Коши, Лопитал. Дискретният вариант на теоремата на Лагранж е приложен към задача за собствените стойности на p - диференчно уравнение.*

Ключови думи*: Дискретни функции, диференчно смятане, теорема на Рол, теорема на Коши, теореми за средните стойности.*

POLYNOMIAL IDENTITIES OF THE 2x2 MATRICES OVER THE FINITE DIMENSIONAL GRASSMANN ALGEBRA

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***Abstract**: The paper presents a survey of results obtained in the last years by different people in the field of matrix algebras over the Grassmann algebra. Some author's results concerning the Grassmann algebra and the matrix algebra over finite dimensional Grassmann algebra are presented. A conjecture in [8] appeared to be true and a proof of the corresponding theorem is given here.*

***Keywords**: Matrix algebras, Polynomial identities, Grassmann algebra.*

INTRODUCTION

Let K be a field of characteristic 0. A vector space R is called an algebra (or a $K-$algebra) if R is equipped with a binary operation "$*$" (i.e. a map $(R,R)\to R$), called a multiplication such that for any $a,b,c\in R$ and $\forall \alpha \in K$ $(a+b)*c=a*c+b*c$, $c*(a+b)=c*a+c*b$, $\alpha(a*b)=(\alpha a)*b=a*(\alpha b)$.

Usually we denote the multiplication of R by "." and write ab instead $a.b$. The notion of algebra generalizes both the notion of vector space and of ring. The algebra R is associative if $(a*b)*c=a*(b*c)$ for every $a,b,c\in R$, R is commutative if $a*b=b*a$, $a,b\in R$ and R is unitary if R has a unity e (i.e. $\exists\, e\in R:\forall\, a\in R\Rightarrow a*e=e*a=a$). For example $M_n(K)$ - the set of all $n\times n$ matrices with entries from K is an associative, noncommutative, unitary algebra.

Let V be a vector space with ordered basis $\{e_1, e_2,...\}$. The Grassmann (or Exterior) algebra $G(V)$ of V is the associative algebra, generated by the basis of V with defining relations $e_ie_j+e_je_i=0$, for all $i,j=1,2,....$

The elements $e_i\in V, i=1,2,...$ are called generators of $G(V)$. Since $e_ie_j+e_je_i=0$ and $charK=0$ we have $e_i^2=0$.

The set $B=\{1\}\cup\{e_{i_1}e_{i_2}...e_{i_m}\,|\,1\le i_1<i_2<...<i_m, m=1,2,...\}$ is the basis of $G(V)$. If a is a basic element and $1\neq a=e_{i_1}e_{i_2}\ldots e_{i_m}$, then m is called a length of a.

If V_n is a finite dimensional vector space with dimension n we denote by $G_n=G(V_n)$. $B_n=\{1, e_1, e_2, e_1e_2, e_3, e_1e_3, e_2e_3, e_1e_2e_3,...,e_1e_2...e_n\}$ is the basis of $G_n=G(V_n)$ and $\dim G_n=2^n$.

The expression $[x_1,x_2]=x_1x_2-x_2x_1$ is called commutator of x_1 and x_2.

The polynomial $s_n(x_1,x_2,...,x_n)=\sum_{\sigma\in S_n} sign(\sigma)\,x_{\sigma(1)}x_{\sigma(2)}...x_{\sigma(n)}$, where S_n is the symmetric group of degree n is called a standard polynomial.

The smallest degree of the multilinear identities, which an algebra *R* satisfies is called *PI-degree* of the algebra, denoted as $PI\deg(R)$.

POLYNOMIAL IDENTITIES

For the matrix algebra $M_n(K)$ basic results are the Cayley-Hamilton theorem and the famous Amitsur-Levitzki theorem. Amitsur and Levitzki [1] proved that in the matrix algebra $M_n(K)$ of order n over a field K the standard identity of degree $2n$ holds, i.e. $s_{2n}(x_1, x_2, ..., x_{2n}) = 0.$

Krakowski and Regev proved in 1973 the following

Proposition 1 [6, Corollary, p.437] *The T-ideal T(G) is generated by the identity* $[[x_1, x_2], x_3] = [x_1, x_2, x_3] = 0.$

For the algebra $G_n = G(V_n)$ holds

Proposition 2 [5, Exercise 5.3] *For* $G_n = G(V_n)$ *over* n*-dimensional vector space* V_n, $n > 1$, *all identities follow from the identity* $[x_1, x_2, x_3] = 0$ *and the standard identity* $s_{2p}(x_1, x_2, ..., x_{2p}) = 0$, *where* p *is the minimal integer with* $2p > n.$

Berele and Regev proved

Proposition 3 [3, Lemma 6.1] *The algebra* $G(V)$ *satisfies the identity* $(s_n(x_1, x_2, ..., x_n))^k = 0$ *for all* $n, k > 1.$

Proposition 4 [3, Lemma 3.2, p.123] *Let* R *be an algebra with* $PI\deg(R) = r$, *then* $PI\deg(M_n(R)) \geq nr$. *In particular,* $PI\deg(M_n(G)) \geq 3n.$

Proposition 5 [2, Lemma, p.1509] *The algebra* $M_n(G)$ *satisfies the identity* s_{2n}^k *for some* $k > 1$ *but satisfies neither* s_{2n} *nor identities of the form* s_m^k *for any* k *when* $m < 2n.$

A connection between the identities in $M_n(K)$ and $M_n(G)$ is given by M. Domokos and A. Popov.

Proposition 6 [4, Proposition 2.1, p.13] *Let* $f_1, \ldots, f_d \in K\langle x_1, \ldots x_m \rangle$ *be elements of the T-ideal of identities of* M_n. *If* $d > \frac{1}{2}n^2 m$, *then* $f_1 \ldots f_d = 0$ *is an identity on* $M_n(G).$

The above Proposition 6 has an analogue for the upper triangular matrices U_n [12].

A. Popov sets a more precise estimation of $PI\deg(M_n(G))$.

Proposition 7 [11, The main Theorem] *Let* $M_n(G)$ *be the matrix algebra of order* n *over the (infinite dimensional) Grassmann algebra. Then* $M_n(G)$ *has no identities of degree* $4n-2.$

USING *MATHEMATICA* TO OBTAIN IDENTITES IN THE MATRIX ALGEBRA OVER THE FINITE DIMENSIONAL GRASSMANN ALGEBRA

The elements of the Grassmann algebra are called *grassmann numbers*. A grassmann number containing only monomials with even length is called an *even grassmann number*, and a grassmann number containing only monomials with odd length is called an *odd grassmann number.*

Ts. Rashkova and A. Mihova find a correspondence [10] between the integers from 0 to $2^n - 1$ and the basic elements of the Grassmann algebra over a *n*-dimensional vector space.

Let i be an integer, $0 \le i \le 2^n - 1$ and $i = \alpha_1 \alpha_2 \dots \alpha_{n(2)}$ for $\alpha_i \in \{0,1\}, i = 1, 2, \dots, n$ be its binary representation. To each i is juxtaposed the basic element $e_1^{\alpha_n} e_2^{\alpha_{n-1}} \dots e_{n-1}^{\alpha_2} e_n^{\alpha_1}$.

Then any grassmann number $x \in G_n = G(V_n)$ can be express in the form:

$$x = a_0 + a_1 e_1 + a_2 e_2 + a_3 e_1 e_2 + a_4 e_3 + a_5 e_1 e_3 + a_6 e_2 e_3 + a_7 e_1 e_2 e_3 + \dots + a_{2^n - 1} e_1 e_2 \dots e_n,$$

$a_i \in K, i = 0,1,\dots, 2^n - 1.$

The formulated correspondence gives the possibility to work mainly with the indices of coefficients.

Using the above described correspondence two programs in *Mathematica* are done - one for multiplication of grassmann numbers [10] and another one for multiplication of 2×2 matrices with entries from a finite Grassmann algebra [9]. For a guide book in the system *Mathematica* we consider [15].

These two programs are used to verify identities related to the standard polynomial for the matrix algebra over finite dimensional Grassmann algebras. Some identities are verified for small *n*. Based on the obtained results the next propositions are formulated.

Let $M_k(G)$ be the matrix algebra of order k with entries from G. We denote by $M_2(G_n^0)$ the set of 2×2 matrices with entries even grassmann numbers and by $M_2(G_n^1)$ the set of 2×2 matrices with entries odd grassmann numbers from a finite Grassmann algebra G_n.

Proposition 9 [7, Proposition 5, p.19] $s_4(x_1, x_2, x_3, x_4) = 0$ *is an identity on* $M_2(G_n^0)$.

Proposition 10 [7, Proposition 6, p.19] $s_{n+1}(x_1, \dots, x_{n+1}) = 0$ *is an identity on* $M_2(G_n^1)$.

The following theorem was formulated as a conjecture in [8]. Here we give the proof.

Theorem 1 The algebra $M_2(G_n)$ satisfies the identity $s_4(x_1, x_2, x_3, x_4)^p = 0$, where p is the minimal integer with $2p > n$.

Proof. Let $X = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$ be a matrix with entries from $G_n = G(V_n)$ and

$$a = a_0 + a_1 e_1 + a_2 e_2 + a_3 e_1 e_2 + a_4 e_3 + \dots + a_{2^n - 1} e_1 e_2 \dots e_n,$$
$$b = b_0 + b_1 e_1 + b_2 e_2 + b_3 e_1 e_2 + b_4 e_3 + \dots + b_{2^n - 1} e_1 e_2 \dots e_n,$$
$$c = c_0 + c_1 e_1 + c_2 e_2 + c_3 e_1 e_2 + c_4 e_3 + \dots + c_{2^n - 1} e_1 e_2 \dots e_n,$$
$$d = d_0 + d_1 e_1 + d_2 e_2 + d_3 e_1 e_2 + d_4 e_3 + \dots + d_{2^n - 1} e_1 e_2 \dots e_n,$$

$a_i, b_i, c_i, d_i \in K$, $i = 0,1,\dots, 2^n - 1.$

We can express X as follows

$$X = \begin{pmatrix} a_0 & b_0 \\ c_0 & d_0 \end{pmatrix} + \begin{pmatrix} a_1 & b_1 \\ c_1 & d_1 \end{pmatrix} e_1 + \begin{pmatrix} a_2 & b_2 \\ c_2 & d_2 \end{pmatrix} e_2 + \begin{pmatrix} a_3 & b_3 \\ c_3 & d_3 \end{pmatrix} e_1 e_2 +$$

$$+\begin{pmatrix} a_4 & b_4 \\ c_4 & d_4 \end{pmatrix}e_3+\cdots+\begin{pmatrix} a_{2^{n-1}} & b_{2^{n-1}} \\ c_{2^{n-1}} & d_{2^{n-1}} \end{pmatrix}e_n+\cdots+\begin{pmatrix} a_{2^n-1} & b_{2^n-1} \\ c_{2^n-1} & d_{2^n-1} \end{pmatrix}e_1e_2\ldots e_n.$$

Let denote the matrix $\begin{pmatrix} a_i & b_i \\ c_i & d_i \end{pmatrix}$ by X_i, $i=0,1,\ldots,2^n-1$. Then

$$X=X_0+X_1e_1+X_2e_2+X_3e_1e_2+X_4e_3+\cdots+X_{2^{n-1}}e_n+\cdots+X_{2^n-1}e_1e_2\ldots e_n.$$

We consider the matrices XJ and XJ_k for $J=1,2,3,4$ and $k=1,\ldots,2^n-1$, namely

$$XJ=XJ_0+XJ_1e_1+XJ_2e_2+XJ_3e_1e_2+XJ_4e_3+\cdots+XJ_{2^{n-1}}e_n+\cdots+XJ_{2^n-1}e_1e_2\ldots e_n.$$

Using the multilinearity of the standard polynomial we transform it as:

$$\begin{aligned}
&s_4(X1,X2,X3,X4)=\\
&s_4(X1_0+X1_1e_1+X1_2e_2+X1_3e_1e_2+X1_4e_3+\cdots+X1_{2^n-1}e_1e_2\ldots e_n,\\
&\quad X2_0+X2_1e_1+X2_2e_2+X2_3e_1e_2+X2_4e_3+\cdots+X2_{2^n-1}e_1e_2\ldots e_n,\\
&\quad X3_0+X3_1e_1+X3_2e_2+X3_3e_1e_2+X3_4e_3+\cdots+X3_{2^n-1}e_1e_2\ldots e_n,\\
&\quad X4_0+X4_1e_1+X4_2e_2+X4_3e_1e_2+X4_4e_3+\cdots+X4_{2^n-1}e_1e_2\ldots e_n)=\\
&s_4(X1_0,X2_0,X3_0,X4_0)+\\
&+s_4(X1_1e_1,X2_0,X3_0,X4_0)+s_4(X1_0,X2_1e_1,X3_0,X4_0)+\\
&+s_4(X1_0,X2_0,X3_1e_1,X4_0)+s_4(X1_0,X2_0,X3_0,X4_1e_1)+\\
&+s_4(X1_2e_2,X2_0,X3_0,X4_0)+s_4(X1_0,X2_2e_2,X3_0,X4_0)+\\
&+s_4(X1_0,X2_0,X3_2e_2,X4_0)+s_4(X1_0,X2_0,X3_0,X4_2e_2)+\cdots\\
&\cdots+s_4(X1_{2^{n-1}}e_n,X2_0,X3_0,X4_0)+s_4(X1_0,X2_{2^{n-1}}e_n,X3_0,X4_0)+\\
&+s_4(X1_0,X2_0,X3_{2^{n-1}}e_n,X4_0)+s_4(X1_0,X2_0,X3_0,X4_{2^{n-1}}e_n)+S=\\
&s_4(X1_0,X2_0,X3_0,X4_0)+\\
&+s_4(X1_1,X2_0,X3_0,X4_0)e_1+s_4(X1_0,X2_1,X3_0,X4_0)e_1+\\
&+s_4(X1_0,X2_0,X3_1,X4_0)e_1+s_4(X1_0,X2_0,X3_0,X4_1)e_1+\\
&+s_4(X1_2,X2_0,X3_0,X4_0)e_2+s_4(X1_0,X2_2,X3_0,X4_0)e_2+\\
&+s_4(X1_0,X2_0,X3_2,X4_0)e_2+s_4(X1_0,X2_0,X3_0,X4_2)e_2+\cdots\\
&\cdots+s_4(X1_{2^{n-1}}X2_0,X3_0,X4_0)e_n+s_4(X1_0,X2_{2^{n-1}},X3_0,X4_0)e_n+\\
&+s_4(X1_0,X2_0,X3_{2^{n-1}},X4_0)e_n+s_4(X1_0,X2_0,X3_0,X4_{2^{n-1}})e_n+S.
\end{aligned}$$

We denoted by S the sum of the other summands which are products of matrices with entries from K and the basic elements e_1e_2, e_1e_3, e_2e_3, $e_1e_2e_3$,...,$e_1e_2\ldots e_n$.

Since $XJ_0, XJ_1, XJ_2, \ldots, XJ_{2^n-1}$ for $J=1, 2, 3, 4$ are matrices with entries from K, applying Amitsur-Levitzki theorem we obtain that

$$s_4(X1_0, X2_0, X3_0, X4_0) = s_4(X1_1, X2_0, X3_0, X4_0) =$$
$$s_4(X1_0, X2_1, X3_0, X4_0) = s_4(X1_0, X2_0, X3_1, X4_0) =$$
$$s_4(X1_0, X2_0, X3_0, X4_1) = s_4(X1_2, X2_0, X3_0, X4_0) =$$
$$s_4(X1_0, X2_2, X3_0, X4_0) = s_4(X1_0, X2_0, X3_2, X4_0) =$$
$$s_4(X1_0, X2_0, X3_0, X4_2) = \cdots = s_4(X1_{2^{n-1}}, X2_0, X3_0, X4_0) =$$
$$s_4(X1_0, X2_{2^{n-1}}, X3_0, X4_0) = s_4(X1_0, X2_0, X3_{2^{n-1}}, X4_0) =$$
$$s_4(X1_0, X2_0, X3_0, X4_{2^{n-1}}) = 0.$$

Hence $s_4(X1, X2, X3, X4) = S$. Then for $2p > n$ we form $s_4^p = S^p$. As the summands of S are of length ≥ 2 then S^p is a sum of monomials with length $\geq 2p$ multiplied by matrices. Since $2p > n$ then each monomial in s_4^p contains at least one repeated generator. Hence $s_4^p = 0$. This completes the proof of the theorem.

Vishne described in [14] an efficient way to use the $Sym(n)$ -module structure of the ideal of multilinear identities in the computation for a given algebra of such identities of degree n. The method was applied to be shown that the algebra $M_2(G)$ has identities of degree 8, but of no smaller degree.

An explicit form of the Vishne identities is given in [13] and identities are verified in $M_2(G_n)$ for small *n*.

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ПОЛИНОМНИ ТЪЖДЕСТВА В МАТРИЧНАТА АЛГЕБРА ОТ ВТОРИ РЕД НАД КРАЙНОМЕРНА ГРАСМАНОВА АЛГЕБРА

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***Резюме**: В статията е направен обзор на резултатите, получени през последните години в областта на матричната алгебра над Грасманова алгебра. Представени са резултати, които се отнасят за Грасмановата алгебра и за матричната алгебра над крайномерна Грасманова алгебра. Доказана е теорема, която е формулирана като хипотеза в [8].*

***Ключови думи**: Матрична алгебра, Полиномни тъждества, Грасманова алгебра.*

ANALYSIS OF THE IMPACT OF THE INCOMING CALLS FLOW INTENSITY ON SOME BASIC CHARACTERISTICS OF AN EMERGENCY AID CENTRE

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Abstract: *The emergency aid centre in Ruse is modelled as a queuing system with an unlimited number of places in the system queue. The influence of the incoming calls flow intensity on some major characteristics of the system is examined. The paper reaches some conclusions about the number of emergency teams needed in order to provide prompt emergency service for the patients at a definite intensity of the incoming calls flow. The results of the simulation of priority service of incoming calls are analysed and the respective conclusions are made.*

Keywords: *Mathematical Modelling, Queuing Theory, Emergency Medical Care, Priority Service.*

The development of technically feasible and socially effective systems of medical service, which form the basis of public health care, is a very suitable medium for the application of the investigation of operations methods. A great number of problems which come up in these cases can be solved with the help of analytical methods; the efficiency of these methods depends on the researcher's ability to form a good enough mathematical model which takes into account as many factors as possible and describes the system as comprehensively as possible.

The paper examines an emergency aid centre (EAC) where the intensity of incoming calls is λ calls per hour. The medical team and the ambulance car accept a new call when they get back to the coordination centre or immediately after they have attended to the previous call [7]. The observations and the analysis of the performance of the EAC in Ruse show that the average time needed to provide the medical service for each call is 28 minutes, i.e. the intensity of the service flow is $\mu = 2.14$ calls per hour and the EAC uses *n*=8 ambulance cars (and the same number of medical teams).

EAC is examined as a queuing system (QS) with an unlimited number of places in the system queue [2]. The transport-medical teams are interchangeable. In order to establish a steady working mode which can guarantee that all patients (incoming calls) in the system will get proper service, the value $\frac{\rho}{n}$, where $\rho = \frac{\lambda}{\mu}$, should be less than 1 [10]. This is a necessary requirement to limit the queue of waiting patients. When $\frac{\rho}{n}$>1 such a mode does not exist.

The graph of the states of the system is shown in fig.1 [1].

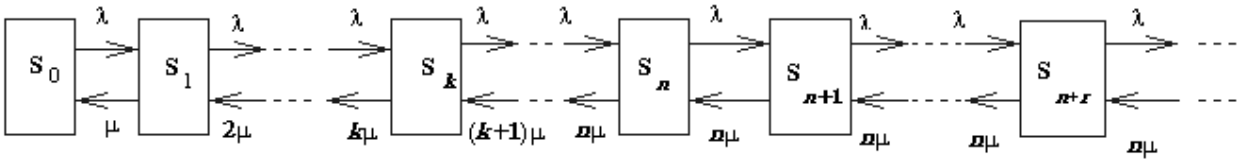

Fig.1 Graph of the states of the system

The separate states correspond to the following meanings:

S_0 - all teams are free;

S_1 - one team is busy, the rest are free;

…….

S_n - all *n* teams are busy, but there is no queue;

S_{n+1} - all *n* teams are busy and one incoming call is waiting in the queue;

…….

S_{n+r} - all *n* teams are busy and *r* incoming calls are waiting in the queue.

In [10] it has been proved that the condition for the final probabilities to exist is expressed with $\frac{\rho}{n}<1$. Then the final probabilities are determined according to the Erlang formulae [3]:

(1) $$P_0=\left[1+\frac{\rho}{1!}+\frac{\rho^2}{2!}+\frac{\rho^3}{3!}+...+\frac{\rho^n}{n!}+\frac{\rho^{n+1}}{n!*(n-\rho)}\right]^{-1}$$

……..

(2) $$P_k=\frac{\rho^k}{k!}*P_0,\ k=1,2,\ldots,n;$$

…….

(3) $$P_{n+r}=\frac{\rho^{n+r}}{n^r*n!}*P_0,\ r=1,2,\ldots.$$

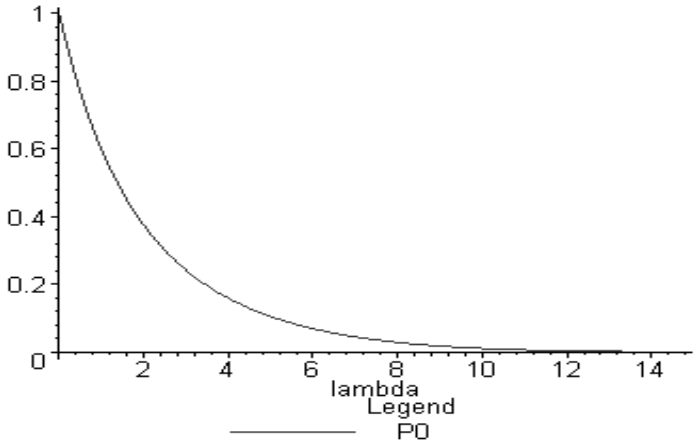

Fig. 2. Dependence of P_0 on λ

Fig. 2 illustrates that when the intensity of the incoming calls flow goes up the probability for the system to have no waiting calls goes down. When the value of λ reaches ten, this probability approaches zero.

The parameters expressing the system's load can be calculated according to the following formulae [8]:

- average length of the queue

(4) $$L_0=\frac{\rho^{n+1}}{n*n!*\left(1-\frac{\rho}{n}\right)^2};$$

- average number of patients in the system

(5) $$L_c=L_0+\rho;$$

- average time the incoming call spends in the system's queue

(6) $W_0 = \frac{L_0}{\lambda}$;

- average time the incoming call spends in the system

(7) $W_c = \frac{L_c}{\lambda}$.

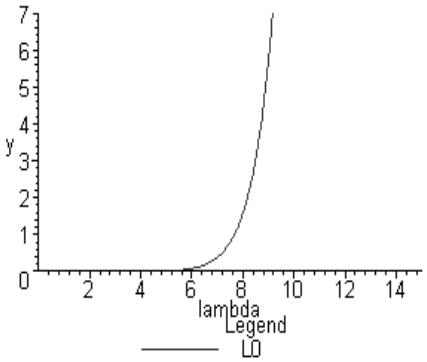

Fig. 3. Dependence of L_0 on λ

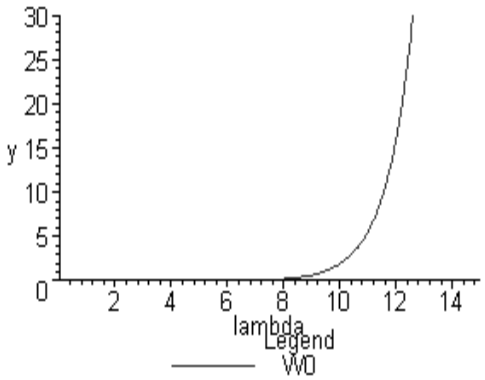

Fig. 4. Dependence of W_0 on λ

Fig.3 demonstrates that when the incoming calls flow intensity reaches the value of 8, the length of the waiting patients queue begins to grow unrestrictedly; this means that the available number of 8 teams is not enough to respond to the incoming calls of this level of intensity and therefore, it is necessary to ask other emergency medical centres for assistance. Such uncontrollably great number of incoming calls for the existing EAC may become a fact at times of traffic accidents, natural adversities or industrial disasters [4].

The dependence of the time each call spends in the system queue as a function of the incoming calls intensity is analogical (fig. 4).

So, the conclusion is that the ambulance cars available at the EAC in Ruse are not enough to provide adequate emergency medical service when the number of incoming calls reaches 8 or more per hour. It is necessary to buy more vehicles or to ask the nearest emergency centres for help. If there is a chance increase in the incoming calls flow intensity, assistance from the nearest emergency aid centres is necessary. However, if the increase in the incoming calls flow intensity is a permanent tendency, new ambulance cars should be purchased.

The present paper deals with the influence of the incoming calls flow intensity on some characteristics of the system when it accepts priority emergency medical service.

In some countries in the world, health services are provided according to the rank or income of the citizens – those with higher rank or higher income are provided with different services from the citizens with lower rank or lower income. The paper examines a case with two levels of priority, and when the priority service does not interrupt the realization of the current emergency medical call.

It is assumed that the incoming calls flow is a Poisson stream, and the service time for each of the *m*-number of queues of waiting patients (depending on the chosen number of priorities) is distributed according to a random law. $M_k[t]$ and $D_k[t]$ respectively, denote the mathematical expectation and the variance for the *k*-team, and λ_k denotes the intensity of the incoming calls flow for the same team.

The influence of the intensity of the incoming calls flow on the basic characteristics of the system is studied. With one team providing the emergency service, their values are determined by the following dependencies [9]:

$W_0^{(k)}$ - average time the patient spends waiting in the *κ*-team queue

(8) $$W_0^{(k)} = \frac{\sum_{i=1}^{m} \lambda_i * (M_k^2[t] + D_k[t])}{2*(1-S_{k-1})*(1-S_k)};$$

$W_c^{(k)}$ - average time the patient spends with the system's *κ*-team

(9) $$W_c^{(k)} = W_0^{(k)} + M_k[t];$$

$L_0^{(k)}$ - average number of patients in the *κ*-team service queue

(10) $$L_0^{(k)} = \lambda_k * W_0^{(k)};$$

$L_c^{(k)}$ - average number of patients with the *κ*-team;

(11) $L_c^{(k)} = L_0^{(k)} + \rho_k$, where $\rho_k = \lambda_k * M_k[t]$;

(12) $$S_k = \sum_{i=1}^{k} \rho_i < 1, \quad \kappa=1,2,\ldots,m.$$

(13) $S_0 \equiv 0$.

The average time the patient spends in the queue does not depend on the kind of priority they have and is equal to

(14) $W_0 = \sum_{k=1}^{m} \frac{\lambda_k}{\lambda} W_0^{(k)}$, where $\lambda = \sum_{i=1}^{m} \lambda_i$.

The average time the incoming calls stay in the system, is determined by the dependency

(15) $W_c = \sum_{k=1}^{m} \frac{\lambda_k}{\lambda} W_c^{(k)}$.

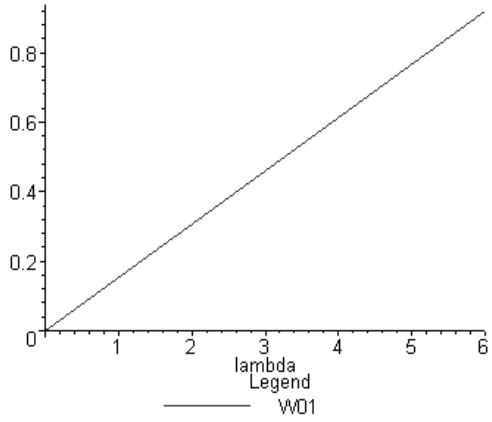

Fig.5. Dependency of $W_0^{(1)}$ on λ with one team providing the service

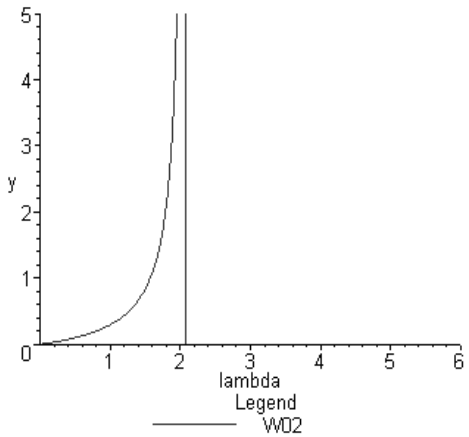

Fig.6. Dependency of $W_0^{(2)}$ on λ with one team providing the service

The results of the examined case with one team are as follows:

$W_0^{(1)}$ - the average time the call stays in the system's queue increases linearly with the increase in the incoming calls flow intensity λ (fig.5). The average time $W_0^{(2)}$ the calls of second (lower) priority stay in the queue increases unrestrictedly when the calls intensity

increases to 2.07 incoming calls per hour (fig.6); so with the introduction of priority service by one team the lower priority calls cannot get the service needed in due time, which can be fatal to the patient. It is possible to provide adequate emergency medical service without threatening the patient's life if the intensity of the incoming calls of second (lower) priority does not exceed 1 call per hour [5].

In the simulation of the emergency aid centre as a multichannel queuing system with a priority channel, in the case which is examined (with two teams), it is supposed that that the time needed to provide the service will be the same for the calls from the two priority categories and the distribution of the time spent providing the service by all the teams (*m* is their number), is according to an exponential law with average service intensity μ. Incoming calls with *k*-priority is distributed in time according to Poisson's law and is characterized by average frequency λ_k *(κ=1,2,…,m)*. So for the k-queue of waiting patients the average time the patient (the call) stays in the queue is [9]:

(16) $$W_0^{(k)} = \frac{M[\xi]}{(1-S_{k-1})*(1-S_k)}, \quad k=1,2,\ldots,m,$$

where $S_0 \equiv 0, S_k \frac{\lambda_i}{m*\mu} < 1$ for *κ=1,2,…m*,

(17) $$M[\xi] = \frac{1}{\mu*m*\left[\rho^{-m}*(m-\rho)*(m-1)!*\sum_{j=0}^{m-1}\frac{\rho^j}{j!}+1\right]}, \ \rho = \frac{\lambda}{\mu}.$$

For the examined case it is supposed that there are two queues, the first one being of higher priority and with intensity $\lambda_1 = 0.5,$ and the second one – with intensity $\lambda_2 = \lambda - \lambda_1$, where λ is the intensity of the incoming calls flow for the whole system. The average service time for the incoming calls is $\overline{t_{serv}}$ =28 minutes. It can be accepted that it is the same for the incoming calls from the two groups and therefore, the service intensity is $\mu_1 = \mu_2 = \frac{1}{t_{serv}} = 2.14$ calls per hour.

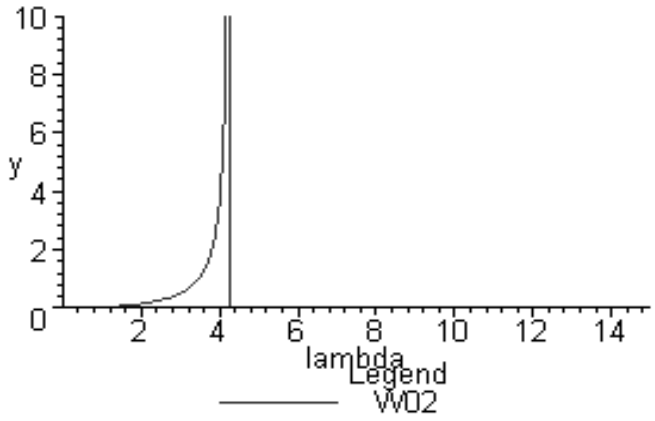

Fig.7. Dependence of $W_0^{(2)}$ on λ with two service teams

The MAPLE program product is used to draw the graphs.

For two service teams the results are shown in fig.7: the intensity of the incoming calls of second priority λ_2 should not exceed 2, as according to this graph the time the calls stay waiting in the queue is practically zero, which means that the patients will get the medical service they need without having to wait in the system's queue. When the intensity

of the incoming calls is larger than 3, the situation becomes intolerable considering the service provided by the emergency aid system [6], as the time spent waiting in the queue of the system increases unrestrictedly. For λ_2 approaching 4.28 calls per hour, $W_0^{(2)}$ approaches infinity.

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ИЗСЛЕДВАНЕ НА ВЛИЯНИЕТО НА ИНТЕНЗИВНОСТТА НА ВХОДЯЩИЯ ПОТОК ОТ ЗАЯВКИ ВЪРХУ НЯКОИ ОСНОВНИ ХАРАКТЕРИСТИКИ НА ЦЕНТЪР ЗА СПЕШНА МЕДИЦИНСКА ПОМОЩ

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Резюме: *Центърът за спешна медицинска помощ в град Русе е моделиран като система за масово обслужване с неограничен брой места в опашката на системата. Изследвано е влиянието на интензивността на входящия поток заявки върху някои основни характеристики на системата. Направени са изводи за необходимия брой екипи, за да може да се осигури своевременно обслужване на пациентите при определена интензивност на входящия поток от заявки. Анализирани са и резултатите от симулацията на въвеждането на приоритетно обслужване на заявки и са направени съответните изводи.*

Ключови думи: *Математическо моделиране, Теория на масовото обслужване, Спешна медицинска помощ, Приоритетно обслужване.*

A STUDY ON THE INFLUENCE OF INCOMING CALLS FLOW INTENSITY ON THE WAITING TIME CHARACTERISTICS OF AN EMERGENCY MEDICAL AID CENTRE

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Abstract: *The present paper studies the influence of the incoming calls flow on the waiting time characteristics of an emergency aid centre with teams collaboration with each other and a deviation in the incoming calls distribution law and the service time. An instance of "all as one" type of collaboration is considered. The functioning of an emergency aid centre has been simulated with Poisson incoming flow and constant service time, Poisson incoming flow and Erlang service time, as well as with regular incoming flow and exponential service time. Conclusions have been drawn, respectively.*

Keywords: *Mathematical Modelling, Simulation, Queuing Theory, Distribution Laws, Emergency Medical Aid.*

Often, in the case of natural disasters and industrial and road accidents, the patients suffer multiple damages. In view of the timely treatment of the injured patients and saving their lives, they have to be served by more than one emergency aid teams. Thus the question of team collaboration arises. This approach cannot be applied to all types of health conditions.

It is natural to suppose that if several teams *(κ)* are working to serve a patient, the intensity of the service $\mu(k)$ should not diminish with the increase of *κ,* i.e. this will be a non-decreasing function of the number *κ* of the teams working. It could be presented with a graph like the one shown in Fig.1 [10].

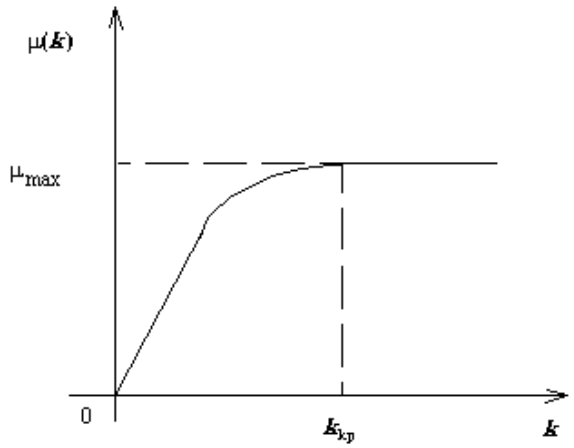

Fig. 1. Dependence of the service intensity on the number of teams

The increase of the number of teams that serve a patient does not always result in proportionate increase of the service intensity. When a certain value $k = k_{kp}$ is reached, a further increase of the number of teams involved does not lead to higher service intensity (Fig.1).

In this case it is important to set the type of the function $\mu(k)$. An example is considered where $\mu(k)$ grows in proportion to *κ* with $k \le k_{kp}$, but with $k > k_{kp}$ it remains constant and $\mu_{\max} = k_{kp} * \mu$. If the number of the teams in the system that can cooperate

with each other is $n \le k_{kp}$, then one can assume that the patient service intensity with several teams available is proportional to the number of teams.

The simplest example of mutual cooperation is of the "all as one" type. So when a call from a patient is received, all *n* teams start serving it immediately and stay busy until they have completed serving this call. Then all teams move over to provide service to the next call (if there is one) or they wait until they receive one (if there isn't one at the moment), etc. Therefore, the system in this case would be working as uni-channel with higher service intensity.

Applying team collaboration of the "all as one" type would be best for the patient and he/she would receive timely help but engaging several teams would lead to greater expenses.

The work at an emergency medical aid centre (EMAC) is viewed as a multichannel queuing system with an indefinite number of places in the queue. The influence of the collaboration accomplished among the teams on the waiting time characteristics is studied:

L_0 - number of calls in the system's queue;

L_c - number of calls in the system;

W_0 - waiting time for the calls in the system's queue;

W_c - waiting time for the calls in the system.

When no collaboration is applied among the teams, the values of the above parameters are defined from the following dependencies [3]:

(1) $L_0 = \dfrac{\rho^{n+1} * P_0}{(n-1)!*(n-\rho)^2}$,

where $P_0 = \dfrac{1}{1+\dfrac{\rho}{1!}+\dfrac{\rho^2}{2!}+...+\dfrac{\rho^n}{n!}+\dfrac{\rho^{n+1}}{n!*(n-\rho)}}$, $\rho = \dfrac{\lambda}{\mu}$, *n* - number of teams;

(2) $L_c = L_0 + \rho$;

(3) $W_0 = \dfrac{\rho^n * P_0}{n*\mu*n!*(n-\kappa)^2} = \dfrac{L_0}{\lambda}$, where $\kappa = \dfrac{\rho}{n}$;

(4) $W_c = W_0 + \overline{t_{serv}} = W_0 + \dfrac{1}{\mu} = \dfrac{L_c}{\lambda}$.

In the case of collaboration of the "all as one" type, the system will work as uni-channel with parameters $\mu^* = n*\mu$, $\rho^* = \dfrac{\lambda}{\mu^*} = \dfrac{\lambda}{n*\mu} = \dfrac{\rho}{n} = \kappa$ and its characteristics would be defined in the following way [10] :

(5) $L_c = \dfrac{\kappa^2}{1-\kappa}$,

(6) $W_0 = \dfrac{\kappa}{n*\mu*(1-\kappa)}$,

(7) $W_c = \overline{t_{wait}} + \overline{t_{serv}} = W_0 + \overline{t_{serv}} = W_0 + \dfrac{1}{n*\mu} = \dfrac{1}{n*\mu*(1-\kappa)}$.

The study is conducted with service intensity of μ=2.14 c./h. and *n*=4 teams. The following conclusions can be made from the graphs of L_0 and W_0 (W_0 - without collaboration, W_{0ve} - with "all as one" type collaboration) in Fig. 2 and Fig. 3: The acceptable values for λ should not exceed 4, which will allow the call waiting time in the

system's queue to be reduced practically to zero. For λ growing to over four calls per hour, the number of calls in the system's queue starts increasing and tends to infinity for λ approaching 8.56 c./h.

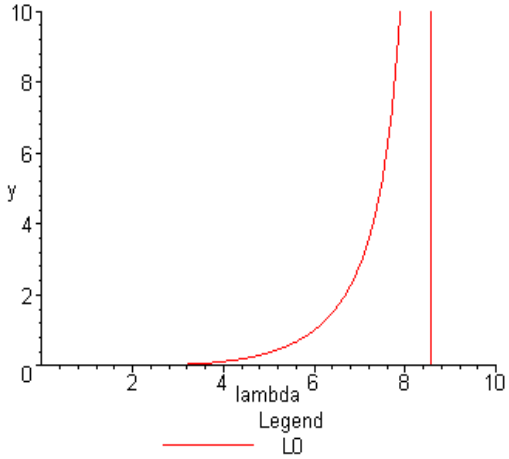

Fig. 2. Dependence of L_0 on the intensity of the incoming calls flow λ

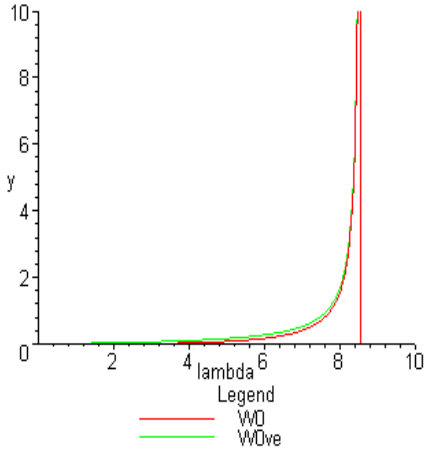

Fig. 3. Dependence of W_0 on the intensity of the incoming calls flow λ

There are also considerable differences in the values of L_c and W_c. The number of calls in the system with no collaboration taking place L_c is larger than the number of those where "all as one" type collaboration is applied L_{cve} (Fig. 4). When the results for the values of W_c are compared (without collaboration among the teams and with "all as one" type collaboration respectively), it turns out that calls waiting time in the system with collaboration applied W_{cve} is almost twice longer than the calls waiting time in a system without collaboration W_c (Fig. 5).

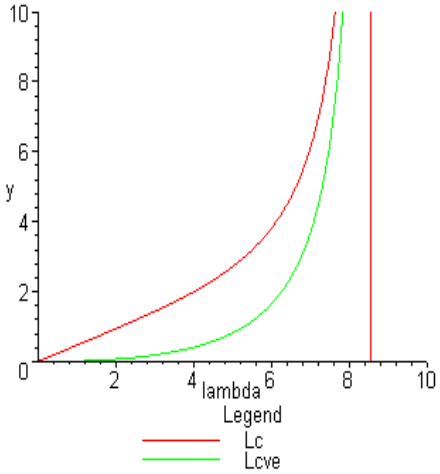

Fig. 4. Dependence of L_c without and with collaboration L_{cve} on the intensity of the incoming calls flow λ

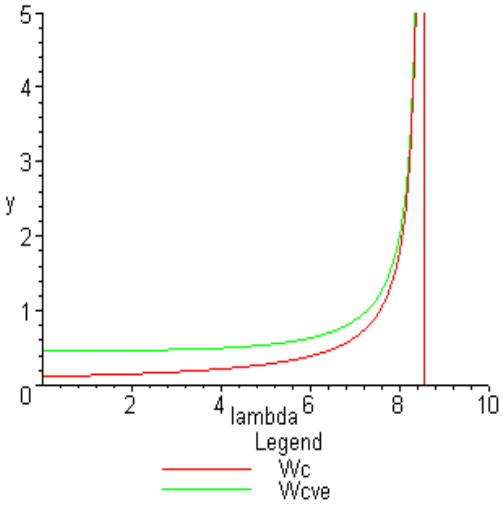

Fig. 5. Dependence of W_c without and with collaboration W_{cve} on the intensity of the incoming calls flow λ

It is evident from the graphs (Fig. 4 and Fig. 5) that the system can work with these parameters with a maximum intensity of incoming calls flow of not more than four calls per hour because the calls waiting time in the system increases and this could be fatal for the

health and the life of the patient. It is important for a patient with a heart attack or a stroke to receive the necessary medical aid within the so called “golden hour” [4, 5].

On the basis of the research on the functioning of the emergency medical aid centre in the town of Ruse, the laws regulating the distribution of incoming calls flow and the service time have been defined. It has been established that the incoming calls flow is distributed in accordance with Poisson’s law and the service time - in accordance with an exponential law [7].

Sometimes deviations from these laws are likely to occur. In some of the affiliate branches of the emergency medical aid centre in the town of Ruse [2] the distance travelled for one call is about twice longer than the distance travelled by the teams from the Ruse emergency medical aid centre. The increased time for reaching a patient increases the service time [8, 9]. The share of the transportation time as a portion of the service time goes up, respectively. This also causes deviations in the laws for the distribution of the service time.

When the incoming flow is not of Poisson’s type, and the service time is not distributed in accordance with an exponential law, the mathematical apparatus of the research becomes too complicated and systems characteristics are found only for the simplest cases [6]. A simulation has been developed of the functioning of the emergency medical aid centre in the town of Ruse with Poisson’s incoming flow and constant service time, Poisson’s incoming flow and Erlang service time, as well as with regular incoming flow and exponential service time.

Coffman and Kryuon [1] have shown that for a uni-channel queuing system with Poisson’s flow and random distribution of service time, the average number of calls located in the queue is defined by the following dependency:

(8) $$L_0 = \frac{\rho^2 * (1+\nu^2)}{2*(1-\rho)},$$

where $\rho = \frac{\lambda}{\mu}$; λ is the incoming flow intensity, μ is the service intensity, ν is the variation coefficient of service time.

The average waiting time in the system’s queue is calculated according to the formula (9):

(9) $$W_0 = \frac{\rho^2 * (1+\nu^2)}{2*\lambda*(1-\rho)}.$$

When the service time for all queries is a constant value equal to its mathematical expectation and $\overline{t_{serv}} = \frac{1}{\mu}$, it follows that $\sigma_{\overline{t_{serv}}} = 0$, $\nu = 0$. Then [6]:

(10) $$L_0 = \frac{\rho^2}{2*(1-\rho)}, \qquad W_0 = \frac{\rho^2}{2*\lambda*(1-\rho)}.$$

For a uni-channel queuing system with Poisson’s incoming flow and exponential service time, the waiting time characteristics are defines by the following dependencies (11), see [10]:

(11) $$L_0 = \frac{\rho^2}{(1-\rho)}, \quad L_c = \frac{\rho}{1-\rho}, \quad W_0 = \frac{\rho^2}{\lambda*(1-\rho)}, \quad W_c = \frac{1}{\mu*(1-\rho)}.$$

The following dependencies are obtained (12) for the values characterizing the system efficiency for Poisson’s incoming flow and constant service time, see [6]:

(12) $L_c = \frac{\rho^2 - 2*\rho}{2*(\rho-1)}$, $L_0 = L_c - \rho = \frac{\rho^2}{2*(1-\rho)}$, $W_c = \frac{L_c}{\lambda} = \frac{\rho-2}{2*\mu*(\rho-1)}$,

$W_0 = \frac{L_0}{\lambda} = \frac{\rho}{2*\mu*(1-\rho)}$.

With regular incoming flow and exponential service time, the average calls waiting time in the system's queue is obtained from the dependency

(13) $W_0 = \int_0^{\infty} t.dP(T<t) = \frac{\rho}{2*\mu*(1-\rho)}$,

where $P(T<t)$ is the probability for the waiting time to be <*t.*

The system parameters are defined according to the following formulas:

(14) $W_0 = \frac{\rho}{2*\mu*(1-\rho)}$; $L_0 = W_0 * \lambda$; $L_c = L_0 + \rho$; $W_c = \frac{L_c}{\lambda}$.

If the incoming flow is of Poisson's type and the service time is distributed according to Erlang's law, then changes in the system parameters occur.

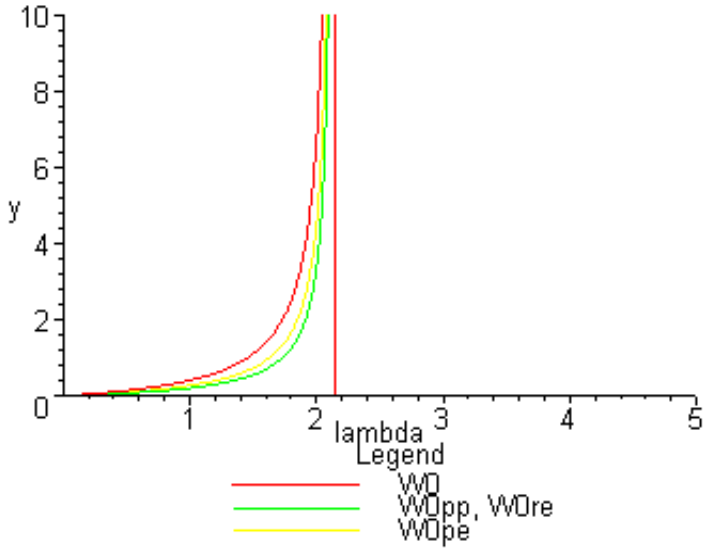

Fig. 6. Dependence of W_0 on the incoming calls flow intensity λ

For Erlang's distribution of service time E_k, it can be assumed that the call coming into the system passes through *κ* service phases, which have the same exponential distribution with a $\mu*k$ parameter. The density of the distribution of the sum of *κ* mutually independent random values which have identical exponential distribution with a $\mu*k$ parameter, is Erlang's flow of *κ*-th order E_k. In this case the incoming flow will have a mathematical expectation λ/k. This means that only $\frac{1}{k}$ part of the calls received in accordance with Poisson's law are used.

In the examined case the system characteristics will be defined in accordance with the formulas (15), see [6]:

(15) $L_c = \frac{\rho*(k+1)}{2*(1-k*\rho)}$; $W_c = \frac{L_c}{\lambda}$; $W_0 = \frac{\rho*(k+1)}{2*\mu*(1-k*\rho)}$; $\rho = \frac{\lambda}{k*\mu}$.

The study of Erlang's distribution of service time is done for *κ=3*.

The following can be inferred from the research on the waiting time characteristics with different variants of the distribution laws related to the incoming calls flow and the service time: When increasing the incoming calls flow intensity, the system achieves best waiting time characteristics with Poisson's incoming flow and constant service time as well as with regular incoming flow and exponential service time because in these cases the calls waiting time in the system's queue remains always smaller than the values W_o in the other cases (Fig. 6). Thus the most favourable situation for the serviced patient could be accomplished – treatment with the minimum waiting time in the queue of the system.

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НЯКОИ ИЗСЛЕДВАНИЯ НА ВЛИЯНИЕТО НА ИНТЕНЗИВНОСТТА НА ВХОДЯЩИЯ ПОТОК ОТ ЗАЯВКИ ВЪРХУ ХАРАКТЕРИСТИКИТЕ НА ИЗЧАКВАНЕ НА ЦЕНТЪР ЗА СПЕШНА МЕДИЦИНСКА ПОМОЩ

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Русенски университет „Ангел Кънчев"

Резюме: *В настоящата работа се изследва влиянието на интензивността на входящия поток от заявки върху характеристиките на изчакване на център за спешна медицинска помощ при прилагане на взаимопомощ между екипите и при отклонение в законите на разпределение на входящия поток от заявки и на времето на обслужване. Разглежда се случай на взаимопомощ от вида „всички като един". Симулирано е функционирането на център за спешна медицинска помощ при поасонов входящ поток и постоянно време на обслужване, поасонов входящ поток и ерлангово време на обслужване, както и на регулярен входящ поток и експоненциално време на обслужване. Направени са и съответните изводи.*

Ключови думи: *Математическо моделиране, Симулация, Теория на масовото обслужване, Закони на разпределение, Спешна медицинска помощ.*

NUMERICAL SOLUTION OF THE TWO-PHASE STEFAN PROBLEM FOR SPHERE

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***Abstract**: We consider two-phase Stefan problem for spheres in cases of small diffusion or large Stefan number limit. Landau's transformation with the Gupta & Kumar [1] variable time-step method to solve numerically the problem is combined. A second order difference scheme with respect to space is derived and an algorithm for solution of the algebraic equations system is proposed. Shishkin meshes are used in the region of small diffusion. Numerical experiments show more accurate results in case of Shishkin mesh.*

***Keywords:** Two-phase Stefan problem for spheres, free boundary problems, difference scheme, Shishkin mesh*

INTRODUCTION

One of the most simple moving boundary problems to pose is the classical Stefan problem for the inward solidification of a spherical ice ball. Even in this idealized case there is no (known) exact solution, and the only way to obtain meaningful results is through numerical or approximate means. In this study, the full two-phase problem is considered, and in particular, the attention is given to large Stefan limit or small diffusion. By applying the method of matched asymptotic expansion the temperature in both two phases the authors show that the solid-melt interface $r = R(t)$ moves slowly and the two phase are weakly coupled for large Stefan number ($\beta >> 1$). The singular region of small diffusion is considered.

The paper [9] is concerned with modelling the melting process of a nanoscaled sphere or cylinder and the resulting boundary value problem takes the form below.

Numerical analysis of heat and mass transfer with moving interface boundaries between two or more subdomains often bring us to diffraction boundary value problems. In the case of the presence of concentrated sources and small diffusion coefficient it is necessary to develop special numerical methods whose errors depend rather weakly on the parameter ε. The behavior of the solutions is very complicated in the case of moving concentrated sources [2, 6, 7, 8].

The purpose of the present study is using the Landau transformation to transform the two-phase Stefan problem for sphere into an interface problem. The left parabolic problem is defined on a rectangle and the right one is an one-phase Stefan problem while the interface is a segment parallel to axe Ot. We use layer adapted meshes (Shishkin's) [4, 6], see Fig.2 for the left problem in case of small diffusion. On the base of the Gupta & Kumar [1] variable time-step method, for the right problem we develop a tracking algorithm.

The rest of the paper is organized as follows: In Section 2 we consider the differential problem and we apply the Landau's transformation. In Section 3 we construct a second-order approximation of the problem in the left, right domain and in the interface. In Section 4 we present numerical results.

THE DIFFERENTIAL PROBLEM

We consider the dimensionless solidification problem

$$\frac{\partial v}{\partial t} = k\left(\frac{\partial^2 v}{\partial r^2} + \frac{2}{r}\frac{\partial v}{\partial r}\right), \quad 0 < r < R(t), \tag{1}$$

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial r^2} + \frac{2}{r}\frac{\partial u}{\partial r}, \quad R(t) < r < 1 \tag{2}$$

with fixed boundary conditions

$$\frac{\partial v}{\partial r}|_{r=0} = 0, \quad v(R(t), t) = 0; \tag{3}$$

$$u(R(t), t) = 0, \quad u(1, t) = -1, \tag{4}$$

moving boundary condition (the Stefan condition)

$$\frac{\partial u}{\partial r} - k\frac{\partial v}{\partial r} = \beta\frac{dR}{dt}, \text{ on } r = R(t) \tag{5}$$

and initial conditions

$$v(r,0) = v_0(r); \quad R(0) = 1. \tag{6}$$

Here $\boldsymbol{u(r,t)}$ and $\boldsymbol{v(r,t)}$ are the temperature fields in the the solid and liquid respectively, $\boldsymbol{r}$ is traditional distance, $\boldsymbol{t}$ represents time and $\boldsymbol{r = R(t)}$ describes the location of the solid-melt interface. The three parameters in the problem are the dimensionless initial temperature v_0, the Stefan number β and the ratio of thermal diffusivities k.

The two-phase problem (1)-(6) is highly nonlinear with no known exact analytical solution. We put:

$$\xi = r/R(t), \quad v = v(r,t) = V(\xi, t), \quad u = u(r,t) = U(\xi, t).$$

Then the equations (1)-(2) are converting into

$$\frac{\partial V}{\partial t} = \frac{k}{R^2(t)}\left(\frac{\partial^2 V}{\partial \xi^2} + \frac{2}{\xi}\frac{\partial V}{\partial \xi}\right) + \xi\frac{\dot{R}(t)}{R(t)}\frac{\partial V}{\partial \xi}, \quad 0 < \xi < 1, \tag{7}$$

$$\frac{\partial U}{\partial t} = \frac{1}{R^2(t)}\left(\frac{\partial^2 U}{\partial \xi^2} + \frac{2}{\xi}\frac{\partial U}{\partial \xi}\right) + \xi\frac{\dot{R}(t)}{R(t)}\frac{\partial U}{\partial \xi}, \quad 1 < \xi < \frac{1}{R(t)}; \tag{8}$$

the boundary conditions (3)-(4) into

$$\frac{\partial V}{\partial \xi}|_{\xi=0} = 0, \quad V(1,t) = 0, \quad U(1,t) = 0, \quad U\left(\frac{1}{R(t)}, t\right) = -1. \tag{9}$$

The moving boundary condition (5) takes the form

$$\frac{\partial U}{\partial \xi} - k\frac{\partial V}{\partial \xi} = \beta\dot{R}(t)R(t) \text{ on } \xi = 1, \tag{10}$$

and the initial conditions (6)

$$V(\xi,0) = v_0(\xi R(t)), \quad R(0) = 1. \tag{11}$$

NUMERICAL METHOD

In this section we discretize the transformed equations (7)-(11).

1. Left domain

First, we will construct a second-order approximation of the problem (7)-(11). By Lopital's rule, we have

$$\lim_{\xi\to 0}\frac{\partial V}{\partial \xi} = 0, \quad \lim_{\xi\to 0}\frac{1}{\xi}\frac{\partial V}{\partial \xi} = \lim_{\xi\to 0}\frac{\partial^2 V}{\partial \xi^2} = \frac{\partial^2 V}{\partial \xi^2}|_{\xi=0}.$$

Then, it follows from equation (7)

$$\frac{\partial V}{\partial t}|_{\xi=0} = \frac{3k}{R^2(t)}\frac{\partial^2 V}{\partial \xi^2}|_{\xi=0}. \tag{12}$$

Therefore,

$$\frac{\partial^2 V}{\partial t \partial \xi} = \frac{k}{R^2(t)}\left(\frac{\partial^3 V}{\partial \xi^3} - \frac{2}{\xi^2}\frac{\partial V}{\partial \xi} + \frac{2}{\xi}\frac{\partial^2 V}{\partial \xi^2}\right) + \frac{\dot{R}(t)}{R(t)}\frac{\partial V}{\partial \xi} + \xi\frac{\dot{R}(t)}{R(t)}\frac{\partial^2 V}{\partial \xi^2}.$$

Next,

$$\frac{\partial^3 V}{\partial \xi^3}|_{\xi=0} = 2\lim_{\xi\to 0}\frac{\frac{1}{\xi}\frac{\partial V}{\partial \xi} - \frac{\partial^2 V}{\partial \xi^2}}{\xi} = 2\lim_{\xi\to 0}\left(-\frac{1}{\xi^2}\frac{\partial V}{\partial \xi} + \frac{1}{\xi}\frac{\partial^2 V}{\partial \xi^2} - \frac{\partial^3 V}{\partial \xi^3}\right).$$

Hence,

$$\frac{\partial^3 V}{\partial \xi^3}|_{\xi=0} = 2\lim_{\xi\to 0}\frac{\frac{\partial^2 V}{\partial \xi^2} - \frac{1}{\xi}\frac{\partial V}{\partial \xi} - \frac{\partial^3 V}{\partial \xi^3}}{\xi}, \text{ wich implies } \lim_{\xi\to 0}\frac{\partial^3 V}{\partial \xi^3} = 0.$$

Let introduce the mesh $w_h = \{0 < \xi_1 < \ldots < \xi_{N-1} < 1\}$, $\xi_0 = 0$, $\xi_N = 1$, $\overline{w}_h = w_h \cup \{\xi_0\} \cup \{\xi_N\}$ and $h_i = \xi_i - \xi_{i-1}$, $\hbar_i = 0.5(h_i + h_{i+1})$ [5]. Now, we have

$$\frac{V(h_1,t) - V(-h_1,t)}{2h_1} = \frac{\partial V}{\partial \xi}|_{\xi=0} + \frac{h_1^2}{6}\frac{\partial^3 V}{\partial \xi^3}|_{\xi=0} + O(h_1^4).$$

Using $V(-h_1,t) = V(h_1,t) + O(h_1^5)$ and (12) we get

$$\frac{\partial V}{\partial t}|_{\xi=0} = \frac{6k}{h_1^2 R^2(t)}\big(V(h_1,t) - V(0,t)\big) + O(h_1^3). \tag{13}$$

From (7) we obtain

$$\frac{\partial V}{\partial t}|_{\xi_i} = \frac{k}{\hbar_i R^2(t)}\left[\left(1 + \frac{h_i}{\xi_i}\right)\frac{V_{i+1} - V_i}{h_{i+1}} - \left(1 - \frac{h_{i+1}}{\xi_i}\right)\frac{V_i - V_{i-1}}{h_i}\right] \tag{14}$$

$$+ \frac{\xi_i \dot{R}(t)}{2\hbar_i R(t)}\left[h_i\frac{V_{i+1} - V_i}{h_{i+1}} + h_{i+1}\frac{V_i - V_{i-1}}{h_i}\right] + O(\hbar_i^2),\ 1 \le i \le N-1,$$

where $V_i = V(\xi_i, t)$.

We require

$$1/R(t_j) = 1 + jh. \tag{15}$$

We differentiate $\frac{1}{R(t)}$ in $t = t_j$ and equalize to the angular factor of the segment connected the points $((j-1)h, t_{j-1})$ and (jh, t_j), to obtain

$$-\dot{R}(t)/R^2(t_j) = h/\tau_j. \tag{16}$$

We discretize (13) as follows:

$$C_0^j V_0^j - B_0^j V_1^j = F_0^j,\ C_0^j = 1 + 6\sigma k\tau_j\left(\frac{1+jh}{h_1}\right)^2,\ B_0^j = 6\sigma k\tau_j\left(\frac{1+jh}{h_1}\right)^2,$$

$$F_0^{\,j} = \left(1 - 6(1-\sigma)k\tau_j\left(\frac{1+(j-1)h}{h_1}\right)^2\right)V_0^{\,j-1} + 6(1-\sigma)k\tau_j\left(\frac{1+(j-1)h}{h_1}\right)^2 V_1^{\,j-1}.$$

Further, we use the Crank-Nicalson scheme to obtain from (14)

$$-A_i^j V_{i-1}^j + C_i^j V_i^j - B_i^j V_{i+1}^j = F_i^j,\ 1 \le i \le N-1.$$

$$A_i^j = \frac{\sigma}{h_i \hbar_i}\left(k\tau_j\left(1-\frac{h_{i+1}}{\xi_i}\right)(1+jh)^2 + \frac{h_{i+1}\xi_i}{2(1/h+j)}\right),$$

$$C_i^{\,j} = 1 + \frac{\sigma}{h_i h_{i+1}}\left(2k\tau_j(1+jh)^2\left(1+\frac{h_i - h_{i+1}}{\xi_i}\right) + \frac{\xi_i(h_{i+1}-h_i)}{1/h+j}\right),$$

$$B_i^j = \frac{\sigma}{h_{i+1}\hbar_i}\left(k\tau_j\left(1+\frac{h_i}{\xi_i}\right)(1+jh)^2 - \frac{h_i\xi_i}{2(1/h+j)}\right),$$

$$F_i^{\,j} = \frac{(1-\sigma)\tau_j}{h_i\hbar_i}\left(k\left(1-\frac{h_{i+1}}{\xi_i}\right)(1+(j-1)h)^2 + \frac{h_{i+1}\xi_i}{2\tau_{j-1}(1/h+j-1)}\right)V_{i-1}^{j-1}$$

$$+\left[1 - \frac{(1-\sigma)\tau_j}{h_i h_{i+1}}\left(2k(1+(j-1)h)^2\left(1+\frac{h_i-h_{i+1}}{\xi_i}\right) + \frac{\xi_i(h_{i+1}-h_i)}{\tau_{j-1}(1/h+j-1)}\right)\right]V_i^{\,j-1}$$

$$+\frac{(1-\sigma)\tau_j}{h_{i+1}\hbar_i}\left(k\left(1+\frac{h_i}{\xi_i}\right)(1+(j-1)h)^2 - \frac{h_i\xi_i}{2\tau_{j-1}(1/h+j-1)}\right)V_{i+1}^{j-1}.$$

We use the right Thomas's method to find V_{N-1}^j:

$$V_i^{\,j} = \alpha_{i+1}^l V_{i+1}^j + \beta_{i+1}^l,\ 1 \le i \le N-1.$$

$$\alpha_{i+1}^l = \frac{B_i^j}{C_i^j - A_i^j\alpha_i^l},\ \alpha_1^l = \frac{B_0^j}{C_0^j}\ 1 \le i \le N-1,$$

$$\beta_{i+1}^l = \frac{F_i^{\,j} + \beta_i^l A_i^j}{C_i^j - A_i^j\alpha_i^l},\ \beta_1^l = \frac{F_0^j}{C_0^j},\ 1 \le i \le N-1.$$

$$V_{N-1}^j = \alpha_N^l V_N^j + \beta_N^l = \beta_N^l.$$

2. Right Domain

Let $\xi_i = 1+ih,\ 0 \le i \le j,\ U_0^j = 0,\ U_j^j = -1.$ For $j \ge 1$

$$\frac{\partial U}{\partial t}|_{\xi_i} = \frac{1}{h^2R^2(t)}\left[\frac{\xi_{i+1}}{\xi_i}(U_{i+1}-U_i) - \frac{\xi_{i-1}}{\xi_i}(U_i - U_{i-1})\right] \qquad (17)$$

$$+\xi_i\frac{\dot{R}(t)}{R(t)}\frac{U_{i+1}-U_{i-1}}{2h} + O(h^2),\ 1 \le i \le j-1.$$

We discretize (17) as follows:

$$-A_i^j U_{i-1}^j + C_i^j U_i^j - B_i^j U_{i+1}^j = F_i^j,\ 1 \le i \le j-1.$$

$$A_i^j = \sigma\left(\tau_j\left(1-\frac{h}{1+ih}\right)(1/h+j)^2 + \frac{1+ih}{2(1+jh)}\right),$$

$$C_i^j = 1 + 2\sigma\tau_j(1/h+j)^2,$$

$$B_i^j = \sigma\left(\tau_j\left(1+\frac{h}{1+ih}\right)(1/h+j)^2 - \frac{1+ih}{2(1+jh)}\right),$$

$$F_i^j = (1-\sigma)\tau_j\left(\left(1-\frac{h}{1+ih}\right)(1/h+j-1)^2 + \frac{1+ih}{2\tau_{j-1}(1+(j-1)h)}\right)U_{i-1}^{j-1}$$

$$+\left(1-2(1-\sigma)\tau_j(1/h+j-1)^2\right)U_i^{j-1}$$

$$+(1-\sigma)\tau_j\left(\left(1+\frac{h}{1+ih}\right)(1/h+j-1)^2 - \frac{1+ih}{2\tau_{j-1}(1+(j-1)h)}\right)U_{i+1}^{j-1}.$$

We use the left Thomas method to find U_1^j.

$$U_{i+1}^j = \alpha_{i+1}^r U_i^j + \beta_{i+1}^r,\ 1 \le i \le j-1.$$

$$\alpha_i^r = \frac{A_i^j}{C_i^j - B_i^j \alpha_{i+1}^r},\ \alpha_j^r = 0,\ 1 \le i \le j-1,$$

$$\beta_i^r = \frac{F_i^j + \beta_{i+1}^r B_i^j}{C_i^j - B_i^j \alpha_{i+1}^R},\ \beta_j^r = -1,\ 1 \le i \le j-1.$$

$$U_1^j = \alpha_1^r U_0^j + \beta_1^r = \beta_1^r.$$

3. Interface

For $\xi = 1$ we have the next discrete equation:

$$\frac{\partial U}{\partial \xi}|_{1^+} = \left(1 + 1/h + \frac{R(t)\dot{R}(t)}{2}\right)U_1 + O(h^2),$$

$$k\frac{\partial V}{\partial \xi}|_{1^-} = -\left(k(1/h_N - 1) - \frac{R(t)\dot{R}(t)}{2}\right)V_{N-1} + O(h_N^2).$$

From (10) we obtain

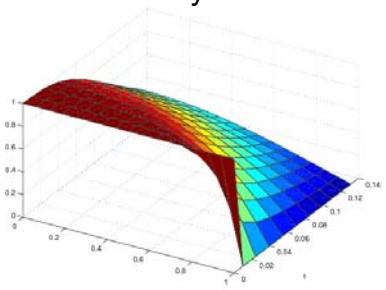
$$R(t)\dot{R}(t) = \frac{2\left[(1+1/h)U_1 + k(1/h_N - 1)V_{N-1}\right]}{2\beta + V_{N-1} - U_1}. \qquad (18)$$

After integration of (18) and use of (15) and (16), we get

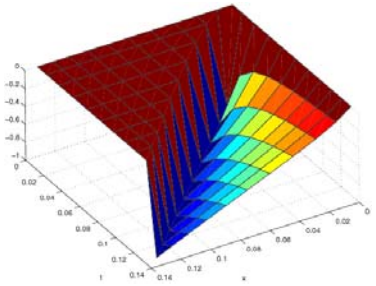
$$\tau_j = \frac{(2\beta + V_{N-1} - U_1)\left(1/(1+jh)^2 - (1/(1+(j-1)h)^2\right)}{4\left[(1+1/h)U_1 + k(1/h_N - 1)V_{N-1}\right]}.$$

NUMERICAL RESULTS

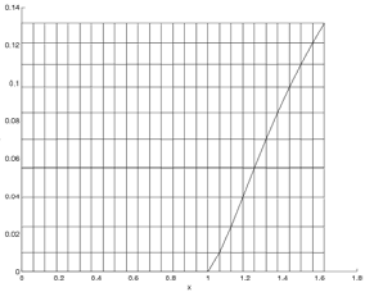
We present the numerical solution of $\{V_i^j\}$, $\{U_i^j\}$, the moving boundary for $\beta = 1$ and for $k = 1$ in Fig. 1 on the uniform mesh and for $k = 2^{-6}$ in Fig. 2 on the Shishkin's mesh. The figures illustrate the efficiency of the Shishkin's mesh.



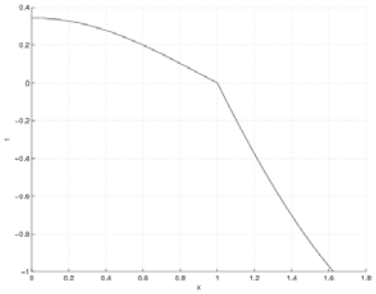
a) $\{V_i^j\}$



b) $\{U_i^j\}$

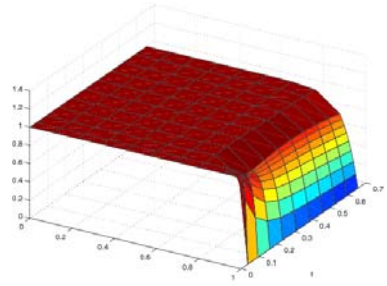


c) Mesh and curve

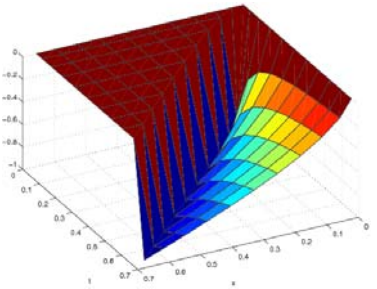


d) V and U on 10-th time layer

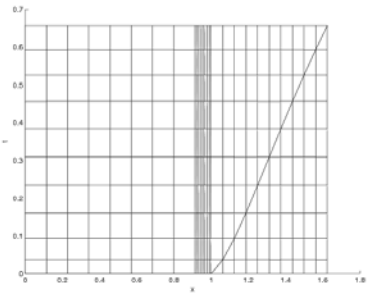
Table 1: N=16, j=10, k=1.



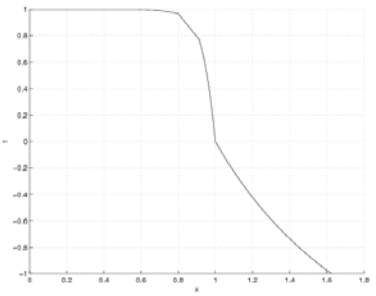
a) $\{V_i^j\}$



b) $\{U_i^j\}$



c) Mesh and curve



d) V and U on 10-th time layer

Table 2: N=16, j=10, $\boldsymbol{k} = 2^{-6}$.

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ЧИСЛЕНО РЕШАВАНЕ НА ДВУФАЗОВА ЗАДАЧА НА СТЕФАН ЗА СФЕРА

Иванка Ангелова

Русенски университе "Ангел Кънчев"

Резюме: В статията се разглежда двуфазова задача на Стефан за сфера в случай на малка дифузия и голямо число на Стефан. Комбинирани са трансформация на Ландау и метод на Гупта и Кумар с променлива стъпка по времето за числеността решаване на задачата. Изведена е схема от втори ред на апроксимация относно пространствената променлива и е предложен алгоритъм за решаване на проблема. Използвана е мрежа на Шишкин в областта на малката дифузия. Обсъдени са числените експерименти.

Ключови думи: Двуфазова задача на Стефан за сфера, задача със свободна граница, диференчна схема, мрежа на Шишкин.

MATHEMATICAL MODELS OF INTERFACE PROBLEMS FOR STEADY-UNSTEADY HEAT CONDUCTION

Ivanka Angelova

Angel Kanchev University of Ruse

***Abstract**: We study mathematical models describing non-stationary heat conduction in two bodies separated by steady conductor (isolation). These problems are related to parabolic equations with discontinuous coefficients and concentrated sources. As a result across the interfaces contact (jump) conditions arise. It is proved that this problem can be reduced to a variational problem. An asymptotic analysis of the interface problem is derived for the case when the thickness of the isolation tends to zero. As a result a new parabolic interface problem with non-ideal contact conditions is derived.*

***Keywords:** Heat conduction, interface, contact conditions, elliptic and parabolic equations, asymptotical analysis*

INTRODUCTION

There are two main reasons for coupling different models in different regions: the first are problems where the physics is different in different regions [2, 3, 7], and hence different models need to be used, for example in steady-unsteady heat conduction coupling. The second are problems where one is in principle interested in the full physical model, but the full model is too expensive computationally over entire region, and hence one would like to use a simple model in parts of the region, and full one only where it is essential to capture the physical phenomena [3, 5, 9]. Here we will discuss models that concern the two cases.

We consider a general problem where the domain consist of the following three parts: unsteady conductor - steady conductor - unsteady conductor. A survey on mathematical aspects of coupled conduction-radiation energy transfer problems is given in [7].

The stability of solutions to interface problems is studied in [4]. Elliptic and parabolic interface problems on disjoint domains are studied in [4, 9].

One is also interested in efficient algorithms to solve the coupled problems. One of the most effective method is the so called immersed interface method (IIM) [6]. This method uses uniform meshes and has second order of local approximation.

We want to emphasize that the purpose of this paper is not only to model a realistic application, but also to study theoretically a prototype linear initial boundary-value problems.

The paper is organized as follows. Our model is presented in Section 2. We prove that this problem can be reduces to variational problem, Theorem 1. In Section 3 we investigate the case when the thickness of the isolation tends to zero. The result is an interface problem with *non-ideal contact* conditions.

GENERAL MATHEMATICAL MODEL

Let consider the steady state heat conduction problem, Fig.1: differential equations

$$\frac{\partial \boldsymbol{u}_i}{\partial \boldsymbol{t}} - \frac{\partial}{\partial \boldsymbol{x}}\left(\boldsymbol{p}_i(\boldsymbol{x},\boldsymbol{y}), \frac{\partial \boldsymbol{u}_i}{\partial \boldsymbol{x}} \right) - \frac{\partial}{\partial \boldsymbol{y}}\left(\boldsymbol{q}_i(\boldsymbol{x},\boldsymbol{y}), \frac{\partial \boldsymbol{u}_i}{\partial \boldsymbol{y}} \right) = \boldsymbol{f}_i(\boldsymbol{x},\boldsymbol{y},\boldsymbol{t}), \qquad (1)$$

$$(\boldsymbol{x},\boldsymbol{y}) \in \Omega_i \equiv (\boldsymbol{a}_i,\boldsymbol{b}_i)\times(\boldsymbol{c},\boldsymbol{d}),\ 0<\boldsymbol{t}<\boldsymbol{T},\ \boldsymbol{i}=1,2;\ -\infty<\boldsymbol{a}_1<\boldsymbol{b}_1<\boldsymbol{a}_2<\boldsymbol{b}_2<+\infty;$$

$$-k\left(\frac{\partial^2 u_0}{\partial x^2}+\frac{\partial^2 u_0}{\partial y^2}\right)=f_0(x,y,t),\quad (x,y)\in\Omega_0\equiv(b_1,a_2)\times(c,d),\quad 0<t<T; \tag{2}$$

$$[u]_{x=b_1}=u_0(b_1,y,t)-u_1(b_1,y,t)=0,\quad \left(k\frac{\partial u_0}{\partial x}\right)_{x=b_1}-\left(p_1\frac{\partial u_1}{\partial x}\right)_{x=b_1}=0, \tag{3}$$

$$[u]_{x=a_2}=u_2(a_2,y,t)-u_0(a_2,y,t)=0,\quad \left(p_2\frac{\partial u_2}{\partial x}\right)_{x=a_2}-\left(k\frac{\partial u_0}{\partial x}\right)_{x=a_2}=0; \tag{4}$$

zero-Dirichlet boundary conditions:

$$u_1(a_1,y,t)=0,\quad u_2(b_2,y,t)=0,\quad y\in(c,d), \tag{5}$$

$$u_1(x,c,t)=u_1(x,d,t)=0,\ x\in(a_1,b_1);\ u_2(x,c,t)=u_2(x,d,t)=0,\ x\in(a_2,b_2). \tag{6}$$

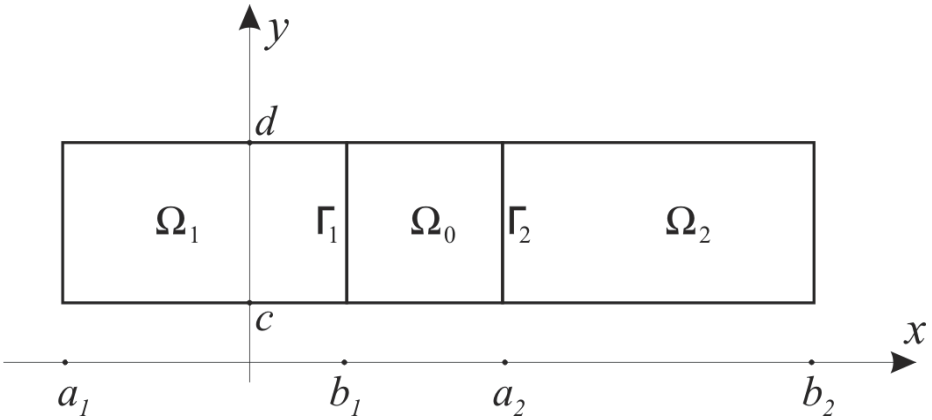

Figure 1: The geometry of bodies Ω_1,Ω_2 conductivities with thin isolation Ω_0.

Let us note that the heat transfers between conductivities and isolation across the interfaces

$$\Gamma_1=\{(b_1,y):y\in(c,d)\},\quad \Gamma_2=\{(a_2,y):y\in(c,d)\}$$

is realized according to the *ideal contact* conditions (3) , (4).

Finally, in order to complete the initial boundary value problem we pose initial conditions

$$u_i(x,y,0)=u_{i0}(x,y),\ i=1,0,2. \tag{7}$$

Throughout the paper we assume for $i=1,2$ the usual regularity conditions

$$p_i(x,y)>0, q_i(x,y)>0,\ p_i,q_i\in C^1(\Omega_i),\ k=const.>0,\ f_i(x,y,t)\in C(\Omega_i)\times C(0,T). \tag{8}$$

Then we can prove that the solution of the interface problem (1)-(8)

$$u\equiv(u_1,u_0,u_2)\in\left(C^2(\Omega_1\cup\Omega_0\cup\Omega_2)\cap C(\Omega)\right)\times C^1(0,T).$$

Let us introduce the piecewise continuous coefficients

$$p(x,y)=\begin{cases}p_1(x,y) & ,(x,y)\in\Omega_1,\\ k & ,(x,y)\in\Omega_0,\\ p_2(x,y) & ,(x,y)\in\Omega_2;\end{cases}\quad q(x,y)=\begin{cases}q_1(x,y) & ,(x,y)\in\Omega_1,\\ k & ,(x,y)\in\Omega_0,\\ q_2(x,y) & ,(x,y)\in\Omega_2;\end{cases}$$

and the function

$$F(x,y,t)=\begin{cases} f_1(x,y,t) & ,(x,y)\in\Omega_1,\\ f_0(x,y,t) & ,(x,y)\in\Omega_0,\\ f_2(x,y,t) & ,(x,y)\in\Omega_2. \end{cases}$$

We can prove the following assertion.

THEOREM 1. Let (7), (8) hold. Then the solution $u\in\left(C^2(\Omega_1\cup\Omega_0\cup\Omega_1)\cap C(\Omega)\right)\times C^1(0,T)$ of the interface problem (1)-(8) is also the solution of the variational problem: find $u\in H^1(\Omega)\times C^1(0,T)$ with boundary conditions (5), (6), which satisfies the following integral identity

$$\iint_{\Omega_1} v_1(x,y)\frac{\partial u_1}{\partial t}dxdy+\iint_{\Omega_2} v_2(x,y)\frac{\partial u_2}{\partial t}dxdy$$
$$+\iint_{\Omega}\left(p(x,y)\frac{\partial u}{\partial x}\frac{\partial v}{\partial x}+q(x,y)\frac{\partial u}{\partial y}\frac{\partial v}{\partial y}\right)dxdy=\iint_{\Omega} v(x,y)F(x,y,t)dxdy,\ \forall\, v\in\overset{\circ}{H}{}^1(\Omega).$$

Proof. Let us multiply the both sides of (1), $i=1,2$ and (2) by $v\equiv(v_1(x,y),\ v_0(x,y),\ v_2(x,y))$ and integrate on Ω_1,Ω_2 and Ω_0 separately. Then, applying integration by parts, we obtain

$$\iint_{\Omega_1} v_1(x,y)\frac{\partial u_1}{\partial t}dxdy+\iint_{\Omega_1}\left(p_1(x,y)\frac{\partial u_1}{\partial x}\frac{\partial v_1}{\partial x}+q_1(x,y)\frac{\partial u_1}{\partial y}\frac{\partial v_1}{\partial y}\right)dxdy$$
$$-\int_c^d\left(v_1 p_1\frac{\partial u_1}{\partial x}\right)(b_1,y,t)dy=\iint_{\Omega_1} v_1(x,y)\,f_1(x,y,t)dxdy.$$

$$k\iint_{\Omega_0}\left(\frac{\partial u_0}{\partial x}\frac{\partial v_0}{\partial x}+\frac{\partial u_0}{\partial y}\frac{\partial v_0}{\partial y}\right)dxdy+k\int_c^d\left[\left(v_0\frac{\partial u_0}{\partial x}\right)(b_1,y,t)-\left(v_0\frac{\partial u_0}{\partial x}\right)(a_2,y,t)\right]dy$$
$$=\iint_{\Omega_0} v_0(x,y)\,f_0(x,y,t)dxdy.$$

$$\iint_{\Omega_2} v_2(x,y)\frac{\partial u_2}{\partial t}dxdy+\iint_{\Omega_2}\left(p_2(x,y)\frac{\partial u_2}{\partial x}\frac{\partial v_2}{\partial x}+q_2(x,y)\frac{\partial u_2}{\partial y}\frac{\partial v_2}{\partial y}\right)dxdy$$
$$+\int_c^d\left(v_2 p_2\frac{\partial u_2}{\partial x}\right)(a_2,y,t)dxdy=\iint_{\Omega_2} v_2(x,y)\,f_2(x,y,t)dxdy.$$

Summing these identities, we get

$$\iint_{\Omega_1} v_1(x,y)\frac{\partial u_1}{\partial t}dxdy+\iint_{\Omega_1}\left(p_1(x,y)\frac{\partial u_1}{\partial x}\frac{\partial v_1}{\partial x}+q_1(x,y)\frac{\partial u_1}{\partial y}\frac{\partial v_1}{\partial y}\right)dxdy$$
$$+k\iint_{\Omega_0}\left(\frac{\partial u_0}{\partial x}\frac{\partial v_0}{\partial x}+\frac{\partial u_0}{\partial y}\frac{\partial v_0}{\partial y}\right)dxdy+k\int_c^d\left[\left(v_0\frac{\partial u_0}{\partial x}\right)(b_1,y,t)-\left(v_0\frac{\partial u_0}{\partial x}\right)(a_2,y,t)\right]dy$$
$$+\iint_{\Omega_2} v_2(x,y)\frac{\partial u_2}{\partial t}dxdy+\iint_{\Omega_2}\left(p_2(x,y)\frac{\partial u_2}{\partial x}\frac{\partial v_2}{\partial x}+q_2(x,y)\frac{\partial u_2}{\partial y}\frac{\partial v_2}{\partial y}\right)dxdy$$

$$+\int_c^d\left[\left(v_2 p_2\frac{\partial u_2}{\partial x}\right)(a_2,y,t)-\left(v_1 p_1\frac{\partial u_1}{\partial x}\right)(b_1,y,t)\right]dxdy=\iint_\Omega v(x,y)F(x,y,t)dxdy.$$

for all $v=v(x,y)\in \overset{\circ}{H}{}^1(\Omega)$. Since $u_0(b_1,y,t)=u_1(b_1,y,t),\ u_2(a_2,y,t)=u_0(a_2,y,t)$ it is natural to require that the arbitrary function $v=(v_1,v_0,v_2)$ also satisfies these conditions. Using these conditions we obtain

$$\int_c^d\left[\left(v_2 p_2\frac{\partial u_2}{\partial x}\right)(a_2,y,t)-\left(v_1 p_1\frac{\partial u_1}{\partial x}\right)(b_1,y,t)\right.$$
$$\left.+k\left(v_0\frac{\partial u_0}{\partial x}\right)(b_1,y,t)-k\left(v_0\frac{\partial u_0}{\partial x}\right)(a_2,y,t)\right]dxdy$$
$$=\int_c^d\left[v_0\left(p_2\frac{\partial u_2}{\partial x}-k\frac{\partial u_0}{\partial x}\right)(a_2,y,t)-v_0\left(k\frac{\partial u_0}{\partial x}-p_1\frac{\partial u_1}{\partial x}\right)(b_1,y,t)\right]dy=0.$$

We obtain

$$\iint_{\Omega_1}v_1(x,y)\frac{\partial u_1}{\partial t}dxdy+\iint_{\Omega_2}v_2(x,y)\frac{\partial u_2}{\partial t}dxdy$$
$$+\iint_{\Omega_1}\left(p_1(x,y)\frac{\partial u_1}{\partial x}\frac{\partial v_1}{\partial x}+q_1(x,y)\frac{\partial u_1}{\partial y}\frac{\partial v_1}{\partial y}\right)dxdy$$
$$+k\iint_{\Omega_0}\left(\frac{\partial u_0}{\partial x}\frac{\partial v_0}{\partial x}+\frac{\partial u_0}{\partial y}\frac{\partial v_0}{\partial y}\right)dxdy$$
$$+\iint_{\Omega_2}\left(p_2(x,y)\frac{\partial u_2}{\partial x}\frac{\partial v_2}{\partial x}+q_2(x,y)\frac{\partial u_2}{\partial y}\frac{\partial v_2}{\partial y}\right)dxdy$$
$$=\iint_\Omega v(x,y)F(x,y,t)dxdy.$$

This integral identity with the Neumann transmission conditions (3), (4) completes the proof [8, 10].

This theorem shows the equivalency of the transmission problem (1)-(3) with *variational problem*, although the last one do not contain any transmission condition. This suggests a possibility of construction of such finite difference (or finite element) analogues of the interface problem, which has the similar structure. Specifically, the question is to construct homogeneous conservative difference schemes in the sense of Samarskii [8], that have the same form for all mesh points including ones on the interfaces Γ_1, Γ_2.

THE LIMIT CASE $\varepsilon\to 0$

We assume that the thickness $2\varepsilon=a_2-b_1$ of the isolation Ω_0 is small , $\varepsilon<<1$ and the conductivity $k>0$, see Fig.1.

Suppose that we wish to solve numerically the problem (1)-(6) by difference scheme. If the value of thickness $2\varepsilon=a_2-b_1$ of the steady isolation Ω_0 is less than the mesh size h along the direction Ox , that is $\varepsilon<h$, then the interface conditions (3), (4) cannot be approximated on this mesh. To derive a finite difference approximation of the interface problem (1)-(6), one need to derive an asymptotic analysis of this problem, when $\varepsilon\to 0$.

Let us note that singularly perturbed one-dimensional interface problems were studied in [1].

In order to simplify the exhibition we take $b_1 = -\varepsilon$, $a_2 = \varepsilon$.

THEOREM 2. The limit case, when $\varepsilon \to 0$, (i.e. $b_1 \to a_2$), of the transmission problem (1)-(6) with *ideal* contact conditions (3), (4) is the following transmission problem with *nonideal* conditions:

$$\frac{\partial u_i}{\partial t} - \frac{\partial}{\partial x}\left(p_i(x,y)\frac{\partial u_i}{\partial x}\right) - \frac{\partial}{\partial y}\left(q_i(x,y)\frac{\partial u_i}{\partial y}\right) = f_i(x,y,t),\ (x,y)\in\Omega_i,\ i=1,2;\ t\in(0,T],$$

$$\left(p_1(x,y)\frac{\partial u}{\partial x}\right)_{x=0^-} = \sigma[u]_{x=0} = \left(p_2(x,y), \frac{\partial u}{\partial x}\right)_{x=0^+},\ \sigma = const. > 0, \tag{9}$$

$$u(x,y,t) = 0,\ (x,y)\in\partial(\Omega_1\cup\Omega_2),\ t\in(0,T],$$

$$u(x,y,0) = u_0(x,y),\ (x,y)\in\Omega_1\cup\Omega_2.$$

Proof. Let us assume that $u = u(x,y,t)$ is the solution of the transmission problem (1)-(6). Integrating (2) on $x\in(-\varepsilon,\xi)$, where $\xi\in(-\varepsilon,\varepsilon)$ and $\varepsilon > 0$ is an arbitrary small parameter to get

$$-k\int_{-\varepsilon}^{\xi}\left(\frac{\partial^2 u_0}{\partial x^2} + \frac{\partial^2 u_0}{\partial y^2}\right)dx = \int_{-\varepsilon}^{\xi} f_0(x,y,t)dx,$$

$$k\frac{\partial u_0}{\partial x}(-\varepsilon,y,t) - k\frac{\partial u_0}{\partial x}(\xi,y,t) = \int_{-\varepsilon}^{\xi}\left(k\frac{\partial^2 u_0}{\partial y^2} + f_0(x,y,t)\right)dx.$$

Since the parameter $\xi\in(-\varepsilon,\varepsilon)$ is an arbitrary one , integrating both sides of the last identity with respect to this parameter on $(-\varepsilon,\varepsilon)$ and use (3) and (4), we obtain

$$2\varepsilon p_1(-\varepsilon,y)\frac{\partial u_1}{\partial x}(-\varepsilon,y,t) - k[u_2(\varepsilon,y,t) - u_1(-\varepsilon,y,t)]$$

$$= \int_{-\varepsilon}^{\varepsilon}\int_{-\varepsilon}^{\xi}\left(k\frac{\partial^2 u_0}{\partial y^2} + f_0(x,y,t)\right)dxd\xi.$$

Let us divide now both sides by $2\varepsilon \neq 0$. Then passing to the limit as $\varepsilon, k \to 0$ and requiring $\sigma = \frac{k}{2\varepsilon} = const$, we get

$$\left(p_1\frac{\partial u_1}{\partial x}\right)(0-,y,t) = \sigma[u_2(0+,y,t) - u_1(0-,y,t)],\ y\in(c,d),\ t\in(0,T],$$

where $\xi \to 0$ as $\varepsilon \to 0$. This condition can be written in the following form:

$$\sigma[u]_{x=0} = \left(p_1\frac{\partial u}{\partial x}\right)_{x=0-}. \tag{10}$$

Integrating (2) on $x\in(\xi,\varepsilon\}$ respectively, by the same way, we can obtain the second limit condition

$$\sigma[u]_{x=0} = \left(p_2\frac{\partial u}{\partial x}\right)_{x=0+}. \tag{11}$$

Conditions (10) - (11) imply the transmission conditions (9). This completes the proof.

Asymptotic analysis to a one-dimensional version of the problem (9) is given in [1].

CONCLUSIONS

In this paper using three rectangles as the simplest case of multi component model an analysis of a parabolic-elliptic interface problem is presented. This study can obviously be extended to the problems with more complicated geometry. We hope that this short paper will trigger some subsequent works on analytical and numerical analysis of partial differential equations with nonstandard transmission conditions.

ACKNOWLEDGEMENTS

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МАТЕМАТИЧЕСКИ МОДЕЛИ НА ИНТЕРФЕЙСНИ ЗАДАЧИ ЗА СТАЦИОНАРНА - НЕСТАЦИОНАРНА ТОПЛОПРОВОДИМОСТ

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Резюме: Ние изследваме математически модели, описващи нестационарна топлопроводност в две тела, разделени със стационарен изолатор. Тези задачи са свързани с параболични уравнения с прекъснати коефициенти и концентрирани източници. Като резултат над интерфейса, възникват контактни (скокови) условия. Доказано е, че тази задача допуска вариационна формулировка. Извършен е асимптотичен анализ в случая, когато дебелината на изолатора клони към нула. Като резултат възниква нова параболична задача с неидеални контактни условия.

Ключови думи: Стационарна и нестационарни топлопроводимост, интерфейс, елиптични и параболични уравнения, асимптотичен анализ.

SOME POSSIBILITIES FOR AUTOMATIC PROGRAMS GENERATION

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***Abstract**: Automatic program generation is a direction in the software industry, connected with saving time and human resources, as well as and receiving syntactic clear and logically correct units. It is possible to separate the application to interface and business logic, too. That means to create a new or use different existing toolsets for interactive generation of the necessary system.*

***Keywords**: automatic programs generation, DBMS, User interface*

INTRODUCTION

In many places people are working in the automatic software generation area. That is a problem, connected not only with human resources and time for development saving. Program generation allows to create syntactic clear and logically correct units – that is connected with time and price for software development, too. Another reason – some time it's difficult to find the suitable specialist to create the necessary correction in a software unit.

It's possible to examine the Automatic software/application generation in a different direction. One of classifications can be on a functional sign – we can separate the application in two parts: user interface and a functional part. So we can differentiate two directions:

1. Interfaces automatic generation;
2. Business-logic automatic generation (i.e. – application logic – some information system).

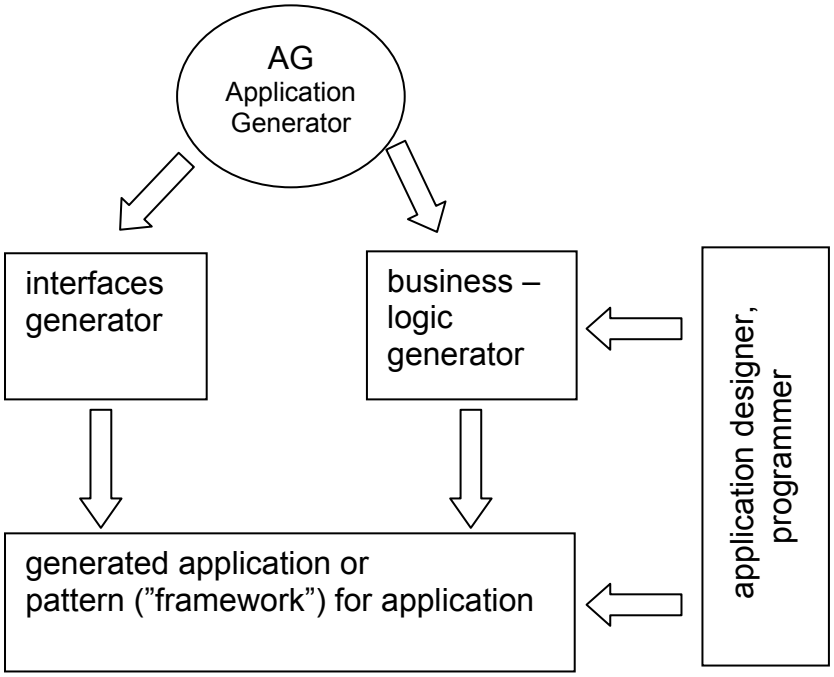

fig. 1 – automatic system generation

DETAIL DESCRIPTION

Interfaces automatic generation – there are many toolsets for visual interface creating (windows and objects in them) – MS Visual C, MS Visual Basic, Delphi, [3] and so on. Summary – they describe the objects and their attributes (size, position, colours; actions for responding – mouse, keyboard, another objects; the interaction with another objects and so on).

Business-logic generator: create software units, which can be parts of code, competed finished application or description of documents streams only (using them, the designer team can create a working application). The purpose is time saving (i.e. – resources) to software development. There are a few systems in that area, one of the leaders is from IBM - Rational System Architect. But to use this very expensive, very good and very effective system are necessary good knowledge of UML [2].

We can examine The Menu generator in few aspects:

1. Natural languages analysis. In this case, using a natural language description [1] (possible – limited language), it's generating frames (or filling of beforehand creating such, describing stage or scenarios);
   - stage – describe a static situation;
   - scenarios – describe a dynamic situation (actions);
2. Using preliminarily created frames (describing stages or scenarios), filling from response designer, it's creating a software generation for application with the necessary possibilities.

As a condition of primary importance for effective automation the highly efficient interaction between the user and the system is also pointed out. As the requirements to the functioning of the interface system are completely independent from the problems been solved in the course of interaction, the development of the interaction itself can be differentiated in a separate research area. In many cases it's more reasonable to divide the construction of a software system into an interactive module and a problem-oriented module. From another point of view these modules can be considered as managing and executive modules. In the executive module there are included subroutines performing particular actions on the functioning of the system. To the managing module the so called "cover" belongs, i.e. the hierarchical set of submenus, providing a unique choice and activation of the correspondent subroutine from the executive module. A great deal of the time for the implementation of a software system is spent for the designing and testing of this "cover". Hence the idea of computer aided design of this module comes into being.

It's convenient to develop a specialized graphics editor, which will allow describing iteratively the menus in the system being designed. By means of this graphics editor the designer of the system (fig. 2) determines the place of each menu in the hierarchy of the specified menus, defines its attributes (type and displacement of the frame on the screen, text, colours, etc.). Thus a description is entered iteratively of all the submenus and the procedures connected to the options of the main menu, accordingly of the submenus stemming from the main menu. For instance (fig. 3): an option in the created menu can activate either a subroutine (an executable file – in this case the path of the file must be specified, as well as its name), or can activate the creation of a new subroutine which is to be described in the same way (i.e. a recursive subroutine can be applied for the description of the menus). It's appropriate all the values of the menu attributes to be taken from previously defined sets. This allows a full formal and logical control from the system.

Two basic approaches are possible when creating this system:

a.) Retrieval of a previously fixed template of menus, marking those of them, which will be used, thus making them active. The inactive fields in the menu are no longer displayed. At the bottom of the tree (the template) – as the elements of the "leaves" the

user specifies the path and name of the program which is to be activated. To start working with the system the template thus prepared is activated. An advantage of this approach is that the menu interface is easier to implement. A disadvantage is the larger program (managing "cover") – it contains the codes of possible, but not used alternatives.

b.) A menu description is made according to a previously specified algorithm, which takes its hierarchical place in the tree of menus. For each position of this menu definite information is filled in, which indicates whether another menu will be activated though it, or a subroutine will be started. The action is a recursive. This tree is being built, containing information on the hierarchical sequence of menus, connected with the function of the software system being designed. The next stage is the retrieval of the tree, thus a text file is generated, which contains a set of commands in a given programming language, providing the work of the defined "cover" (i.e. – the source of the program). The last stage is compilation in the corresponding programming language, as previous additional corrections and tuning of the obtained text file are possible. An advantage of this approach is the possibility of replacing just the generator module to get programs in different programming languages. The remaining part of the software system – the creating and retrieval of the internal machine representation of the data structure (multy-moving tree) remains standard and does not require additional changes and tuning.

According to the internal machine representation of the menus being described it's convenient to keep information on them in a multy-moving tree (fig. 4). A node of the tree corresponds to each submenu. The hierarchical place of the node determines the hierarchical place of the submenu. Each node keeps part of the specific information on the menu. This menu attributes are stored in an array. The elements of the tree are records/structures (fig. 4), providing information on:

1. option name in the menu;
2. path to an executable subroutine in case this option is chosen;
3. a message to the option;
4. row on which the message is displayed;
5. number of an element in the attribute array;
6. a pointer to a submenu;
7. a pointer to the next option of the same menu.

The array elements are also records/structures containing information on:

1. row and column coordinates;
2. coordinate of the frame upper left corner;
3. number of the characters in a row;
4. number of the rows in a menu;
5. frame type;
6. colour of the text displayed in the menu;
7. background colour of the text;
8. text colour of the chosen option;
9. background colour of the chosen option;
10. frame colour;
11. background frame colour.

After the description of the interface of the software system is finished the multy-moving tree (fig. 4) can be saved in a file (in this case – a text file, including additional control characters). Editing is possible – deleting/adding of a submenu, changing of a attributes and so on. It's an advantage that the user of the system is not interested in a tree – on the screen he gets the menus as they were created and he can edit the existing image.

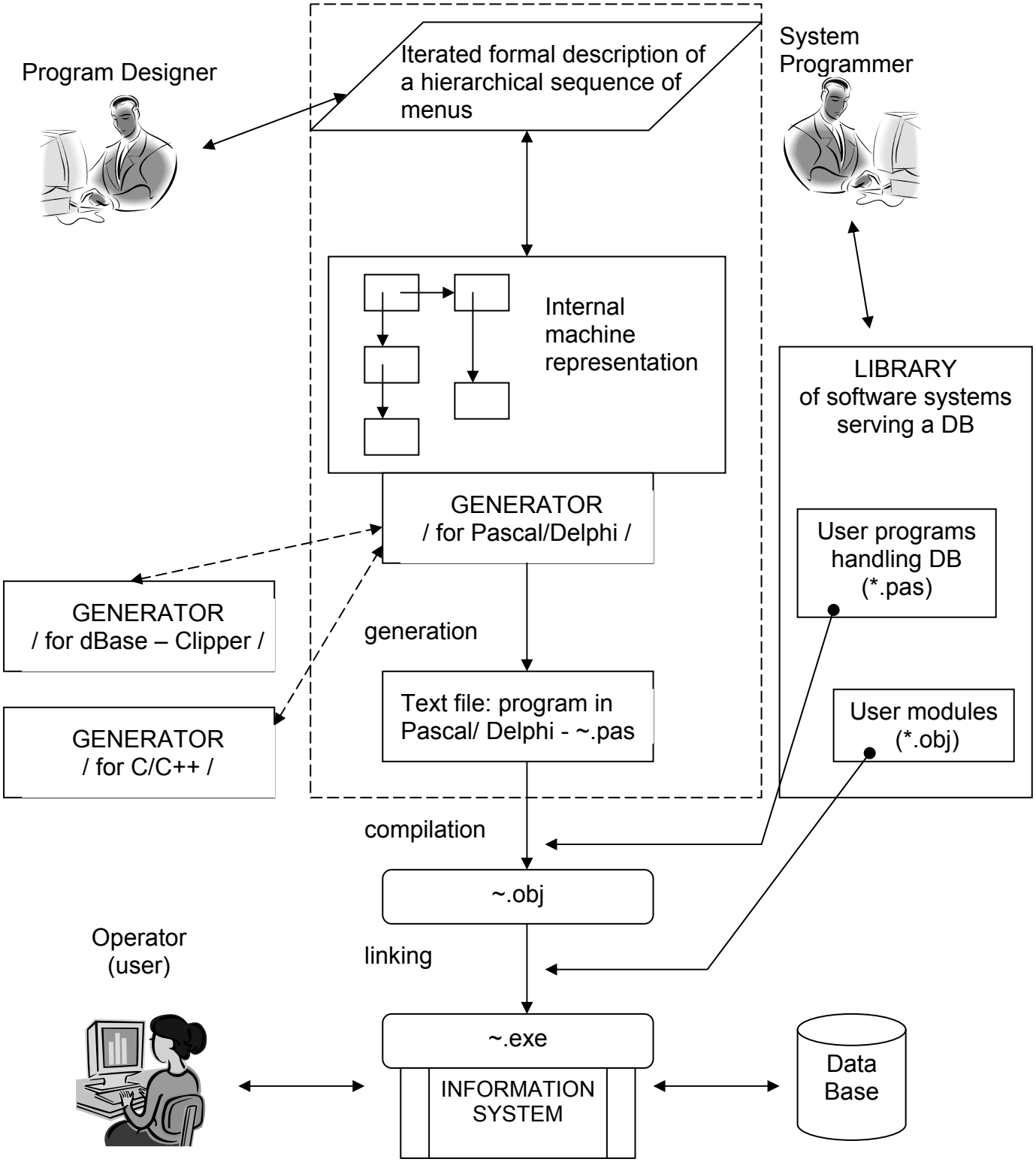

fig. 2 – an application system with automatic generated user interface

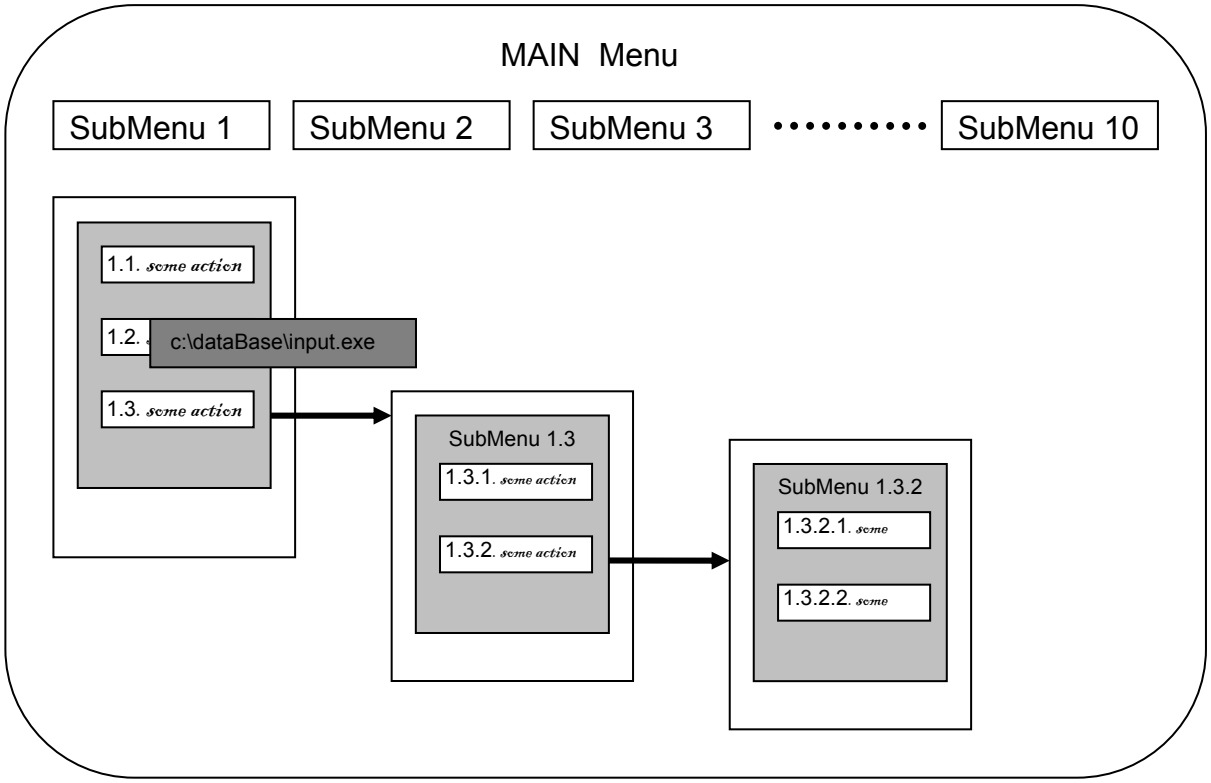

fig. 3 – Automatic generated menus

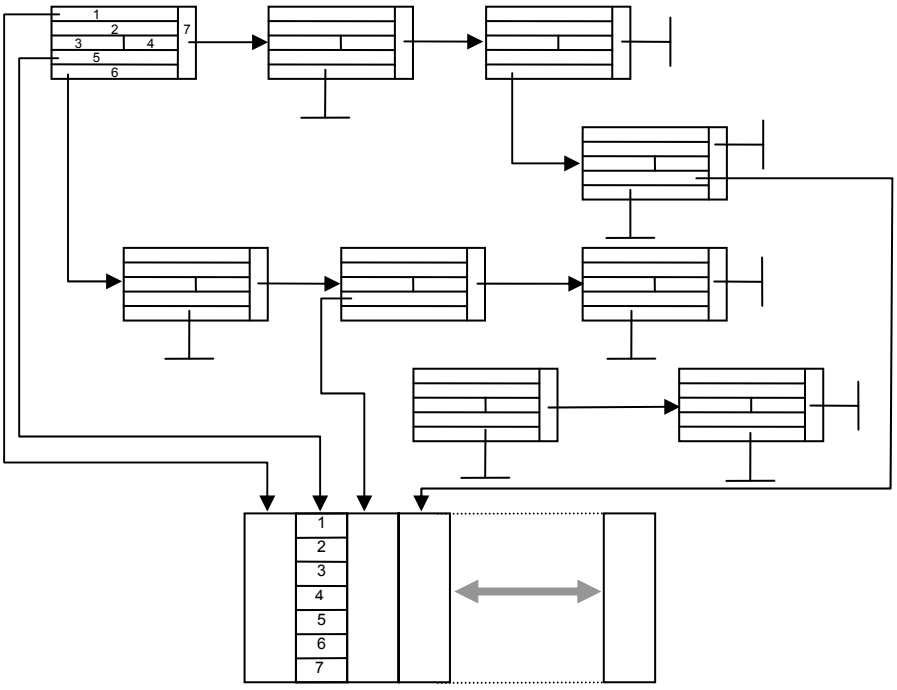

fig. 4 The multy-moving tree

CONCLUSION

Several limitations which are not of grate importance, are inherent to this approach for design of the menu generator – it's assumed that the main menu will not have more than 10 alternatives; the number of the nested levels of submenus is 3.

The suggested architecture is widely applicable by its means any managing module ("cover") of a software system can be designed (fig. 3). No direct connection is necessary to exist between the designers of an information system and the designers of programs (completed modules) for managing the corresponding database(fig. 2). By replacing just the generating module, work with any DBMS is possible.

Creating and using applications of similar systems is closely connected with the automation of programmer's work.

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НЯКОИ ВЪЗМОЖНОСТИ ЗА АВТОМАТИЗИРАНО ГЕНЕРИРАНЕ НА ПРОГРАМИ

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***Резюме**: Автоматизирано генериране на програми – това е направление в софтуерната индустрия, свързано не само с печелене на време и човешки труд, но и с получаването на синтактично чисти и логически коректни модули. Възможно е едно приложение да се раздели на интерфейс и бизнес-логика, като се създадат или използуват различни съществуващи инструменти за итеративно генериране на желаната система.*

***Ключови думи**: автоматизирано генериране на програми, БДИС, Потребителски интерфейси*

INFORMATION SYSTEM FOR MEDICINES

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***Abstract**: The paper describes an information system developed for the needs of medicines database maintenance. It contains information related to the characteristics and availability of medicines and therapeutic substances in a storehouse. Pharmacists are provided with a convenient and easy-to-use system for making relevant references.*

***Keywords**: Information System, Data Base, HTML documents, Medicines, Internet*

METHODS

Different methods can be applied for developing a centralized data repository for a storehouse database [1]. After a careful analysis of the recent trends in software development, the author chose the Web-oriented approach. It is especially appropriate considering the remoteness of the objects, the easiness and elegancy of the system performance as well as the compatibility of the available software and hardware.

No additional programs are needed to be installed. The user simply opens a Web browser, inserts the URL of the site, and enters the system.

Server-side scripting technology based on Active Server Pages (ASP) has been preferred for creating a dynamic website.

The combination of ASP with the functionality of diverse Microsoft's ActiveX controls on one hand, and the application of recent methods for database access (ADO) on the other hand, is a leading technology for server-side scripting [2]. The usage of ASP was predetermined also by the choice of Windows 2008 server platform.

Working with ASPs requires the installation of Microsoft Internet Information Services (IIS) control system on the server.

Fig.1 shows ASP compared to the most popular technologies for creation of dynamic HTML content (CGI script, CGI program and ISAPI dynamic library):

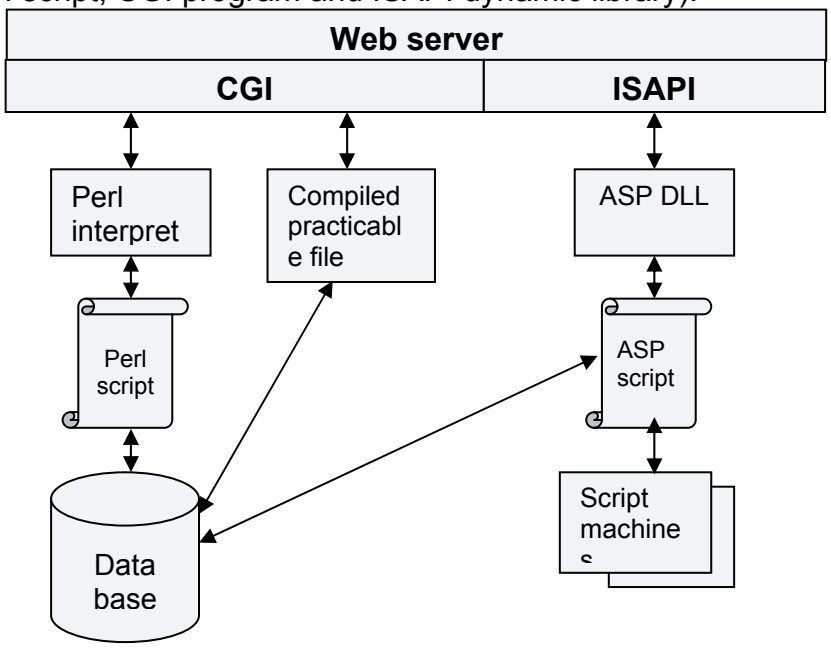

Fig. 1. CGI Script, CGI Program and ISAPI Dynamic Library

ASP ensures the creation of .asp scripts (similar to Perl scripts), which are processed by a special ISAPI library, asp.dll, and the relevant script machines. By standard, the ASP uses VBScript and JavaScript as script languages. ASP combines the comfort for elaboration of script languages (typical for a Perl CGI) with the optimized efficiency of ISAPI (which process the queues by setting parallel branches in the main process instead of starting a new one, as CGI appliances do).

IMPLEMENTATION

Fig. 2 shows modules connection diagram.

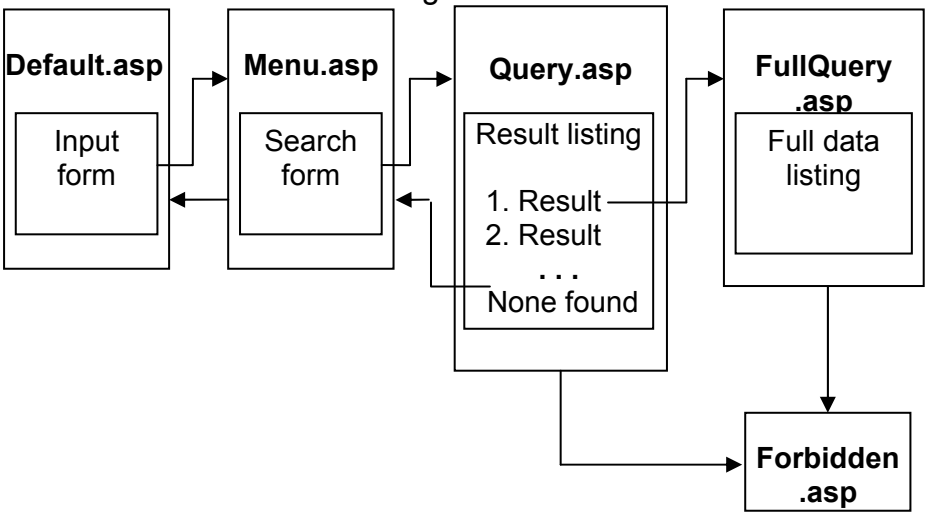

Fig. 2. Models Connection Diagram

Default.asp module accepts the data necessary for user identification and sends it to **Menu.asp** module through the data form. **Menu.asp** module fulfils the connection to the database containing users' accounts. Valid users are allowed to access the system and they can see the system menu for further searches. Invalid users are sent back to the starting point – **Default.asp**.

Search criteria are sent again to the next module, **Query.asp,** through the data form. This module implements the connection with the medicines database. It carries out relevant checkups and displays the results.

The **FullQuery.asp** module shows the full information concerning the medicine in question. The **Forbidden.asp** module is activated when an unauthorized user makes an attempt for direct access to **Query.asp** and **FullQuery.asp** modules.

To access the system the user has to point out the website URL and wait for a connection to the Web server. The server generates HTML page for the system entry, displayed as it follows:

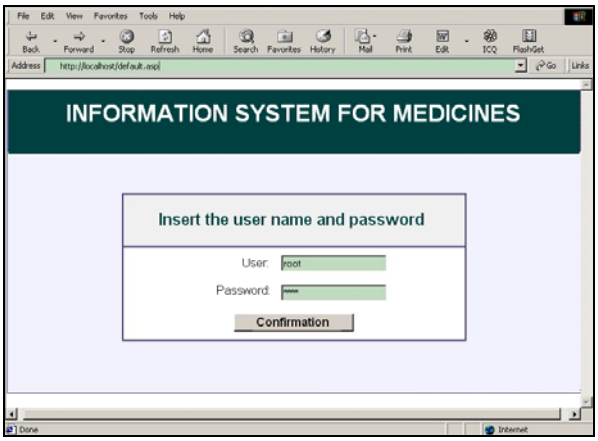

Fig. 3. Users' verification

Here the user enters his/her user name and password. Then he/she has to press either the button 'Enter', or 'Confirmation' using the PC mouse.

If the user is identified, he will be allowed to access the system menu.

The system allows carrying out complex searches by one, two or more parameters, introduced fully or partially. The user enters the parameters he needs and presses the Confirmation button.

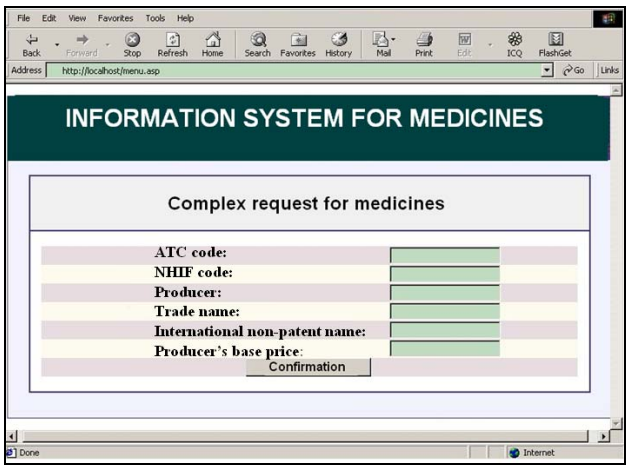

Fig. 4. Parameters for complex search

If there are no records in the system responding to the search criteria, an adequate message is displayed on the screen.

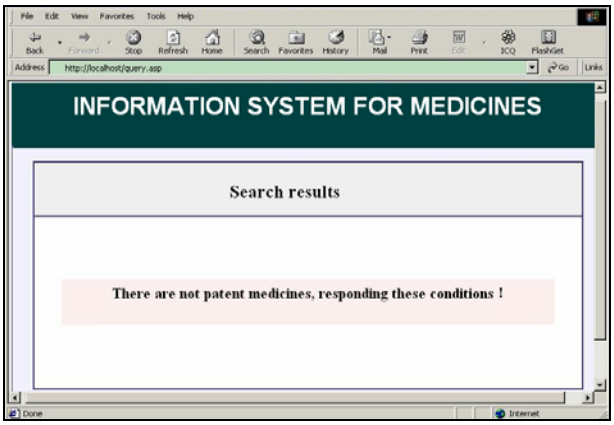

Fig. 5. Results of searching when nothing was found

Using the standard 'Back' button of the browser, the user returns to the previous page and can start a new search.

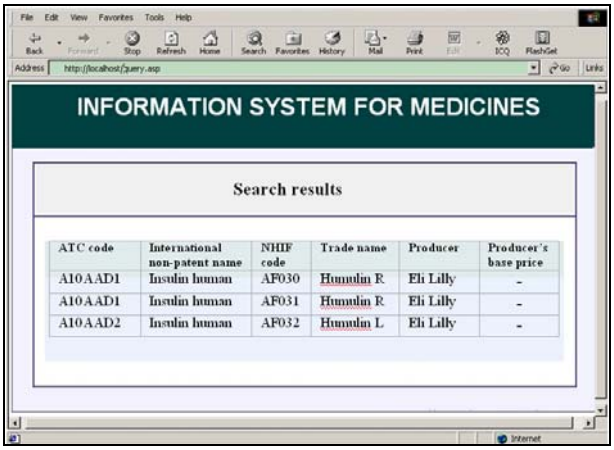

Fig. 6. Search results

If one or more records, consistent to the search conditions, are found in the database, they will be retrieved, but only those fields which correspond to the search will be displayed, as shown on fig.6.

Selecting the relevant hyperlink with the mouse (NHIF code field), the user can get all information about a certain medicament.

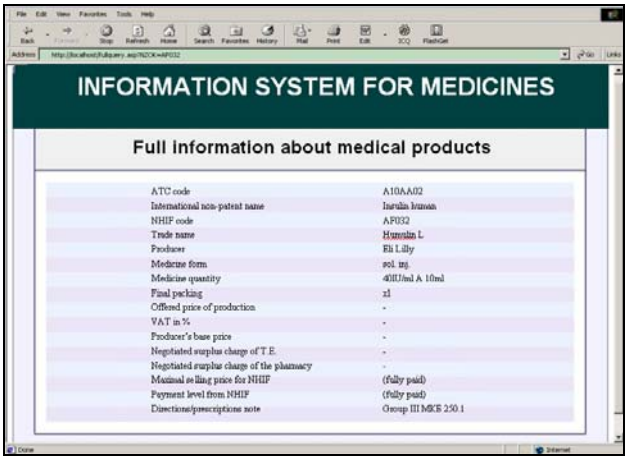

Fig. 7. Information about a medicine

For new references the user presses the Back button and enters the search criteria again.

If the user does not register in the system and tries to start any of the Query.asp and Fullquery.asp modules, the access will be denied because he is not identified.

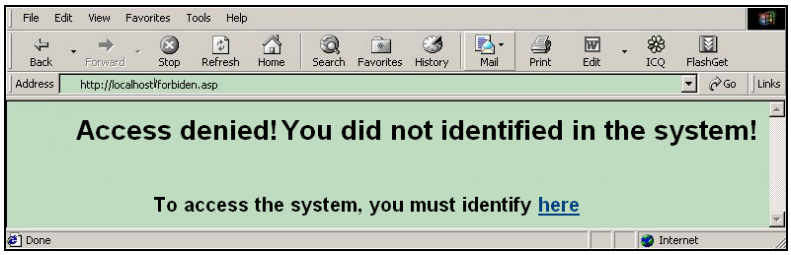

Fig. 8. Not registered user

Since it may happen due to a mistake or timeout of user's session, the author has developed a possibility for returning to the system's home page by selecting the hyperlink, marked with 'here'.

CONCLUSIONS

- The websites generated by the system are in conformity with the available versions of HTML protocol supported by the web browsers Microsoft Internet Explorer and Netscape Navigator, considering their wide usage. Internet Explorer is recommended, as it was used for this project development.
- There are no any special requirements concerning the system hardware.
- The requirements, set on the server's hardware however, are determined by the range of anticipated visits and the database space. The system designed by the author was developed on Pentium III, 1GHz, 256 MB RAM and 100 GB hard disc.
- The system may be further developed with an administrative part that will allow the database expanding and editing through Web interface. Thus, the need of MS Access 2000 installation on the server, as used in the proposed system, will be avoided.

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[4] http://www.lcaydata.com/sql.htm

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ИНФОРМАЦИОННА СИСТЕМА ЗА ЛЕКАРСТВА

Маргарита Теодосиева

Русенски университет "Ангел Кънчев"

Резюме: *Публикацията представя информационна система, разработена за нуждите на поддръжка на база данни за информация за лекарства. Тя съдържа информация, свързана с характеристиките и наличието на лекарствата, на веществата за терапия и складовете. На фармацевтите е предоставена удобна и лесна за използване система, за да направят съответните справки.*

Ключови думи: *Информационна система, База от данни, HTML документи, Лекарства, Интернет*

EXTENDING THE LIFETIME OF WIRELESS SENSOR NETWORKS BY USING A MODIFIED METHOD FOR HIERARCHICAL ORGANIZATION OF THE SYSTEM IN CLUSTERS WITH UNEQUAL NUMBER OF DEVICES

Mihail Iliev

Angel Kanchev University of Ruse

Abstract: *Wireless sensor networks are a new type of telecommunication networks with many areas of implementation. These systems are known for their many advantages and few disadvantages. This paper investigates one of the biggest problems in this research field – the unequal energy dissipation and the unequal lifetime of the sensor motes. In order to solve this problem, first the standard approach for hierarchical organization of the networks is analyzed and then a solution for solving of this problem is proposed. Simulation models of wireless sensor networks are created using MatLAB, and the results of the evaluation of the new approach are compared to the results obtained by the standard one.*

Keywords: *Wireless sensor networks, clusters, hierarchical networks, sensor motes, cluster heads*

INTRODUCTION

Sensor networks are used in many aspects of modern life and are implemented for home automation, consumer electronics, military application, agriculture, environmental and health monitoring geophysical and weather measurement. Usually the sensor devices are small and inexpensive and can be produced and deployed in large numbers. Due to the requirements for their small size and low price, these devices are severely constrained in terms of energy resources, memory, computational speed and bandwidth. Therefore, it is important to design sensor networks aiming to maximize their life expectancy. There are many factors that can influence the lifetime of a sensor mote but the approach for organization of the network is probably the most critical one. This is why this research is focused exactly at them.

ANALYSIS OF THE STANDARD APPROACH FOR ORGANISATION OF THE CLUSTERS IN WSN

The standard approach for organization of the wireless sensor networks defines the division of the system into clusters, composed of equal number of devices. The algorithm that defines to witch layer a device is belonging is presented in the next figure.

By analyzing the block scheme from Fig.1, a conclusion can be made, that when in the system is used the standard approach for hierarchical organization the first layer of the network will consist of the devices, which are in communication range of the base station. The devices of every other layer will communicate with the sensors from the previous one, but not with the devices from the layers before that (Fig.2).

After the conclusion of this process the total number of the clusters in the system can be divided by the number of the layers N_L, and thus obtaining the average number of clusters per layer:

(1) $$N_{CL}^{avg} = N_{CL} / N_L$$

Assuming that the devices are distributed equally then the average number of devices for a layer can be calculated by:

(2) $$n^{avg} = n / N_L$$

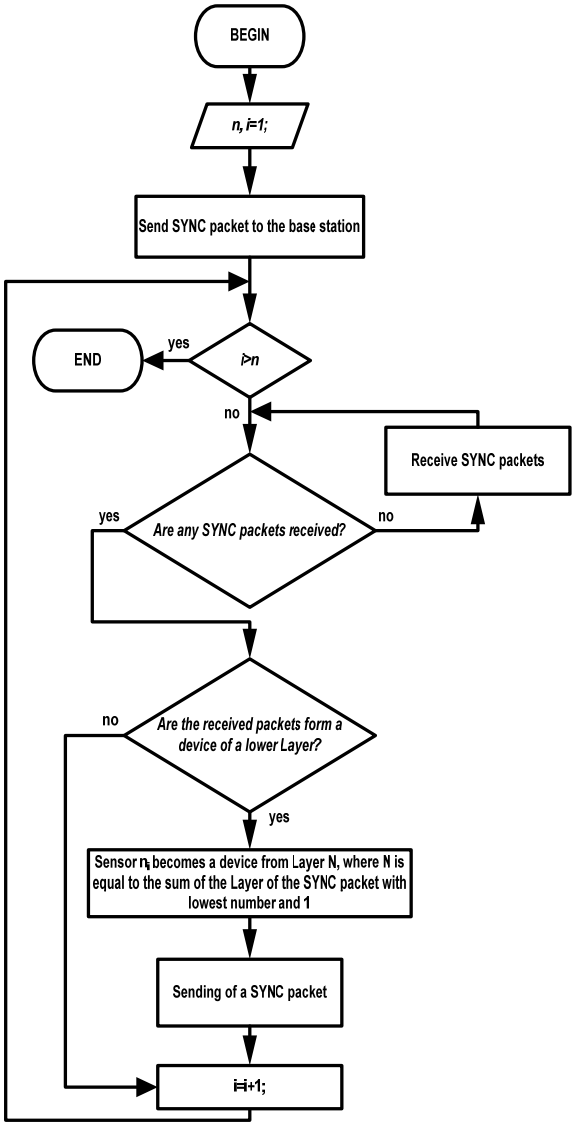


Fig.1. Block scheme of the standard approach for organization of the hierarchical WSN

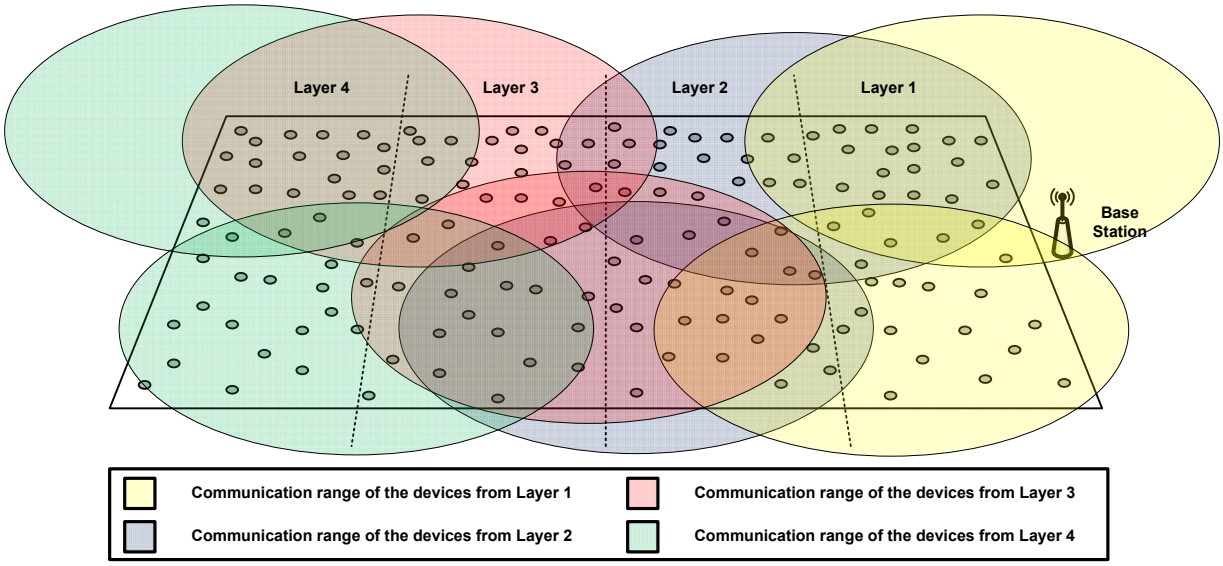


Fig.2. Organization of a hierarchical WSN using the standard approach.

After the average number of devices is determined, they are distributed equally in the corresponding clusters for every layer.

By using these rules, the possibility for a certain module from a given layer to become a cluster head can be given by:

$$P_{n_i}(t)\begin{cases}\dfrac{N_{CL}{}^{avg}}{n^{avg}-N_{CL}{}^{avg}\left(R_e \bmod \dfrac{n^{avg}}{N_{CL}{}^{avg}}\right)} & npu \quad C_{n_i}(t)=1 \\ 0 & npu \quad C_{n_i}(t)=0\end{cases} \tag{3}$$

After the completion of the process for organization of the hierarchical wireless sensor network, the system is divided into clusters of equal number of sensor modules.

SYNTEZIS OF A ADVANCED APPROACH FOR HIERARCHICAL ORGANIZATION OF WSN IN CLUSTERS OF UNEQUAL NUMBER OF SENSOR MOTES

As discussed in the literature [1], the cluster heads are using out their energy reserves mainly for communication purposes in their own cluster and between their cluster and other clusters in the network. In the first case the amount of energy, necessary for receiving of the information is proportional to the number of devices, which are transmitting to the cluster head, while in the second case this amount can be expressed as a function of the expected amount of data, which this device is transmitting toward the base station. If it is assumed that the cluster heads can be positioned precisely in the sensor field, than by changing the size of the clusters (and by that changing also the number of the sensor nodes in the cluster) we can change the amount of energy that every cluster head is going to need for the communication processes. The implementation of this approach will lead to a situation, where for all communication rounds in a epoch the average amount of energy in the cluster heads will be almost equal and by that one of the major problems of the WSN will be solved – the early depletion of the energy of some of the network devices, and by that the reduction of the network lifetime. The main reason for this study of the parameters of the cluster heads is the fact, that these modules have the largest impact on the network performance, and the depletion of the energy of even a single cluster head can lead to the loss of data from the whole cluster under its management. To study the above mentioned parameters a WSN, which consists of *n* sensor nodes can be investigated. These sensor motes are equally distributed on a circle with radius of R_{SF}. The cluster heads for every layer are placed in this sensor field at an equal distance one from another. By placing them is such a matter, the coordinates of these devices will match the coordinates of points on the internally concentric circles of the given circular sensor area. The base station, which will receive the data of the sensor field, is placed in the center of the area (Fig.3). The data received by all sensors in the clusters is transmitted to the corresponding cluster head, which aggregates the information, and forwards it to the base station. The transmission of the aggregated packets is completed by forwarding the packets to the closest cluster head in direction toward the base station.

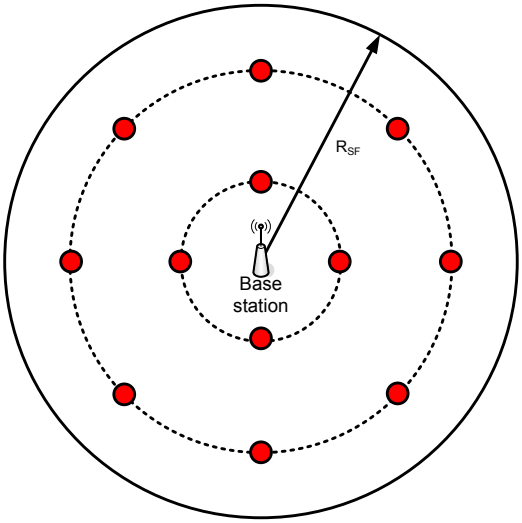
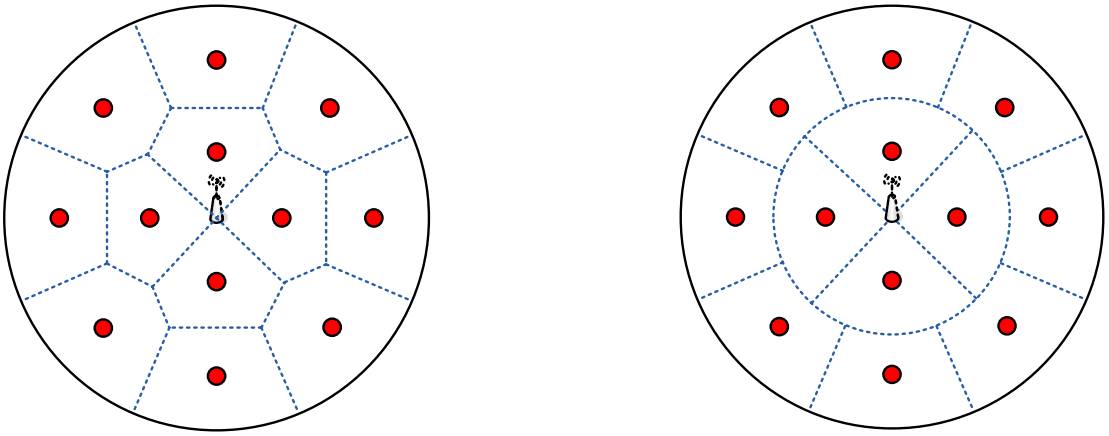


Fig.3. Deterministic distribution of the cluster heads in internally concentric circles around the base station.

Assuming the distribution of the cluster heads as shown in Fig.3, every of the clusters can be represented by a Voronoi tessellation with center the cluster head. By doing this a multilayer hierarchical structure of a sensor network can be created. Fig.4 (a) shows a two layered network, with the internal layer (Layer 1) consisting of N_{CLL1} clusters, and the external layer (Layer 2) consisting of N_{CLL2} cluster. In order to simplify the analysis of this model the Voronoi tessellations will be presented as parts of circles as shown on Fig. 4 (b).



a) *b)*

Fig.4. Wireless sensor network with the clusters represented as Voronoi tessellations (a) and parts of circles (b).

Due to the symmetrical distribution of the cluster heads in concentric circles, all clusters for a given layer will be characterized by a common shape, size and area, but will be different, compared to the clusters of the other layers like in Fig.4 (b). If R_{SFL1} is the radius of the circle, which contains the given number of clusters from the first layer of the system, then by changing this parameter the area of coverage of the circle will change, and by that the number of the sensor motes in every of the clusters will change.

If it is assumed, that all cluster heads are equally effective in the implementation of the data aggregation mechanism, and that this effectiveness is represented by the aggregation coefficient – γ, than the amount of data send to the base station by every of the cluster heads for a communication round is γn_c, where n_c is the sum of the sensor motes in the cluster and the devices sending data to the investigated cluster head, and γ is

changing I the limits between 1 and $1/n_c$. This means that when $\gamma=1/n_c$, then we have a system with full aggregation of the data, and if $\gamma=1$ the cluster head is not performing any aggregation at all. By assuming the model for distribution of the information given in [2] and by using a data delivery approach with retransmission of the information as the one in [3], then the amount of energy, which is used for the transmission of a packet with the size of b bits at a distance of d meters is given by the following equation:

(4) $$E_{TX} = b\left(E_{elect} + E_{fs} d^{k}\right).$$

The amount of energy used for the reception of a packet with the same size is given with:

(5) $$E_{RX} = bE_{elect}\ .$$

For the studies of the approaches for organization of hierarchical wireless sensor networks is assumed the model for distribution of the information in free space, which means that the fading coefficient k is equal to 2. Additionally it is assumed that there are ideal conditions for the network (there are no transmission errors and the data overhead for system messages is not investigated).

For every cluster in the network the total amount of energy of the devices is determined by the location of the cluster head. In order to achieve constant value for the amount of energy used for every communication round in the cluster, every cluster head has to be static and not movable. In this case if it is assumed that the cluster heads are in the center of the clusters, as in Fig.4, then the distances between the cluster heads from both Layers of the system and the base station can be expressed by the following equations:

(6) $$d_{CH1BS} = \frac{\int_0^{R_{SFL1}} r2r\sin\left(\frac{\beta_1}{2}\right)dr}{R_{SFL1}^2\frac{\beta_1}{2}} = \frac{2}{3}R_{SFL1}\frac{\sin\left(\frac{\beta_1}{2}\right)}{\frac{\beta_1}{2}}$$

(7) $$d_{CH2BS} = \frac{\int_{R_{SFL1}}^{R_{SF}} r2r\sin\left(\frac{\beta_2}{2}\right)dr}{\left(R_{SF}^2 - R_{SFL1}^2\right)\frac{\beta_2}{2}} = \frac{2}{3}\frac{R_{SF}^3 - R_{SFL1}^3}{R_{SF}^2 - R_{SFL1}^2}\frac{\sin\left(\frac{\beta_2}{2}\right)}{\frac{\beta_2}{2}}$$

where β_1 and β_2 are the angles defined by the number of clusters in every layer of the system and are equal to:

(8) $$\beta_i = \frac{2\pi}{N_{CLL_i}}, i \in [1,2]$$

Analyzing the model above, one can conclude that the system is organized during the network convergence phase, and the formed clusters remain untouched for the lifetime of the WSN. Considering this, the lifetime of the network can be defined as the time interval from the beginning of the exploitation of the system till the depletion of the energy of any sensor mote. In this way the situations in which the cluster heads are depleting their energy and are having impact on the total system performance are ruled out.

The total amount of energy, necessary by the cluster heads at Layer 1 and Layer 2 for the communication processes can be obtained by using:

(9)
$$E_{CH1} = \begin{pmatrix} bE_{elect}\left(n_{SM_{CL1}} - 1\right) + \\ bE_{DA} n_{SM_{CL1}} + \gamma b n_{SM_{CL2}} \dfrac{N_{CLL2}}{N_{CLL1}} E_{elect} + \\ + b\gamma\left(n_{SM_{CL2}} \dfrac{N_{CLL2}}{N_{CLL1}} + n_{SM_{CL1}} \right)\left(E_{elect} + E_{fs} d^2_{CH1BS}\right) \end{pmatrix}$$

(10)
$$E_{CH2} = \begin{pmatrix} bE_{elect}\left(n_{SM_{CL2}} - 1\right) + \\ bE_{DA} n_{SM_{CL2}} + \\ \gamma b n_{SM_{CL2}}\left(E_{elect} + E_{fs} d^2_{CH2CH1}\right) \end{pmatrix}$$

where d_{CH2CH1} and d_{CH1BS} are correspondingly the distance between the cluster head at Layer 2 and its neighbor at Layer 1 and the distance between the base station and the cluster head at Layer 1. The total amount of energy used to aggregate the data is given by the parameter E_{DA}, and n_{SMCL1} and n_{SMCL2} are the numbers of the sensor motes for the clusters in Layer 1 and 2 of the system. The last two parameters are proportional to the area covered by the clusters and can be calculated with:

(11)
$$n_{SMCL\,1} = n \frac{R^2_{SFL\,1}}{R^2_{SFL\,2} N_{CLL\,1}}$$

(12)
$$n_{SMCL\,2} = n \frac{R^2_{SFL\,2} - R^2_{SFL\,1}}{R^2_{SFL\,2} N_{CLL\,2}}$$

The ratio N_{CLL2} / N_{CLL1} in (9) and (10) is used to show that the packets generated by the cluster heads at Layer 2 of the system are equally distributed among the cluster heads in Layer 1 of the network. Organization of a hierarchical WSN using the modified approach is presented on Fig. 5.

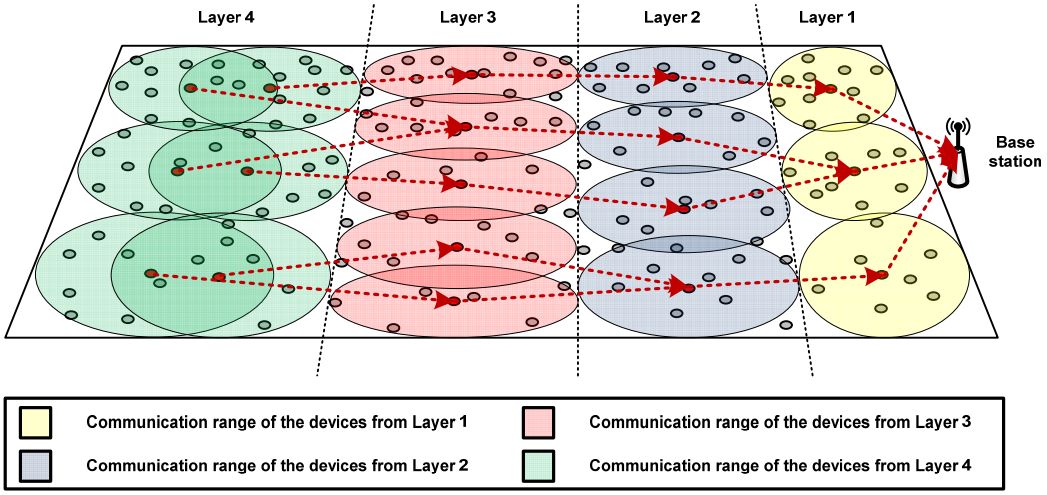


Fig.5. Organization of a hierarchical WSN using clusters with unequal number of sensor

SIMULATION EVALUATION OF THE METHODS FOR HIERARCHICAL ORGANIZATION OF WSN

In order to evaluate the consummation of energy it is necessary to study the results obtained by the simulation experiments of both approaches. For those purposes two simulation model were created using MatLab. For the simulations we assume all simulation and system parameters as in [4].
The first of the conducted simulations is done with a sensor field of 100x100 meters and with the base station at the center of this field. The initial energy of all 100 sensor devices and cluster heads is equal to 0.5 J. Results ofdevices the conducted simulation are shown of Fig.6.

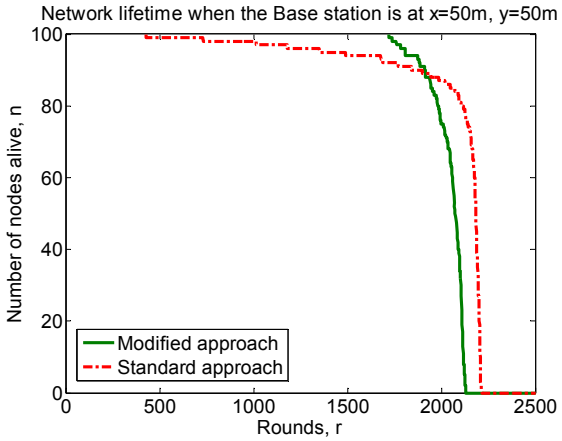


Fig.6. Network lifetime for 100 sensor nodes using both approaches

As shown in the figure the total lifetime of the modified approach is less than the one of the system with the standard approach, but the modified approach provides a longer and stable operation of the system and the first sensor node depletes its energy around the 1650 round compared to the 450 round in the system running with the standard approach.

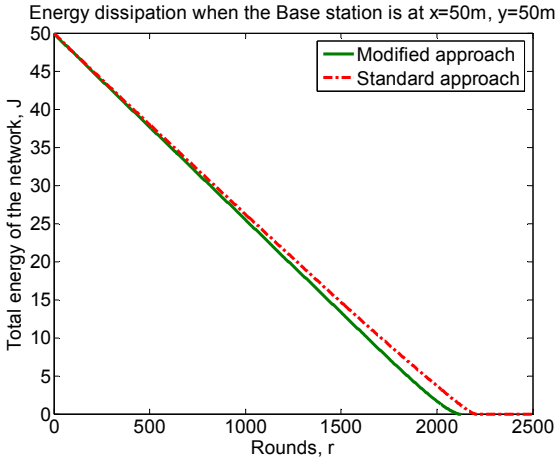


Fig.7. Organization of a hierarchical WSN using clusters with unequal number of sensor devices

Fig.7. presents the total amount of energy in the network for the systems running on both approaches. As seen from the figure the modified approach is consuming more energy than the standard approach. This is explaining the shorter total network lifetime of this approach.

CONCLUSION

From the conducted analysis and the realized simulation experiments it is obvious that the modified approach is better in terms of system lifetime. One of the directions for further improvement of this approach will be to increase the total lifetime of the systems, which use this approach by reducing the increased energy usage. Despite this the modified approach is showing significant improvement in terms of stability of the systems compared to the standard one.

ACKNOWLEDGEMENTS

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УВЕЛИЧАВАНЕ ЕКСПЛОАТАЦИОННАТА ПРОДЪЛЖИТЕЛНОСТ НА БЕЗЖИЧНИ СЕНЗОРНИ МРЕЖИ ЧРЕЗ МОДИФИЦИРАН МЕТОД ЗА ЙЕРАРХИЧНА ОРГАНИЗАЦИЯ НА СИСТЕМАТА В КЛЪСТЕРИ ОТ РАЗЛИЧЕН БРОЙ УСТРОЙСТВА

Михаил Илиев
Русенски университет "Ангел Кънчев"

Резюме: *Безжичните сензорни мрежи са нов тип телекомуникационни системи с много области на приложение. Тези системи са известни с многото си предимства и разнообразни приложения. В тази статия е разгледан един от най-значимите проблеми на тези мрежи – неравномерното изразходване на количеството енергия от сензорните устройства и тяхната различна експлоатационна продължителност. За да се реши този проблем, първоначално е анализиран стандартния подход за йерархична организация на мрежите, след което е предложен алтернативен вариант на този процес. Симулационните модели на безжичните сензорни мрежи са създадени с MatLAB, като резултатите от подходите са анализирани и сравнени.*

Ключови думи: *Безжични сензорни мрежи, клъстери, йерархични мрежи, сензорни модули, устройства за управление на клъстери.*

ONE APPROACH FOR CONTINUOUS SIGNALS REPRESENTATION

Georgi Krastev, Tsvetozar Georgiev

Angel Kanchev University of Ruse

Abstract: *The purpose of this article is to describe how to provide signals geometrically as vectors. Discussed are the theoretical foundations of this approach and a concrete example in Matlab environment is presented.*

Keywords: *Signal Processing, Vectors, Vector spaces.*

INTRODUCTION

There is an extraordinary diversity in the classification of signals and methods of their presentation or description [1, 2, 3, 5]. The larger or smaller success in applying one method or another depends on and is determined mainly thereof how the contained in the signal information will be used. The mathematical apparatus of the functional analysis makes it possible to conduct full and sufficient universal research in this regard.

Nowadays, the scientific-technical bodies show increased interest in summarizing the many known ways and methods for analyzing the signals so that they can be treated by a single mathematical positions, from the one new common base. It is believed that implementing this approach different methods can be used for more general and effective application in solving various technical problems.

LAYOUT

1. Vector representation and description of continuous signals

It is not difficult to understand that the task of complex signals decomposition to simple, elementary signals is similar to the task of ordinary vector decomposition in three-dimensional space to its components of basic unit vectors, $\vec{i}$, $\vec{j}$, $\vec{k}$ - Fig.1.

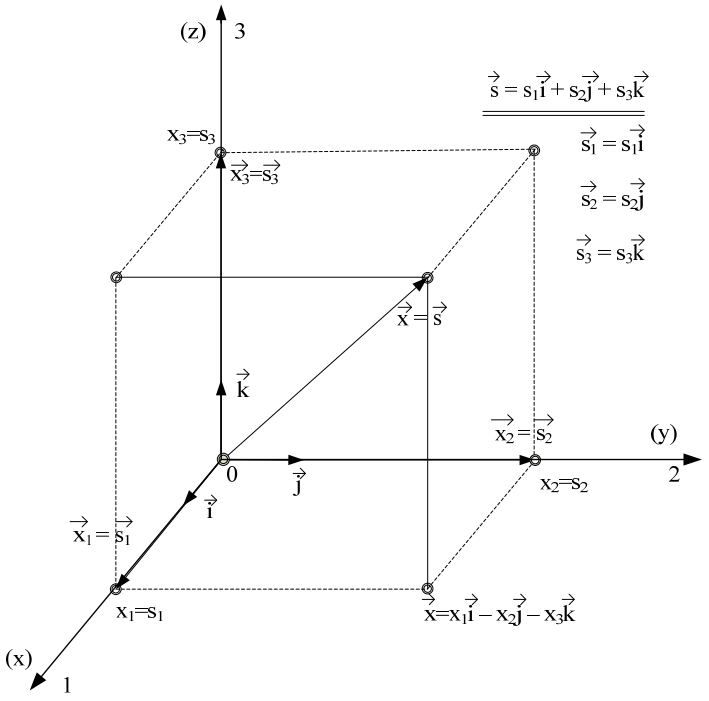

Fig.1. Vector in three dimensional space

Presentation of a signal - "vector" in the form of a vector sum
$\vec{s}(t) = \vec{i}\,s_1(t) + \vec{j}.s_2(t) + \vec{k}.s_3(t);$

$$\vec{s} = \vec{i}\,s_1 + \vec{j}.s_2 + \vec{k}.s_3 \qquad (1)$$

is called the decomposition of the vector $\vec{s}$(t)= $\vec{s}$ to orthogonal unit vectors (orti) $\vec{i}$, $\vec{j}$, $\vec{k}$. Because the "vectors" are elements of decomposed "vector" it is perceived to call them components of the vector $\vec{s}$ at the basic $\vec{i}$, $\vec{j}$, $\vec{k}$. We see that the coefficients s_1, s_2 and s_3 represent himself as projections of the vector $\vec{s}$ on the axes $\vec{i}$, $\vec{j}$, $\vec{k}$, i.e. they are coordinates of the vector $\vec{s}$. Stated otherwise, this means that the vector of three dimensional space is completely determined by the sum of its coordinates.

$$\vec{s}(t) = \{s_1(t), s_2(t), s_3(t)\};\ \vec{S} = \{s_1, s_2, s_3\}. \qquad (2)$$

For the generalization of the vector of three dimensional space concept in the case of n-dimensional space a specific example can be used. In Fig. 2 is shown a graph of a time signal *s(t)*, which represents a continuous time function in the final interval (0,*T*). The idea of this signal can be obtained in the case where an aggregate of its values in the points t_1, t_2, t_3 , ..., t_k ,..., t_n are given. These points are separated one another with a small interval

$$\Delta t = \frac{T}{n}, \qquad (3)$$

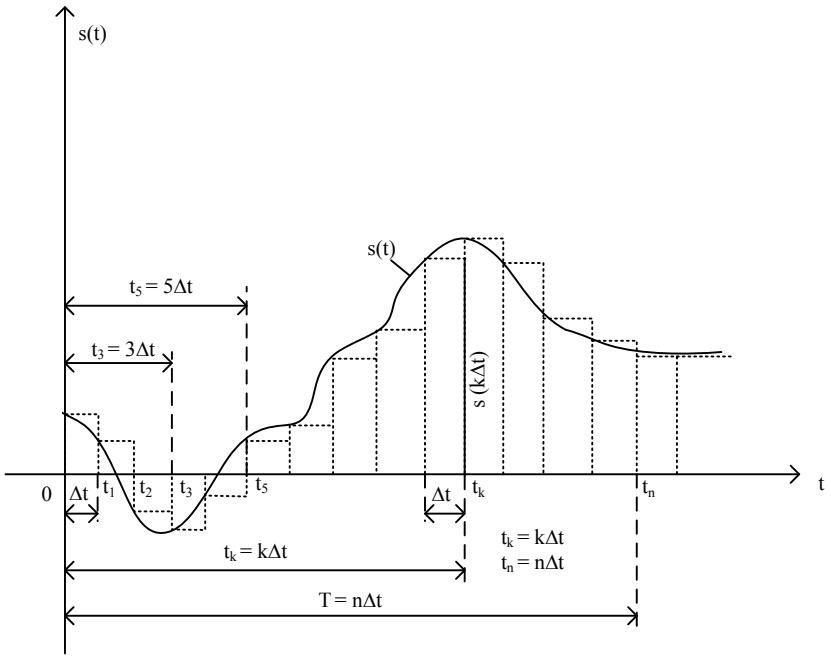

Fig.2. Vector representation of continuous signals

The values of the signal in these discrete points are respectively

$$s_1 = s(\Delta t), s_2 = s(2\Delta t), \ldots, s_k = s(k\Delta t), \ldots, s_n = s(n\Delta t)\ . \qquad (4)$$

Assuming that this signal can be presented with a conditional "vector", it is not difficult to understand that for its full determination are needed

$$n = \frac{T}{\Delta t} \qquad (5)$$

coordinates which represent samples of instant values of the signal at the moments t_1, t_2, t_3 , ..., t_k ,..., t_n.

For major coordinate determinants which conditionally to play the role of a single vectors, can be considered rectangular pulses with a height of 1 - "one", which are shift against each other at an interval *t*, defined by (5). The whole system of these *n* coordinate determinants pulses with a height 1 can be represented "analytical" with the following singular function:

$$\psi_k(t) = \psi_k(t - k\Delta t) = \{1, t_k \le t \le t_{k+1}; 0, t_k > t > t_{k+1}\} \ k=1,2,\ldots,n. \quad (6)$$

Based on all the above arrangements and acceptances, the signal *s(t)* can be approximately represented in the following component form (linear combination of orthogonal functions), similar to (1):

$$s(t) = s_1\psi_1(t) + s_2\psi_2(t) + \ldots + s_n\psi_n(t) = \sum_{k=1}^{n} s_k\psi_k(t). \quad (7)$$

The expression (7) represents the signal *s(t)* in the form which is obtained as the result of signal decomposition in elementary coordinate signal-functions defined by the expression (6), with coefficients (4). By the analogy to (2) the signal *s(t)* can be represented in a more compact form - in the form of vector, given by its *n* coordinates:

$$\vec{s} = (s_1, s_2, \ldots, s_n) \quad (8)$$

This type of recording the signal *s(t)* means that it corresponds to a vector (8) in *n*-dimensional space. Any random signal may be presented in the form of a sum analogous to (7).

2. Presentation of the signals as elements of linear spaces

Once accepted conditionally, that the signal in some preliminary arrangements may be regarded as a vector in *n*-dimensional space, by analogy of the vector in three-dimensional space the term "length" or "norm" of the signal may be defined, as follows:

$$\|\vec{s}\| = \sqrt{s_1^2 + s_2^2 + s_3^2 + \ldots + s_n^2}. \quad (9)$$

If there are two signals *s(t)* and $\nu(t)$, then the norm of their difference $\|s(t) - \nu(t)\|$ will be clearly defined by the expression

$$d\|s(t) - \nu(t)\| = \sqrt{\int [s(t) - \nu(t)]^2 dt} = d(s, \nu). \quad (10)$$

It is not hard to see that (10) characterized actually mean square deviation of the signal *s(t)* from the signal *v(t)*. It is a geometric analogue of the distance between the vectors $\vec{s} = (s_1, s_2, \ldots, s_n)$ and $\vec{\nu} = (\nu_1, \nu_2, \ldots, \nu_n)$, i.e.

$$d(\vec{s}, \vec{\nu}) = \sqrt{\sum_{k=1}^{n} (s_k - \nu_k)^2} = \|\vec{s} - \vec{\nu}\|. \quad (11)$$

Another important concept is the concept of "scalar product" of the signals *s(t)* and $\nu(t)$, defined by the expression

$$\int s(t)\nu(t)dt = (s,\nu)\,. \tag{12}$$

This definition of the scalar product of two signals *s(t)* and $\nu(t)$ is a generalization of the scalar produce of two vectors $\vec{s}$ and $\vec{\nu}$, i.e.

$$(\vec{s},\vec{\nu}) = \sum_{k=1}^{n} s_k \nu_k. \tag{13}$$

It is necessary to pay attention to the following interesting and important fact. In the space of continuous signals *s(t)*, $\nu(t)$ with the scalar product of the type (12), the norm of the no interrupted signal is defined by the expression

$$\|s(t)\| = \sqrt{(s,s)} = \sqrt{\int s^2(t)dt} \tag{14}$$

It is obtained from (12) when substitute $\nu(t)$ with *s(t)*.

Space in which the norm of the signal (function) is given with the scalar product (12) is called Hilbert. It is indicated by the symbol L^2.

In the *n*-dimensional space the norm of the vector is defined also with the scalar product

$$\|\vec{s}\| = \sqrt{(\vec{s},\vec{s})} = \sqrt{\sum_{k=1}^{n} s_k^2} \tag{15}$$

Space in which the norm is given by the scalar product (13) is called Euclidean. It is indicated by the symbol R_n.

The method of determining the rate and the distance is called a metric of the space.

In terms of the above situations should be mentioned very briefly some other more fundamental correlations. They are given below.

From the vector calculus (respectively, from linear algebra) it is known that the absolute value of the scalar product of two vectors can not be greater than the product of their norms, which means that inequality is always true:

$$\left|(\vec{s},\vec{\nu})\right| \le \|\vec{s}\|.\|\vec{\nu}\|. \tag{16}$$

Cosine of the angle between two vectors $\vec{s}$ and $\vec{\nu}$ is given by the expression

$$\cos\varphi_{s\nu} = \frac{(\vec{s},\vec{\nu})}{\|\vec{s}\|.\|\vec{\nu}\|}\,. \tag{17}$$

The absolute value of (17) can never be greater than one.

Cosine of the angle between unit vectors $\vec{\psi}$ and $\vec{\eta}$ is obviously equal to their scalar product, i.e. $\cos\varphi_{\psi\eta} = (\vec{\psi},\vec{\eta})$. The cosine of the angle between normalization signals (functions) $\left[\|\psi(t)\| = \|\eta(t)\| = 1\right]$ - is true: $\cos\varphi_{\psi\eta} = (\vec{\psi},\vec{\eta}) = \int \psi(t)\eta(t)dt$.

On Fig. 3 are shown eight experimental curves after an experiment with a mobile research laboratory [4]. The minimum, average and maximum values are depicted on Fig. 4.

On Fig.5 are shown the results obtained in the Cartesian coordinate system, applying the discussed method.

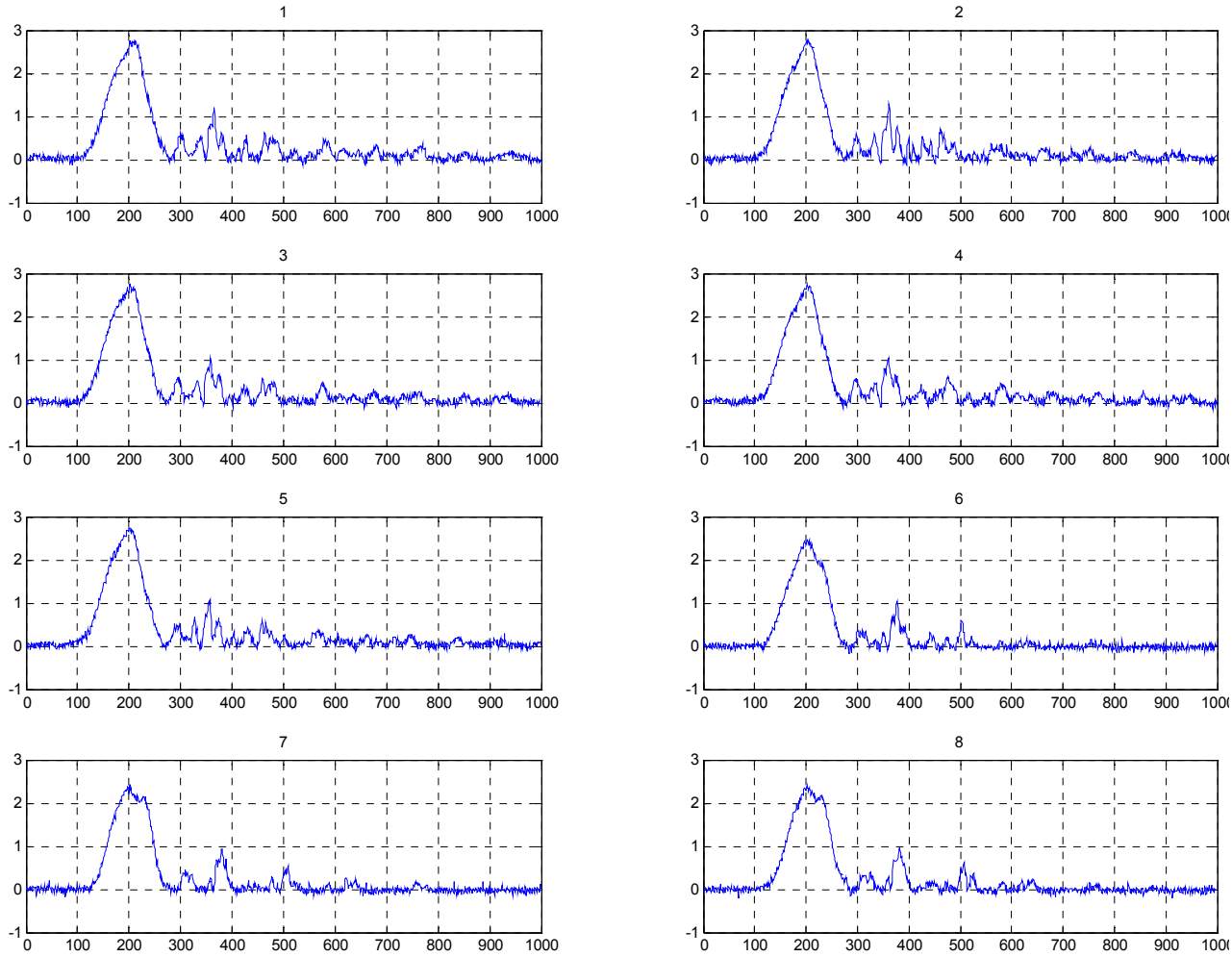

Fig.3. Examples of experimental realizations

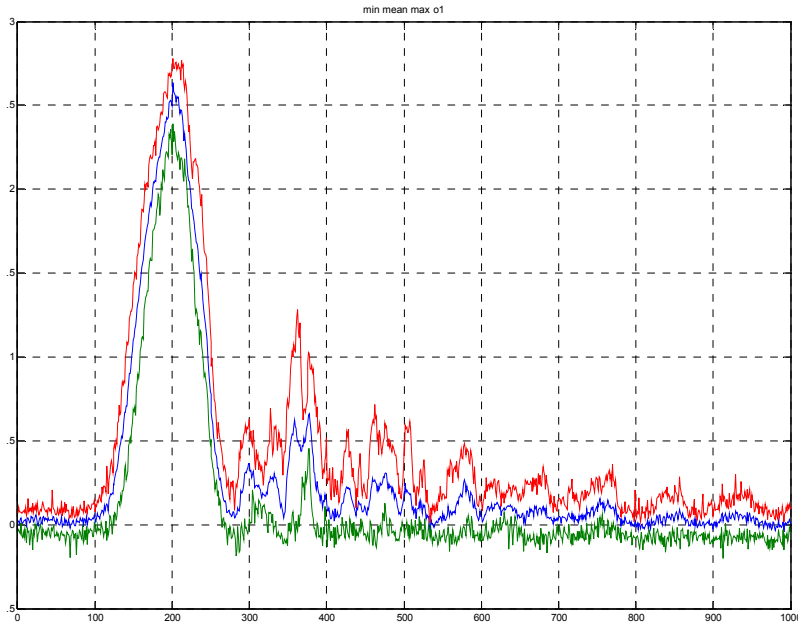

Fig.4. Minimum, average and maximum curves

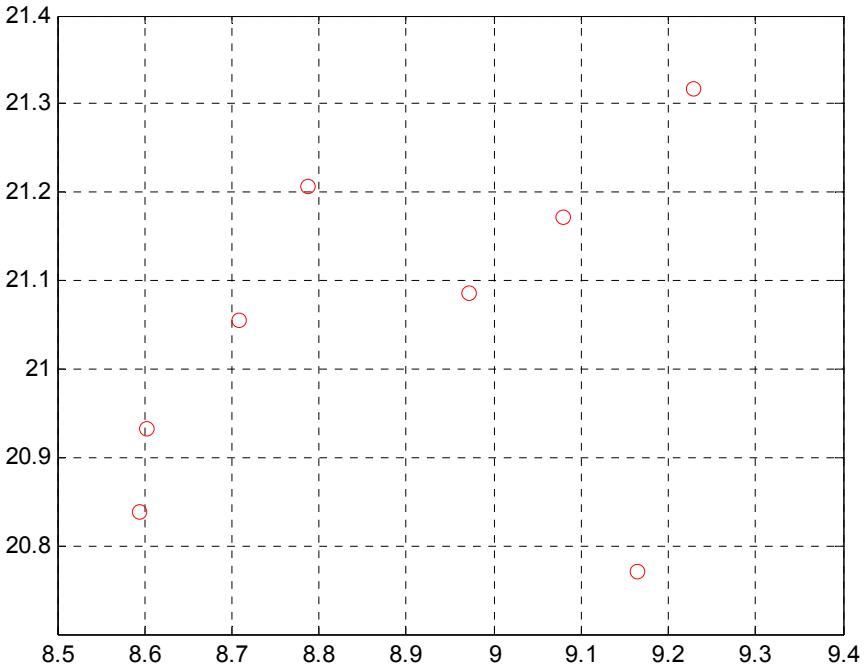

Fig.5. Obtained results

CONCLUSIONS AND FUTURE WORK

By nature for a man is easier, faster and better to understand the mathematical nature of things when they are illustrated geometrically. This feature is based on the idea of signals to be presented geometrically-dimensional and infinite-dimensional or final-vector space as vectors.

The discussed approach will be used for testing objects with continuous action.

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ЕДИН ПОДХОД ЗА ПРЕДСТАВЯНЕ НА НЕПРЕКЪСНАТИ СИГНАЛИ

Георги Кръстев, Цветозар Георгиев

Русенски университет "Ангел Кънчев"

Резюме: *Целта на настоящата статия е сигналите да се представят геометрически като вектори. Разгледани са теоретичните основи на този подход и е представен конкретен пример в среда Matlab.*

Ключови думи: *Обработка на сигнали, Вектори, Векторни пространства*

DESIGN AND IMPLEMENTATION OF A KNOWLEDGE CONTROL TEST SYSTEM

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Abstract*: The paper describes a test system designed for students' knowledge control. The system is composed of three modules: Administrator, Teachers and Students. It contains intuitive, convenient, easy-to-use interface developed in VBA Access environment, as well as relevant tools for tests generation and students' assessment.*

Keywords*: test control of knowledge, subject area,object, feature, property, method, event.*

INTRODUCTION

For each training system, including computerizing, the main problem is how to achieve an adequate control of knowledge. For a qualitative control of knowledge it is important to take into account several special features, namely:

- each teacher uses different methods of control, different scales and criteria of evaluation. This necessitates the possibility of selecting different types of questions when constructing the test;
- establishing a strategy of fair and accurate evaluation dependending on the type of the questions;
- analysing the level at which the studied matter has been acquired.

These features require the selected system to be adaptable to the personal characteristics of teachers and students.

According to Dovgyaldo and many other authors [3, 4] there are four different types of control: prior (pretest) control, current control, border control and final control (posttest).

Prior control is usually used for determing initial level of knowledge before the training has started. Current control is used to determine the level of knowledge, reached at a certain moment of studying able particular subject area (SA). Border control is carried out after study of individual topics or sections of the SA. Final control comes after mastering of a whole SA [3, 4].

The control questions must satisfy the requirement of a complete dialogue there is a confidence that the basics are learned. To perform assessing properly the teacher creates a template pattern of true answers and the system compares the responses of the students with this template. If the student's answer does not satisfy the standard, then the knowladge control test system doesn't provide the specified number of points. This system allows the generation of questions of the four types of control. For creating such a system different programs could be chosen but here we decided to use Visual Basic for Applications (VBA).

Visual Basic for Applications is an object-oriented pogramming language. It was built on the basis of Visual Basic language and is applied for working with the MS Office package-Word, Excel, Access. It has media-controlled pattern of programming, too. In substantial media-managed applications the program doesn't follow a pre-determined model. The program threated different parts of code as a response to a certain action. The events could be caused by the user actions, system performance or another application. Therefore, the sequence of execution of the program code is determined by the sequence in which various events occur [5].

In such a way the flow of the program code executed will be different each time. VBA

is an object-oriented environment, which provides a comprehensive range of objects, each one having its own properties and methods.

In an object-oriented system almost everything is composed of objects. In VBA each element of the application is an object and we call it tool. The properties describe how the object looks (its size, colour, place position) or what its behaviour is (whether you can change its size or not, is it visible, is it active, is it points to another object). The method is an action which could be performed on the object and is realized in the course of its running – member of the class. The Method is get by writing the name of the object and the name of the method, separated with a dot between them. Any user upon an object is threated as an event. All the possibilities, VBA offers makes it convenient for the construction of a system for test control of knowledge [2,5].

QUESTIONS GENERATION FOR THE TEST CONSTRUCTION AND ANALYSIS OF THE ANSWERS

Traditionally the quality in formation of elementary teaching tasks is determined by the erudition of the educator and the level of his training. This way has a number of disadvantages. The most important disadvantages are: much labour intensity in the process of the tasks creation, limited number of the tasks variants. This reduces the degree of reliability and objectivity of control, due to an increased probability of guessing the correct answer. Other disadvantages are: difficulty in circulating the assignments and in collecting statistics. The questions generation and the test construction are first steps towards incorporation of artificial intelligence in Intelligent Systems for Test Control of Knowledge. They provide didactic requirements for multi-variability of, tests with economy of intellectual labour and computer memory at the same time.

Attempts for summarizing experience in this field and to present the existing forms for responses submission and known methods of analysing them are being made. Moreover, a text response is used sometimes, but without analysis, meaning that the answer which fully matches the standard is considered correct [3].

There are several different types questions in the system for test control of knowledge:

- response of choice from several options - the most common form of response is election. The question is accompanied by several variants of ready answers from which it is necessary to choose one, rarely several, correct responses;
- arithmetic and logical response by a formula - the second most popular is response by a formula or numeric response, usually as a result of a decision of the proposed task - numerical answers, which require implementation of a set of interrelated actions. For answers of that kind a template (correct meaning) must be given.
- questions - free-response is the most natural and the same time complex task of organizing the control of knowledge of training. One of the common ways to verify the correctness of free-constructed answers is to control the keywords. Another way of organizing the work with text questions are templates, containing empty spaces with explanations about the way they should be filled;
- questions – “connect with the true meaning”, again using a template to which the given response is compared;
- questions with graphic answers – the usage of graphics (drawings, graphics, etc.) as a response significantly enhances the control system of knowledge. In some cases it is the only possible way of response.

DESIGNING THE USER INTERFACE AND AN APPLIED PROGRAM ENVIRONMENT

The application requirements are determined by the subject it is designed for and the

users who will work with it. The main purpose of this Annex is to provide an opportunity for qualitative evaluation of the students knowledge by their teachers through solving tests electronically using computers [1]. For this purpose the following basic requirements could be determined:

- quick and easy way of composing various tests, depending on the subject of study;
- quick and easy access to students tests.

Concerning basic requirements, a plan of the application opportunities is drawn up. It should:

- be easy to use in terms of navigation and should offer plenty of indications;
- be simple, fast and interactive;
- limit the access to side-issue functions, depending on the permissions of the user groups;
- retain entered information, test and the answers structure after solving them in the database;
- prevent input incorrect information in the database;
- provide an opportunity for quick and easy search of necessary information by relevant audiences;
- perform correct evaluation regarding the student choices and the criteria specified by the teacher.

To design the knowledge control test system we use a uniform style of forms and apropriate controls, that create a sense of integrity and make the system stylish and pleasant to work and navigate with her.

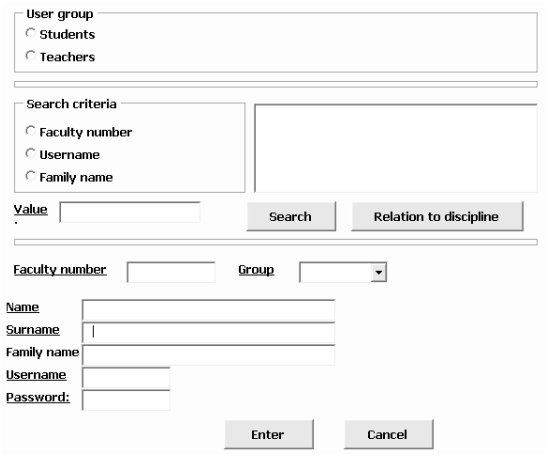

Fig. 1. Module Administrator - create new user.

Three modules are designed for the separate user groups – “Administrators", "Teachers” and “Students” to meet the requirements of the application. The user has to enter his username and password, then choose the group he belongs to. After pressing the "Enter" button, he gets access to the functions which correspond to his group.

Module "Administrator" - this group of users can create accounts for all other user groups, enter and edit database for all other users, provide validation of data before its retention in the database, add and edit data for the disciplines, in which tests will be created, add or mould groups of students who conducted the test. This module provides a simple interface for creating links among the objects in the database so that the work of the administrator could be much simplified and the requirement for having special professional skills in working with databases falls away. Fig. 1. shows working form to edit a user that at the same time provides an option for searching a definite user on a given criterion.

Fig. 2. Module Teacher - construct a question with one correct answer

Module “Teachers”- these users have rights to create or edit tests in a specific discipline. Each teacher determines type of questions to be included on his own test. The system supports all the types of questions. In the

creation of choice questions of one or multiple answers are used CheckBox controls or OptionButton respectively. Fig. 2. contains the elements needed to edit a question of the appropriate type. Such elements are: a field for writing down the question; fields for the possible answers, elements which determine the number of the possible answers; elements for determining the correct answer. For each of selected types of questions, the system allows teacher to set the number of points corresponding to a correct answer to a certain question and also offers an opportunity of keeping the information in the database.

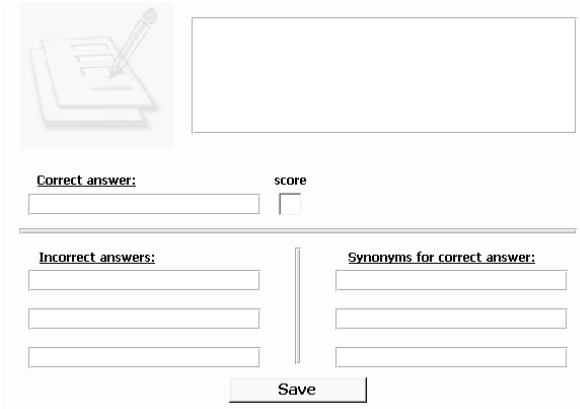

Fig. 3. Modul Teacher - construct a questions in form "free answer"

For questions in form "free answer" (Fig. 3.) the system uses tool - TextBox control when entering the text of the question and fields for entering the question; for entering the answers – one for the correct answer, three for entering variations answers and three for giving synonyms of the correct answer and the parts to be connected plus elements for defining the correct connections.

For question of type connecting the issue with the response, the system provides: a fields for entering the question; entering the answers and comparing their parts (connection) in addition elements to determine the correct connections.

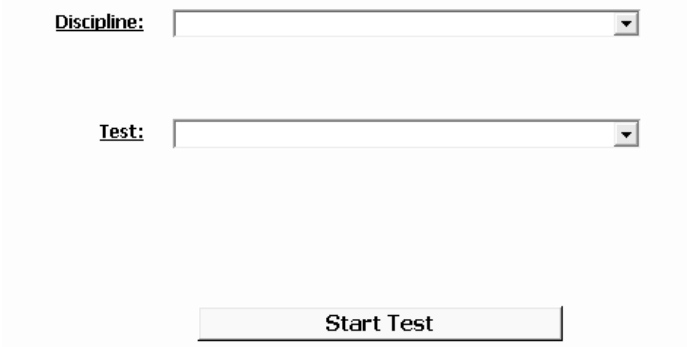

Fig. 4. Module Teacher - constructing test

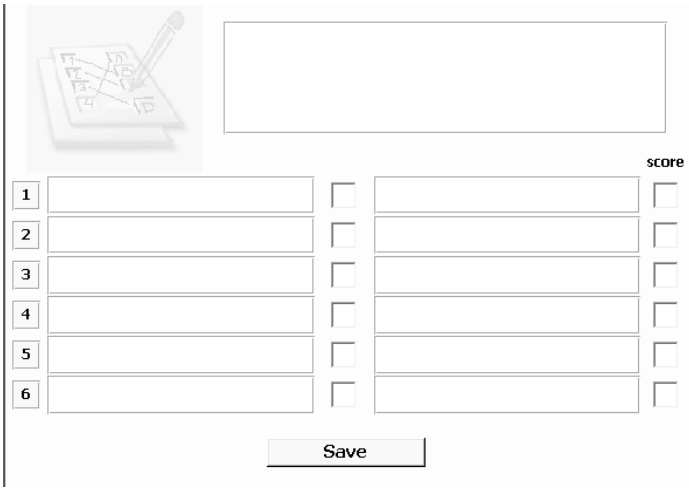

Fig. 5. Module Teacher - simulation of the final test

Users with rights of Teachers are allowed to set separate criteria for evaluating each test. They also determine time given to the students for fulfilling it and have rights to simulate its happening. By selecting the "Start Test" button in Fig. 4. other items this screen contains are displayed shown in Fig. 5. These are: an elements showing the time past from the beginning of simulation, visualizing current issue, moving to the questions and finishing the test. By choosing the "Ready" button a screen appears which gives information for the reached result, given evaluation and criteria on which the assessment was made.

Module "Students" – for users of that group, the system provides opportunity of choosing the discipline and the test they are going to make, after entering their username and password. By selecting the "Start Test" button they start the set time, as well. After answering a question the user goes to the next one by pressing the "Confirm" button and selecting the next issue from the navigation panel (Fig. 6.).

When selecting the "Ready" item or after the time finishes, a screen, visualizing the result, the evaluation and the assessment criteria, appears (Fig. 7.).

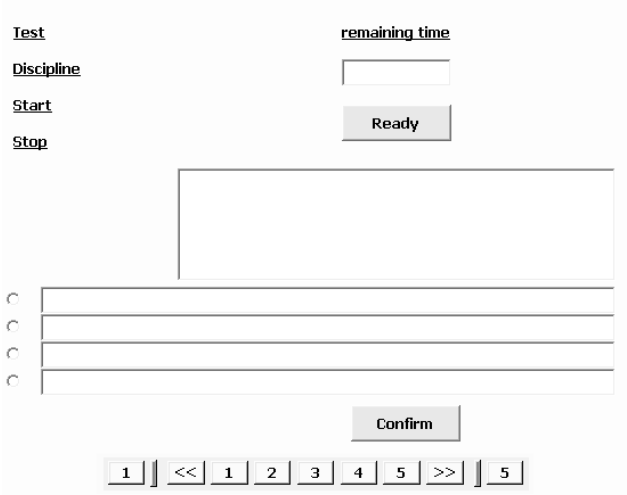

Fig. 6. Module Student - start Test

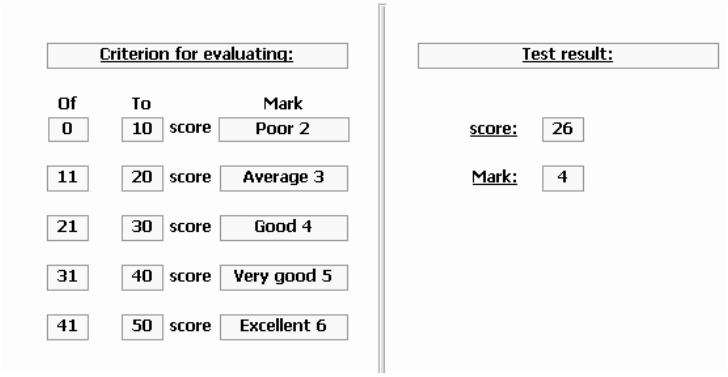

Fig. 7. Module Student- form for test rezults

Details of three Modules of test control system of knowledge are shown in Fig. 8.

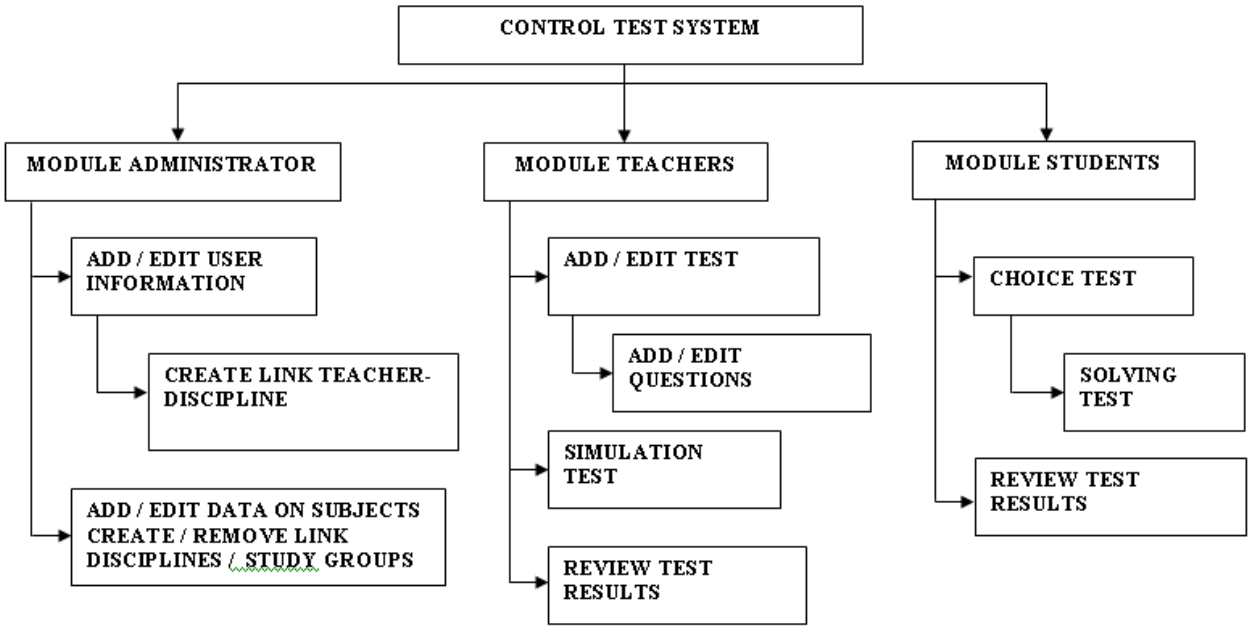

Fig. 8. Module in test control system of knowledge

INTERIOR DESIGNING OF THE INFORMATION SYSTEM

The inner interface of the application consists of Class Module for each form, which contains the procedures for processing the events, which occurred after users handled the application. In MS Access the forms are defined as objects of class "Forms" and the program automatically creates a blank Class Module for each new form, whether it will be used or not. In MS Access the forms could be directly connected to a table from the database thus avoiding another additional programming. The inner interface includes four more standard modules containing common procedures for all forms and application. Such are some of the following procedures: for checking the validity of data, for extracting and storing data in the database, for performing calculations.

Since the system is designed to work as a client-server application, in design of the system to take into account following features:

- When recording information involving the simultaneous update of several tables in the database, we use transactions for record data or in case of an error to prevent from loss of information;
- Queries to the database should be very simple in order to reduce for their implementation time. Also, only the information needed should be extracted, so that the network traffic could not be overloaded.

After creating the forms in the applied environment of MS Access, a code is added to the relevant procedures for handling events. Such procedures include: procedures performed by pushing the button, procedures performed by modifying a text box or a certain list, procedures performed after the time is finished. All basic procedures are contained in standard modules and are being declared as public, providing access to them from anywhere in the application code. This way of organizing the code in VBA helps creating a single procedure at first, and running it as many times as necessary later. If well designed VBA provides the opportunity of performing multiple actions with a few codes only.

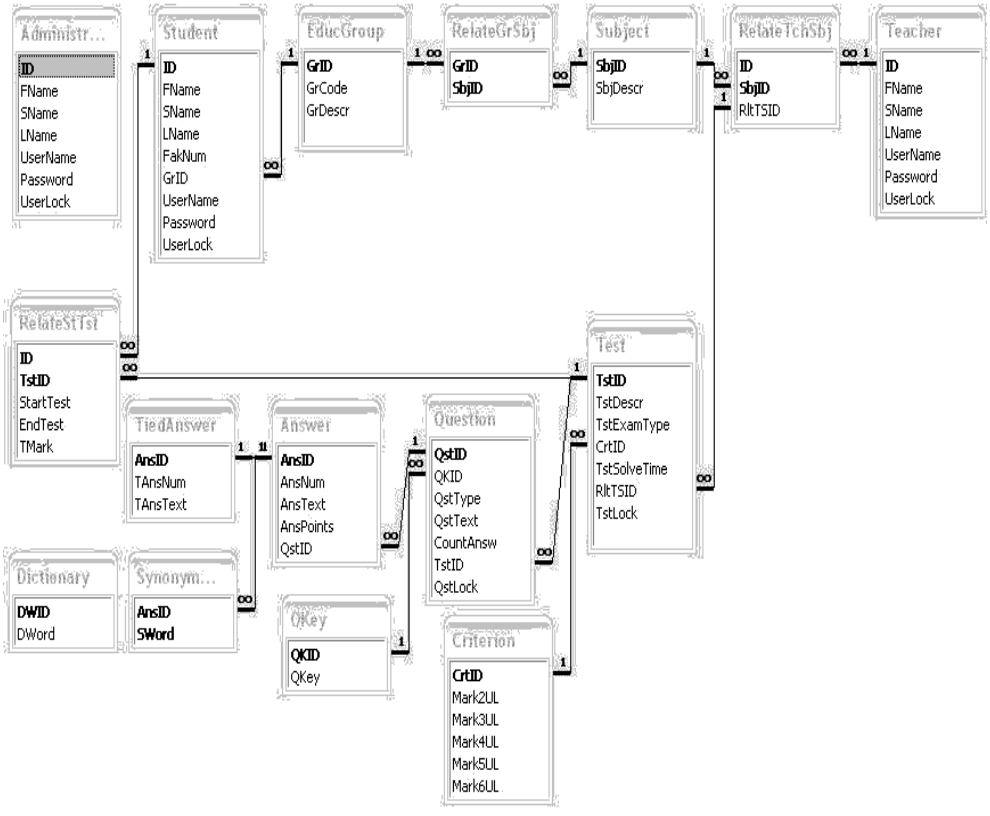

Fig. 9. Relational databases

The test control system of knowledge is created using relational databases. It is shown in Fig. 9.

CONCLUSION

The so designed system for test control of knowledge makes it possible to construct tests containing various types of questions. Since the system is built, in Access environment through VBA, it does not require the installation of an additional software but only the copying of the working file and the database needed. This particular test control system can be used by all teachers and students. It is designed to work with client-server systems and can evaluate up to 20-25 students simultaneously.

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ПРОЕКТИРАНЕ И РЕАЛИЗАЦИЯ НА СИСТЕМА ЗА ТЕСТОВ КОНТРОЛ НА ЗНАНИЯ

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Резюме: *В статията се описва разработената система за тестов контрол на знания. Тя включва три модула: Администратор, Преподаватели и Студенти. Състои се от лесен, удобен и интуитивен интерфейс, създаден на език VBA в среда Access и всички необходими средства за изготвяне на тестове и оценяване на обучаемите.*

Ключови думи: *тестов контрол на знания, предметна област, обект, свойство, метод, събитие.*

CALCULATIONS OF LIGHT, MEDIUM AND HEAVY NEUTRON-RICH NUCLEI CHARACTERISTICS

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Abstract: *Results of charge form factor calculations for several unstable neutron-rich isotopes of light, medium and heavy nuclei (He, Li, Ni, Kr, Sn) are presented and compared to those of stable isotopes in the same isotopic chain. Proton densities are compared to matter densities. Whenever possible a comparison of form factors and densities with available experimental data is also performed. The charge form factor of the ^{6}Li nucleus is obtained also on the basis of its cluster structure.*

Keywords: *Charge form factors, proton and matter density*, *cluster structure*

INTRODUCTION

It has been found from analyses of total interaction cross sections of scattering of particles and ions from nuclei that weakly-bound neutron-rich light nuclei, e.g. ^{6,8}He, ^{11}Li, ^{14}Be, ^{17,19}B, have increased sizes that deviate substantially from the $R \sim A^{1/3}$ rule. It was realized that such a new phenomenon is due to the weak binding of the last few nucleons which form a diffuse nuclear cloud due to quantum-mechanical penetration (the so called "nuclear halo"). Another effect is that the nucleons can form a "neutron skin" when the neutrons are on average less bound than the protons.

Most exotic nuclei are so shortlived that they cannot be used as targets at rest. Instead, direct reactions with radioactive nuclear beams (RNB) can be investigated in inverse kinematics, where the roles of beam and target are interchanged. For example, proton elastic scattering angular distributions were measured at incident energies less than 100 MeV/nucleon for He and Li isotopes and even at energy of 700 MeV/nucleon for the same nuclei at GSI (Darmstadt). The charge and matter distributions of these nuclei were tested in analyses of differential and total reaction cross sections of the proton scattering on exotic nuclei using different phenomenological and theoretical methods. It was shown that elastic scattering of protons serves as a good tool to distinguish between different models of density distributions.

Concerning the charge distributions of nuclei, it is known that their most accurate determination can be obtained from electron-nucleus scattering. For the case of exotic nuclei the corresponding charge densities are planned to be obtained by colliding electrons with these nuclei in storage rings. It is important to study how the charge distribution as well as the radii and diffuseness evolve with increasing neutron number (or isospin) at fixed proton number. This point may be very important for understanding the neutron-proton interaction in the nuclear medium. To this end the preliminary theoretical calculations of the charge form factors of neutron-rich exotic nuclei can serve as a challenge for future experimental work and thus, for accurate determination of the charge distributions in these nuclei. This can be a test of the different theoretical models used for predicting charge distributions.

In recent years theoretical work has been done along these lines focusing on halo nuclei. Various existing theoretical predictions for the charge distributions in light exotic nuclei ^{6,8}He, ^{11}Li, ^{14}Be, ^{17,19}B have been used for calculations of charge form factors - for instance, those of Tanihata *et al.* for He isotopes, the results of the cluster-orbital shell-model approximation (COSMA) for He and Li isotopes, the large-scale shell-model (LSSM) method (for He and Li isotopes) and that of Suzuki *et al.* for ^{14}Be and ^{17,19}B nuclei. The

charge form factors have been calculated within the plane wave Born approximation (PWBA). Calculations of form factors of heavier exotic nuclei within the PWBA are also available.

In [1,2] we extend the range of exotic nuclei for which charge form factors have been calculated earlier. Along with the new calculations for He and Li isotopes, we present results on charge form factors of several unstable isotopes of medium (Ni) and heavy (Kr and Sn) nuclei and compare them to those of stable isotopes in the same isotopic chain. We also give the charge densities and compare them to matter density distributions. The calculated proton, neutron, charge and matter rms radii are compared with those for ^{4,6,8}He and ^{6,11}Li deduced from the proton scattering experiments at GSI and from the total interaction cross sections obtained from the measurements of Tanihata *et al.* and from the re-analysis of the same data. In our calculations for the He and Li isotopes we use the LSSM proton and neutron densities obtained in calculations based on the set of wave functions with exponential asymptotic behaviour. For the isotopes of heavier nuclei Ni, Kr and Sn we use proton and neutron densities which are obtained from self-consistent mean-field (HF+BCS, shortly HFB) calculations with density-dependent Skyrme effective interactions in a large harmonic-oscillator (HO) basis. Secondly, we calculate the charge form factors not only within the PWBA but also in the distorted wave Born approximation (DWBA) by numerical solution of Dirac equation for electron scattering in the Coulomb potential of the charge distribution of a given nucleus.

A theoretical scheme for calculations of the charge density distribution and form factor of ^{6}Li in the framework of the α-d cluster model of this nucleus is suggested in [3,4].

CHARGE FORM FACTOR AND DENSITY DISTRIBUTION CALCULATIONS

The nuclear charge form factor $F_{ch}(q)$ has been calculated as follows:

$$(1) \qquad F_{ch}(q) = [F_{point;p}(q)\, G_{Ep}(q) + (N/Z)\, F_{point;n}(q)\, G_{En}(q)]\, F_{c.m.}(q),$$

where $F_{point;p}(q)$ and $F_{point;n}(q)$ are the form factors which are related to the point-like proton and neutron densities $\rho_{point;p}(r)$ and $\rho_{point;n}(r)$, respectively. These densities correspond to wave functions in which the positions **r** of the nucleons are defined with respect to the centre of the potential related to the laboratory system. In PWBA these form factors are Fourier transforms of the corresponding point-like densities normalized to Z and N. In order that $F_{ch}(q)$ corresponds to density distributions in the centre-of-mass coordinate system, a factor $F_{c.m.}(q)$ is introduced in the standard way [$F_{c.m.}(q) = exp(q^2/4A^{2/3})$]. In Eq. (1) $G_{Ep}(q)$ and $G_{En}(q)$ are the Sachs proton and neutron electric form factors, correspondingly, and they are taken from one of the most recent phenomenological parametrizations.

In [1], in addition to PWBA, we also perform DWBA calculations solving the Dirac equation which contains the central potential arising from the proton ground-state distribution. We use two codes for numerical calculations of the form factors and the results of both calculations are in good agreement.

The theoretical predictions for the point-like proton and neutron nuclear densities of the light exotic nuclei ^{6,8}He and ^{11}Li, as well as of the corresponding stable isotopes ^{4}He and ^{6}Li are taken from the LSSM calculations. For ^{4,6,8}He nuclei they are obtained in a complete 4ħω shell-model space. The LSSM calculations use a Woods-Saxon single-particle wave function basis for ^{6}He and ^{8}He and HO one for ^{4}He. For comparison we use also the "experimental" charge density for ^{4}He and, i.e. the so-called "model-independent" shape of the density. The proton and neutron densities of ^{6}Li are obtained within the LSSM in a complete 4ħω shell-model space and of ^{11}Li - in complete 2ħω shell-model

calculations. For ^{6}Li the single-particle HO wave functions have been used in the LSSM calculations and Woods-Saxon ones for ^{11}Li. For ^{6}Li we also use the point-proton nuclear density distribution which leads to the "experimental" charge distribution with rms radius equal to 2.57 fm.

The point proton and neutron density distributions of Ni, Kr and Sn isotopes are taken from deformed self-consistent HFB calculations with density-dependent SG2 effective interactions using a large HO basis with 11 major shells.

Figs. 1-8 display some of the obtained results.

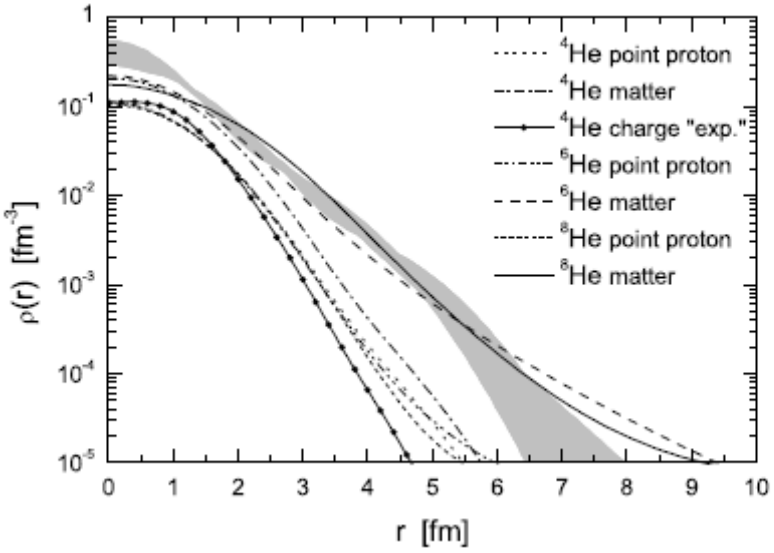

Fig. 1: Thin lines are LSSM point proton densities of ^{4,6,8}He compared to the "experimental" charge density for ^{4}He from "model-independent" analyses. Thick lines are LSSM matter densities of ^{4,6,8}He compared to matter density of ^{8}He deduced from the experimental proton scattering cross section data (grey area).

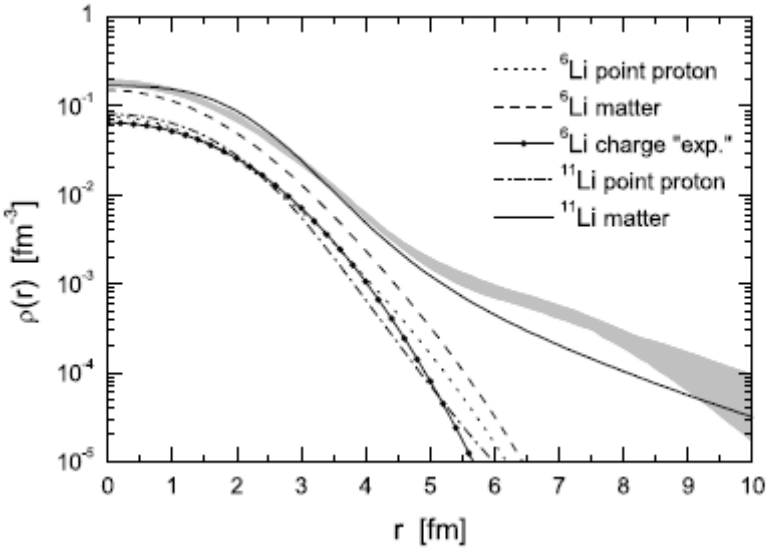

Fig. 2: Thin lines are LSSM point proton densities of ^{6,11}Li compared to the point-proton density of ^{6}Li extracted from the "experimental" charge density in a "model-independent" analysis. Thick lines are LSSM matter densities of ^{6,11}Li compared to matter density of ^{11}Li deduced from the experimental proton scattering cross section data (grey area).

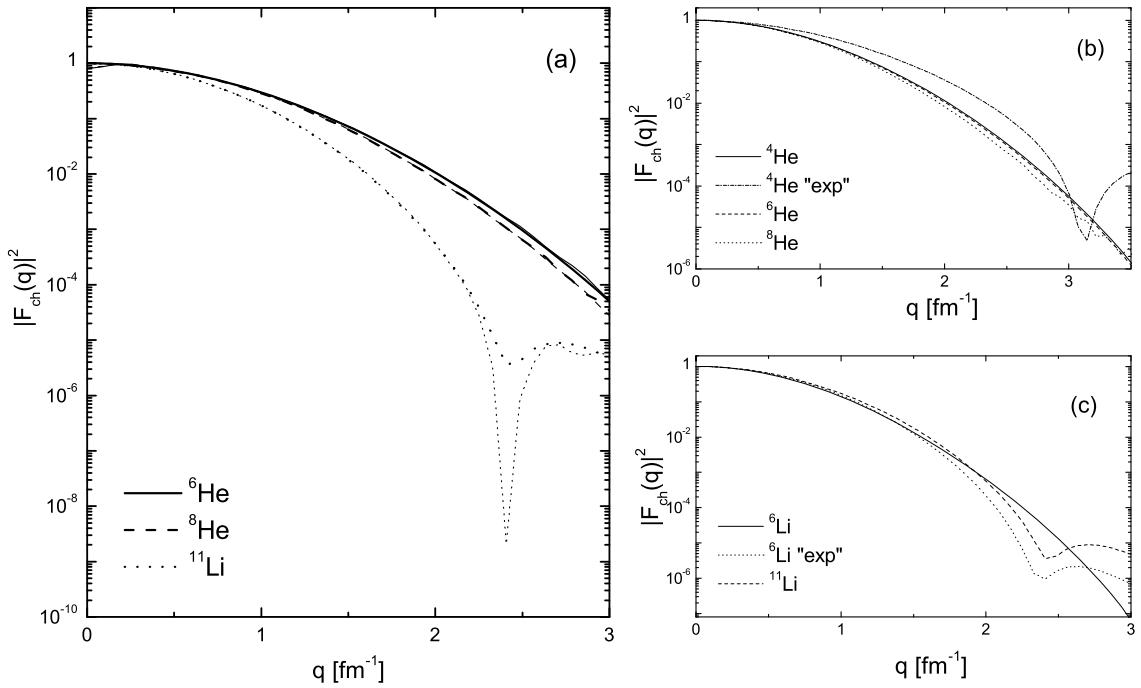

Fig. 3: (a) Charge form factors of ^{6}He, ^{8}He and ^{11}Li calculated in BA (Born approximation) (thin lines) and SDE (solving the Dirac equation) (thick lines) using LSSM densities; **(b)** charge form factors in SDE for ^{4}He (calculated by using "experimental" charge density and the LSSM density) and of ^{6,8}He (using the LSSM densities); **(c)** charge form factor in SDE for ^{6}Li (using the "experimental" charge density and the LSSM densities) and for ^{11}Li (using the LSSM densities).

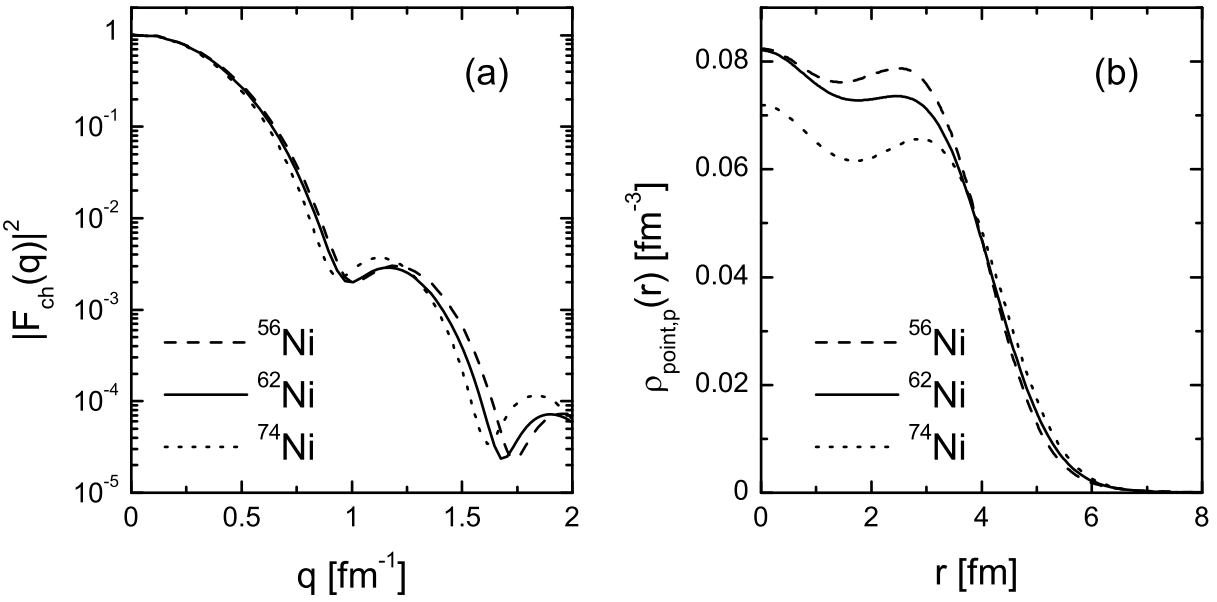

Fig. 4: (a) Charge form factors for the unstable doubly-magic ^{56}Ni, stable ^{62}Ni and unstable ^{74}Ni isotopes calculated by using the HF+BCS densities and the DWBA; **(b)** HF+BCS proton densities of ^{56}Ni, ^{62}Ni and ^{74}Ni.

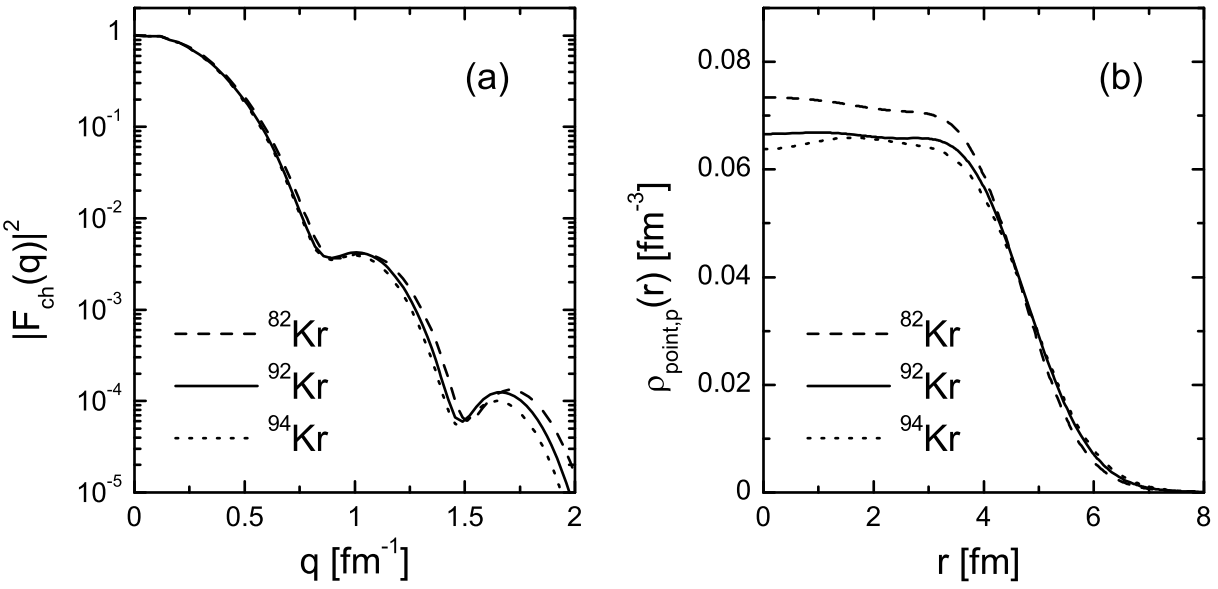

Fig. 5: (a) Charge form factors for the stable isotope ^{82}Kr and for the unstable ^{92}Kr and ^{94}Kr isotopes calculated by using the HF+BCS densities and the DWBA; **(b)** HF+BCS proton densities of ^{82}Kr, ^{92}Kr and ^{94}Kr.

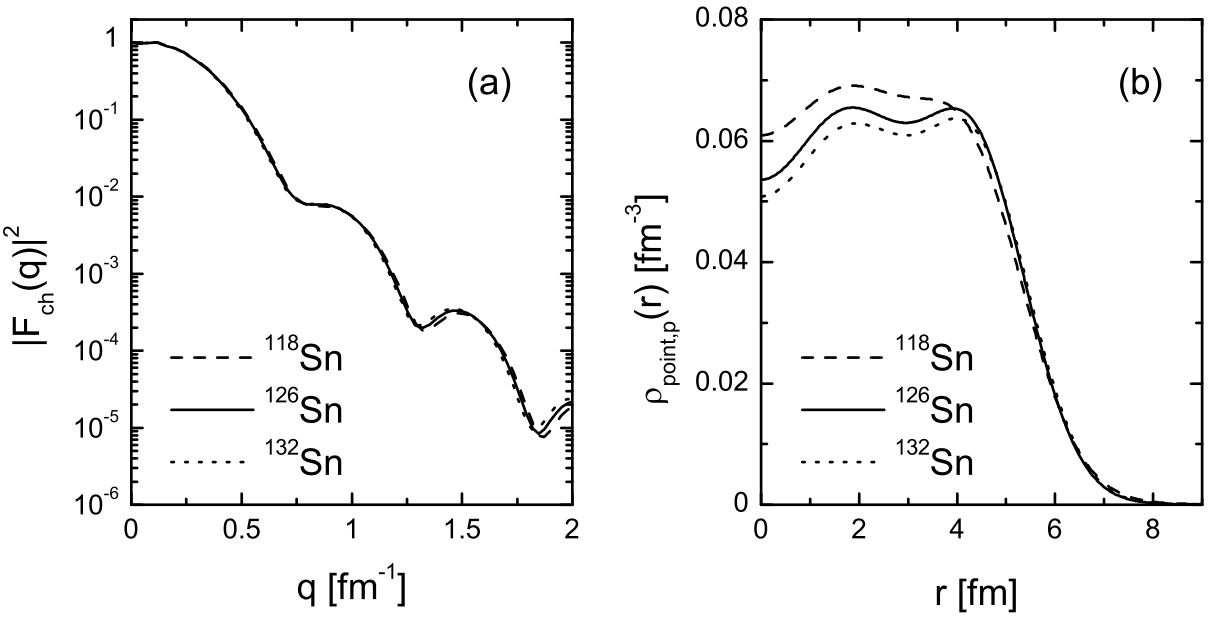

Fig. 6: (a) Charge form factors for the stable isotope ^{118}Sn, unstable ^{126}Sn and unstable doubly-magic ^{132}Sn isotopes calculated by using the HF+BCS densities and the DWBA; **(b)** HF+BCS proton densities of ^{118}Sn, ^{126}Sn and ^{132}Sn.

In addition, the charge form factor of ^{6}Li nucleus is considered on the basis of its cluster structure [3]. The charge density of ^{6}Li is presented as a superposition of two terms. One of them is a folded density and the second one is a sum of ^{4}He and the deuteron densities. Using the available experimental data for ^{4}He and deuteron charge form factors, a satisfactory agreement of the calculations within the suggested scheme is obtained with the experimental data for the charge form factor of ^{6}Li, including those in the region of large transferred momenta (see **Fig. 9**).

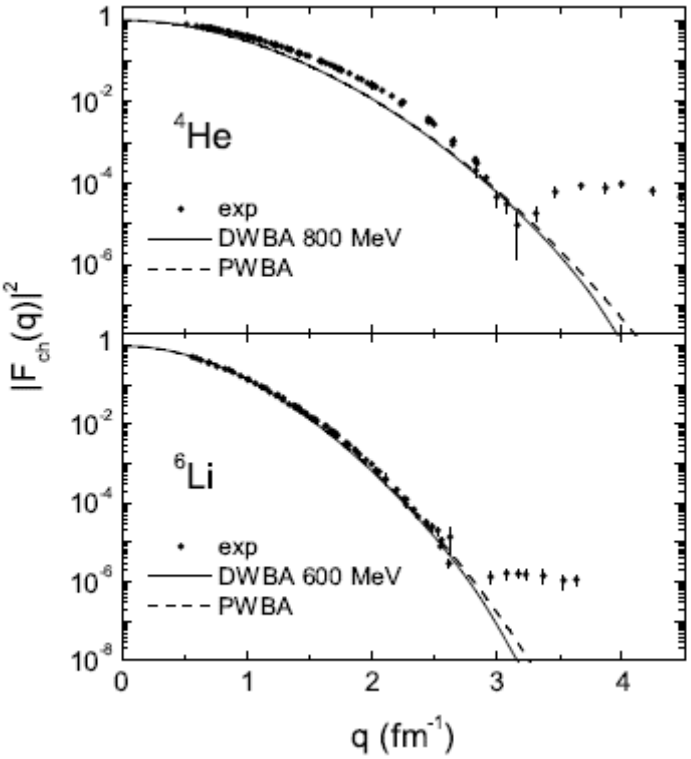

Fig. 7: Charge form factors for the stable isotopes ^{4}He and ^{6}Li calculated using LSSM densities in PWBA and in DWBA in comparison with the experimental data.

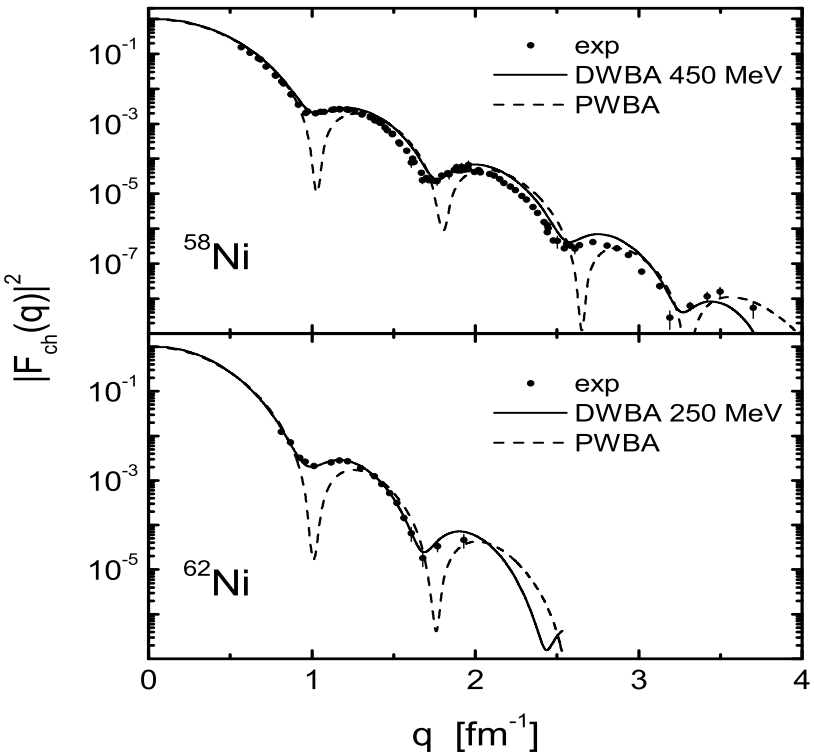

Fig. 8: Charge form factors for the stable isotopes ^{58}Ni and ^{62}Ni calculated by using the HF+BCS densities and the PWBA and DWBA in comparison with the experimental data.

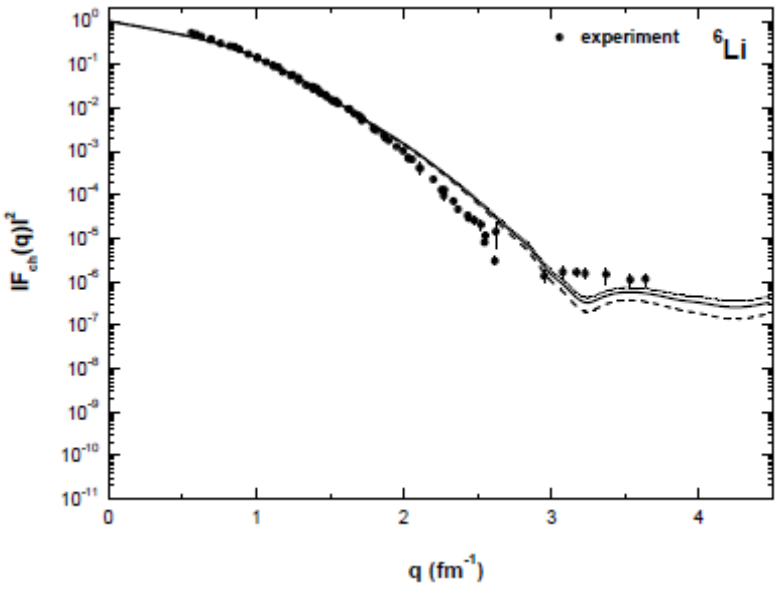

Fig. 9: The charge form factor of ^{6}Li calculated according to Eqs. (9)-(16) of [3] for c_1=0.975, c_2=0.025 (dotted line), c_1=0.979, c_2=0.021 (solid line), and c_1=0.985, c_2=0.015 (dashed line). The experimental data are as in Fig. 7.

CONCLUSIONS

The presented results can be summarized as follows:

1. The previous studies are extended to the proton, neutron and matter densities and related charge form factors from the light neutron-rich exotic nuclei ^{6,8}He, ^{11}Li to examples of unstable medium (Ni) and heavy (Kr and Sn) isotopes in comparison with those of stable isotopes in the same isotopic chain. For He and Li isotopes are used proton and neutron densities obtained from realistic microscopic calculations within the Large-scale shell-model method. The densities of Ni, Kr and Sn isotopes are calculated within HF+BCS approach with a density-dependent effective interaction using a large harmonic-oscillator basis.

2. The proton and matter density distributions for He and Li isotopes are compared. The calculated matter distributions for the halo nuclei are much more extended than the proton ones. The comparison of the proton density distributions for the isotopes of He, Li, Ni, Kr and Sn reveals the differences of the proton densities in a given isotopic chain due to the presence of neutron excess. There is a decrease of the proton density in the nuclear interior and an increase of its tail at large *r* with neutron number increasing.

3. A comparison of the proton, neutron, charge and matter rms radii as well as of the corresponding diffuseness is performed for all isotopic chains under consideration. The general trend of the difference ΔR between the matter and proton rms radii is to increase with the number of neutrons but for the heavy isotopes this increase is moderate compared to that of the light ones.

4. The calculated matter densities for ^{8}He and ^{11}Li are in fair agreement with the experimental data obtained by proton scattering on these isotopes in GSI.

5. The charge form factors of He, Li, Ni, Kr and Sn isotopes are calculated by means of the densities mentioned above. The calculations are performed not only in PWBA but also in DWBA, solving the Dirac equation for electron scattering in the Coulomb potential of the charge distribution in a given nucleus. By accounting for the Coulomb distortion of the electron waves the form factors are shifted to smaller values of *q* which is clearly seen in the cases of the Ni, Kr and Sn isotopes where *Z* is large enough. This shift

is properly parametrized. In addition the charge distribution in the neutron itself is taken into account. The contributions of the neutrons to the charge form factors are less than 20 % up to $q \sim 2$ fm^{-1}.

6. The differences between the charge form factors in a given isotopic chain are shown. A common feature of the charge form factors is the shift of their curves and minima to smaller values of q with the increase of the neutron number in a given isotopic chain. This is due to the corresponding enhancement of the proton tails in the peripherical region of the nuclei.

7. The performed theoretical analyses of the densities and charge form factors can be a step in the studies of the influence of the increasing neutron number on the proton and charge distributions in a given isotopic chain. This is important for understanding the neutron-proton interaction in the nuclear medium.

8. A theoretical scheme for calculations of the charge density distribution and form factor of ^{6}Li in the framework of the α-d cluster model of this nucleus is suggested. The calculations show a reasonable description of the charge form factor of ^{6}Li on the basis of a superposition of two density distributions:

i) a folding density obtained from ^{4}He and the deuteron charge densities. Provided corresponding experimental data for both densities is used, the calculations show that a good agreement with the data can be obtained when the weight of this contribution is about 97.5÷98.5% and; ii) a sum of the ^{4}He and deuteron charge densities with a weight of this contribution of about 2.5÷1.5%.

This scheme has only one free parameter (c_1 or c_2) with a clear physical meaning, namely, it is the weight of the one of the contributions to the density of ^{6}Li.

9. The behavior of the charge form factor of ^{6}Li for $0<q\leq 2.7$ fm^{-1} is determined mainly by the folding contribution (of ^{4}He and the deuteron densities) to the charge density of ^{6}Li.

10. The shell-model α-d cluster density of ^{6}Li (i.e. the sum of ^{4}He and the deuteron charge densities) is important (though with a small weight of about 2.5÷1.5%) in the central nuclear region and, correspondingly, it is responsible for the values of the charge form factor of ^{6}Li at large values of q ($q\geq 3$ fm^{-1}).

11. The calculated within the suggested scheme charge rms radius of ^{6}Li agrees with the experimental estimations of this quantity.

12. The theoretical predictions for the charge form factors of exotic nuclei are a challenge for their measurements in the future experiments in GSI and RIKEN and thus, for obtaining detailed information on the charge distributions of these nuclei. The comparison of the calculated charge form factors with the future data will be a test of the corresponding theoretical models used for studies of the exotic nuclei structure.

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ПРЕСМЯТАНИЯ НА ХАРАКТЕРИСТИКИ НА ЛЕКИ, СРЕДНИ И ТЕЖКИ, БОГАТИ НА НЕУТРОНИ ЯДРА

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Резюме: *В тази работа са изложени резултатите от пресмятанията на зарядовите форм-фактори на някои нестабилни, богати на неутрони изотопи на леки, средни и тежки ядра (He, Li, Ni, Kr, Sn). Същите са сравнени с тези на стабилни изотопи от същата изотопична верига. Сравнени са протонните и масовите плътностни разпределения. Направено е сравнение на форм-факторите и плътностните разпределения с наличните експериментални данни. Получен е зарядовият форм-фактор на ядрото на ^{6}Li на базата на неговата кластерна структура.*

Ключови думи: *зарядови форм-фактори, протонни и масови плътностни разпределения, кластерна структура*

CALCULATION OF THE CHARACTERISTIC IMPEDANCE OF A MICROSTRIP, REVERSED MICROSTRIP AND EMBEDDED MICROSTRIP LINES

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***Abstract**: An uniform approach for calculating the characteristic impedance of microstrip, reversed microstrip and embedded microstrip lines is applied and discussed in the paper. The results from the numerical based method for obtaining the characteristic impedance of all the three lines for a wide spectrum of sizes of the strip conductor in the microstrip and reversed microstrip lines and for the different disposition of the strip conductor in the dielectric slab (plunging) in the embedded microstrip line are presented graphically The results are sufficiently accurate (of 3%) and are suitable for practical applications*

***Keywords**: microstrip, reversed microstrip, embedded microstrip*

INTRODUCTION

During the last decade the reversed microstrip and embedded microstrip lines together with microstrip line are used in designing different microwave devices. The cross-sections of this transmission lines are schematically represented in Fig. 1. Up-to-date the microstrip line is well studied by applying a number of methods for calculating its characteristic impedance *Z*. Several empirical formulas are postulated in the past and the results of their usage give high accuracy and good agreement with other studies. The method for calculating *Z* in the case of infinitely thin strip conductor is solved already analytically and is given in [6]. The obtained results from using this approach allow to make a comparison to other similar studies. However, still the reverse microstrip and embedded microstrip lines are not well investigated.

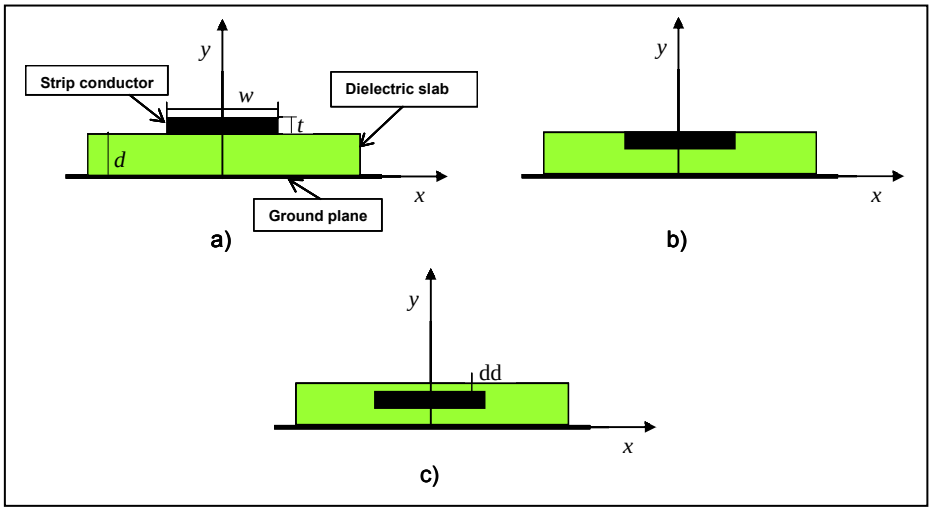

Fig. 1. a) Microstrip line (*d* is the thickness of the dielectric slab, *w* and *t* are the width and thickness of the strip conductor); b) Reversed microstrip line; c) Embedded microstrip line (dd is the plunging of the strip conductor) .

In the paper, an attempt to develop a uniform approach for calculating the characteristic impedance of the three mentioned above lines is presented. In addition it is supposed to work simultaneously for lines with infinitely thin strip conductor *(t=0)* and

relatively thick strip conductor *(t>0)* (see Fig. 1). This is achieved by combining the universal method for calculating of the characteristic impedance of strip transmission lines [3], the self-consistent field method [1] and the extended mirror images method [5]. The similar idea was successfully used earlier for calculating the characteristic impedance of microstrip and coupled microstrip lines [4].

THEORY

The definition of the characteristic impedance Z_0 of the strip transmission line with strip conductor disposed in a homogeneous dielectric media (vacuum) is given as follows:

(1) $$Z_0 = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \frac{E}{I^2},$$

where ε_0 and μ_0 are the dielectric and magnetic vacuum constants, I is the total current flow along the strip conductor and E is the electromagnetic energy per unit length of the line.

The strip line is transmitting a transversal electromagnetic (TEM) wave. If the z axis of the frame of reference is chosen to be parallel to the strip conductors then the energy E can be represented by the next equation:

(2) $$E = \int_S J(x,y) A(x,y) dxdy \quad ,$$

where S is the area of the cross-section of the transmission line, $J(x,y)$ is the current density, and $A(x,y)$ is the vector potential of the magnetic field in the point (x,y). In the TEM wave case the current density and the vector potential have only z components. The function $J(x,y)$ is not known but due to the skin effect when very high frequency signals are transmitted it is different from zero only in the points located along the perimeter of the strip conductor and the above equation takes the following form:

(3) $$E = \int_P J(x,y) A(x,y) dxdy ,$$

where P is the perimeter of the strip conductor.

The integral can be solved analytically as shown in [5] when two assumptions are taken into account:

a) The perimeter of the strip conductor is built by straight line sections L_i, and is independent on the sections number.

b) At any point (x,y) of the straight line section L_i the current density does not change and is equal to the average current density J_i for this section. At first sight the, the replacement of the real current density by its average value will reduce significantly the accuracy in calculating Z, but due to the the equation (3), in which a small deviation in the function $J(x,y)$ does not alter the value of Z, the accuracy may be kept almost unchanged . However, when the perimeter of the strip conductor is divided into sufficiently big number of straight line sections the model of density is very close to the real density. A possibility to make further improvement of the model is to shorten the lengths of the sections close to the strip edges, as the current density sharply increases near the edges. The improved current density model together with the mentioned mathematical feature of the equation (3) gives enough accuracy for the practical usage.

The real distribution of the current density on the conductor's perimeter *P* can not be obtained but for our purposes it appears of no importance. For solving (3) it is only enough to find a proper step function model of the current density corresponding to the above mentioned requirements. This is done by using of self-consistent field method [3]. This method was developed in [6] where the average current densities J_i over linear sections L_i are calculated by solving a system of *N* linear algebraic equations where *N* is the number of the linear sections of the perimeter of the conductor. The total current *I* along the strip conductor is:

$$I = \sum_{n=1}^{N} J_n L_n \ . \tag{4}$$

To define the vector potential *A(x,y),* in case of non homogeneous dielectric filling of the transmission line, the extended mirror images method [2] is used. According to this method the real transmission line is replaced by an equivalent model consisting of infinite number strip conductors suitably disposed in a homogeneous dielectric media. In the case of a microstrip the vector potential A*(x,y)* is defined as:

$$A(x,y) = -\frac{\mu_0 I_0}{4\pi}\left\{\ln\left[(x-x_0)^2 + (y-(d+a))^2\right] + k\ln\left[(x-x_0)^2 + (y-(d-a))^2\right]\right. \\ \left. -(1-k^2)\sum_{n=0}^{\infty} k^n \ln\left[(x-x_0)^2 + (y+(2nd+(d+a)))^2\right]\right. \tag{5}$$

And, in the case of reversed microstrip and embedded microstrip lines *A(x,y)* is as follows:

$$A(x,y) = -\frac{\mu_0 I_0}{4\pi\varepsilon_\alpha}\sum_{n=0}^{\infty}(-k')^n\left\{\ln\left[(x-x_0)^2 + (y-(2nd+(d-a)))^2\right] - \ln\left[(x-x_0)^2 + (y+(2nd+(d-a)))^2\right] + \right. \\ \left. k'\left[\ln\left[(x-x_0)^2 + (y-(2nd+(d+a)))^2\right] - \ln\left[(x-x_0)^2 + (y+(2nd+(d+a)))^2\right]\right]\right\} \tag{6}$$

where ε_α is the relative dielectric permittivity of the material of the dielectric slab, *d* – is the thickness of the dielectric slab, x_0 is the initial *x* coordinate of the linear section L_i . The initial y coordinate of the same section in the microstrip case is *(d+a)* and in the both other cases is *(d-a)*. The parameter *a* is the distance from the upper dielectric surface. The image coefficients *k* and *k´* are defined by the following formula:

$$k = \frac{\varepsilon_\alpha - \varepsilon_0}{\varepsilon_\alpha + \varepsilon_0} = -k'$$

NUMERICAL RESULTS

All calculations are made by using the same model of current distribution for all the three transmission lines. The perimeter of the strip conductor is divided into *N=32* sections. Both horizontal walls have 13 sections each and both vertical walls – 3 sections each. This kind of division is taken because usually the widths of the strip conductors used in practice are much larger than their thicknesses (*w>>t* Fig. 1). The length of the section at the middle of the wall is chosen to be long (half of the wall

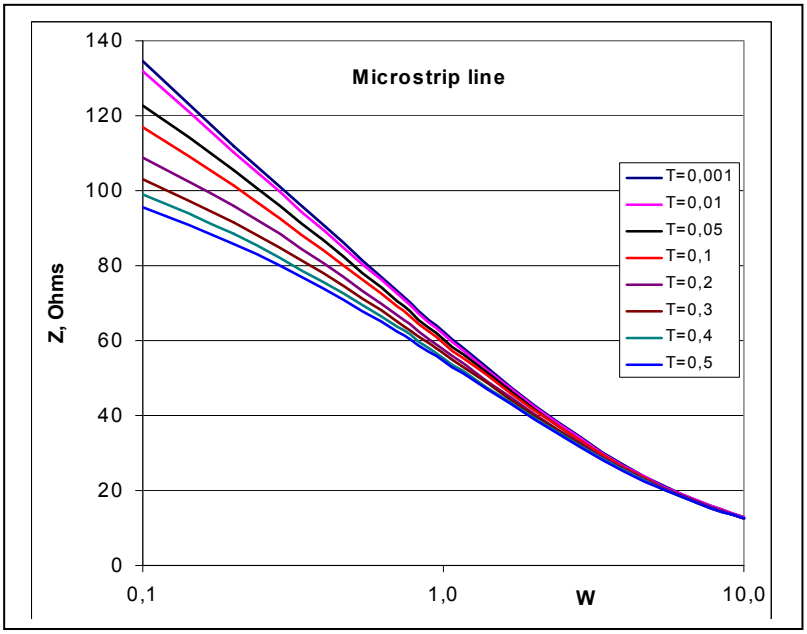

Fig. 2. Dependence of the characteristic impedance *Z* of a microstrip line on the normalized width *W* of the strip conductor for a different normalized thickness *T* of the conductor.

size), and towards the edges the lengths of the sections become twice shorter. In this way the step function model for the current density is very close to the real one. Because of the mentioned feature of the equation (3) the chosen model ensures results with very good precision (the error is expected to be less than 3%). If more precise results are needed the number of sections *N* should be increased. The other possibility for getting higher accuracy is to use more specific arrangement of the sections. Increasing *N* costs increase in the calculation time and gives only a small effect on the precision of the results.

The calculations were done by using a computer program, designed to meet the requirements of the task. The input data are the geometrical sizes and the electrical parameters of the transmission line. The geometrical sizes (Fig. 1.) are the thickness of the dielectric slab *d*, the width of the strip conductor *w*, the thickness of the strip conductor *t* and for the embedded line the plunging distance *dd*. For convenience, all geometrical sizes are normalized according to the thickness of the dielectric slab *d*: *D=d/d=1, W=w/d, T=t/d* and *DD=dd/d* (i.e. all geometrical sizes are presented like a part of *d*). So the geometrical sizes of the strip lines have no dimensions and it is easier to compare the results with other authors if no metric system is used.

The relative dielectric permittivity ε_α appear in this set up to be the only electrical parameter. Many different dielectric materials are used in microwave techniques with a wide range of relative permittivity. However, in this study all calculations are made for a dielectric slab with fixed relative permittivity ε_α *of* value 6.

The theory requires the infinite sums (5), (6) to be applied when determining the vector potential A. Due to a value of $k<1$ ($k'<1$ also) every next addend is less than the previous one. Such, we can replace the infinite sums with finite ones. In the calculating programs the process of summing up stops when the next addend becomes 10^{-12} times less than the initial one.

The results are presented in Fig.2, which shows the dependence of the characteristic impedance *Z* of a microstrip (Fig. 1 a) on the normalized width of the strip conductor *W* for a wide range of normalized strip thicknesses ($0{,}001 \le T \le 0{,}5$). When the strips width becomes very big, *Z* approaches the impedance of the “sandwich” line – two parallel conducting surfaces at a distance d separated by a dielectric slab ($\varepsilon_\alpha = 6$).

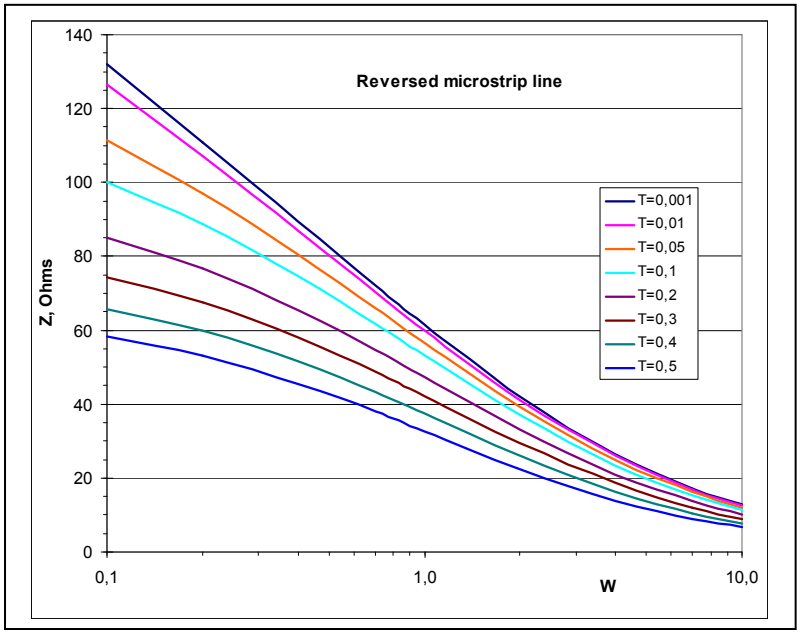

Fig.. 3. The dependence of the characteristic impedance Z of the reversed microstrip line on the normalized width W of the strip conductor for a different normalized thickness T of the conductor.

Fig. 3 presents the results for the characteristic impedance Z of reversed microstrip line (Fig. 1 b) using exactly the same sizes of the strip conductor as in the case of the microstrip line. Fig. 4 presents the results for the characteristic impedance of the embedded line. The sizes of the strip conductor remain the same. The idea is to reveal how the impedance depends on the disposition of the conductor inside the dielectric slab. Normalized plunging parameter *DD=dd/d* is chosen such to describe this disposition (see Fig. 1 c).

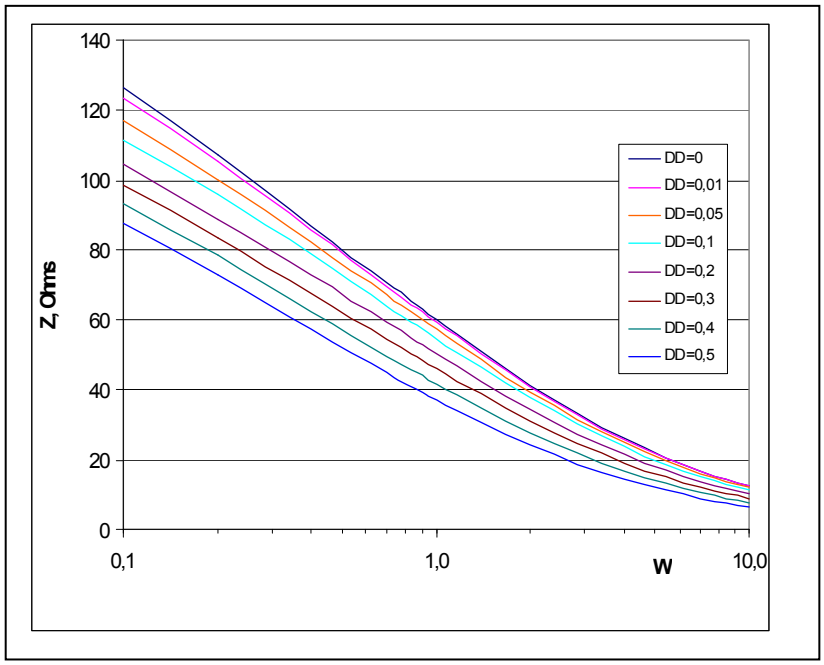

Fig. 4. The figure depicts dependence of the characteristic impedance Z of the embedded microstrip line on the normalized width W of the strip conductor for a different normalized plunges DD of the conductor in the dielectric.

CONCLUSION

The present study shows how the characteristic impedance of three different microwave transmission lines such as microstrip line, reversed microstrip line and embedded microstrip line could be calculated by applying an uniform approach. Unfortunately only the results for the microstrip transmission line could be compared with the available data which was done previously in [4]. The good agreement between the modelled and the reported data for the microstrip is very encouraging and provokes expanding and deepening the recent investigation. The aim will be to find out to what extend the other two transmission lines could meet the accuracy requirements in the practice and successfully be used. However, the good agreement in the first case of microstrip motivates an expectation of reduction of the error less than 3% in the other two cases.

The advantage of the developed uniform method is that the solution for the characteristic impedance is expressed by elementary functions in an explicit form. This facilitates the calculation procedure and there is no necessity of large number of data processing operations, which shortens the calculation time. Furthermore, the method appear to be universal and is not limited only for the investigated in the paper cases but can be applied for transmission lines of a similar type, consisting of larger number of strip conductors.

The present paper is a result of the development of a scientific project financed by Technical University – Varna.

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ПРЕСМЯТАНЕ НА ХАРАКТЕРИСТИЧНИЯ ИМПЕДАНС НА МИКРОЛЕНТОВА, ОБЪРНАТА И ПОТОПЕНА МИКРОЛЕНТОВИ ЛИНИИ

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***Резюме**: В статията е приложен единен подход за пресмятане на характеристичния импеданс на микролентова, обърната и потопена микролентова линия. Резултатите от пресмятането на характеристичния импеданс на трите предаващи линии са представени графично за широк набор геометрични размери на лентовия проводник за микролентова и обърната микролентова линия и при различно позициониране (потапяне) на лентовия проводник в диелектричната подложка за потопената микролентова линия. Получените резултати са с достатъчно висока точност (3%) за практически цели.*

***Ключови думи**: микролентова линия, обърната микролентова линия, потопена микролентова линия.*

SOME PROBLEMS OF ATOMIC AND NUCLEAR PHYSICS TEACHING

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Abstract: *This paper sets out some specific problems arising in Atomic and Nuclear Physics learning process in specialized university courses as well as in General Physics and General Chemistry courses and suggests a transition from lectures to student-centered learning.*

Keywords: *Atomic and Nuclear Physics education, online education*

INTRODUCTION

It is well known that the quantum physical objects are inaccessible to the ordinary human senses. The physical quantities describing them are statistical. The complex mathematical apparatus of Quantum Mechanics presumes developed abstract thinking. All this imposes considerable intellectual efforts during the learning process. This work offers an option for transition from lecture to student-centered learning in which students are 'learning to learn' rather than passively present during the teaching process.

The lecturer has three main functions [9]:

1. He is a manager of the classroom.
2. He applies an individual approach to students and their learning difficulties.
3. He is a generous expert who shares his experience and knowledge if and only if the student needs it.

Some results obtained by data mining method confirmed unequivocally that there can be no uniform method of teaching that works effectively for all students simultaneously. An approach to the individual needs identifying is online testing of students during the learning process. The lecturer develops tests on unlearnt teaching content. Students work online with an open textbook and are encouraged to surf the INTERNET - space during the test. They may ask for assistance and their answers are valued at the moment. If a student does not like the result, he is entitled to repeat the test as many times as he wishes, retaining only the last assessment. He invests time in this study and the final test result affects his annual or semester rating. Thus the student is motivated to learn.

The student-centered method [4] may be enriched with specific proposals for self and mutual training of students through Power Point presentations. Attached is an indicative list of exemplary INTERNET – sites.

SELF TRAINING THROUGH POWER POINT

In student-centered learning the teacher is mainly a manager (appraiser) [9] while the students are expected to be the active part and the initiators of the learning process. Some of the educational challenges in Atomic and Nuclear Physics, described below, can be used alternately from a list of topics from which each student chooses one to study in detail. He has to work for a short time and needs the teacher to designate the initial range of INTERNET – sources for each topic, in order to save time and not to be confused at the very beginning. The sources offered by the teacher are not mandatory. The choice depends on the personal preferences and worldview, and on the ambitions of the student. Students work on their topics in order to present them to the group on a multimedia screen. Each student has the same time for his presentation and answers to any questions. The teacher summarizes, supplements and specifies which parts of the presentation may be included in preparing for the exam.

The proposed in this work concepts aim at students in upper courses-pedagogical specialties like Physics and Informatics, Chemistry and Informatics. The students are expected to have a common interest in the discipline as a part of their teaching future. The independent learning through presentations will find direct application as a motivation in this course and for their development as future teachers.

The APPENDIX displays an exemplary part of Power Point presentation devoted to quarks and elaborated by a student.

THE CHALLENGE OF NUCLEAR PHYSICS

It is known that in the quantum world special units of distance, work and energy, mass and momentum are used - **Å, fm, eV (MeV, GeV), MeV/c^2, MeV/c (GeV/c)**. If you find good examples, these units will not seem so abstract. It is difficult to assimilate the fact that in the natural system (**c = ħ = 1**) the units of all physical quantities are degrees of the length unit. You should look into the nature of conventional measuring systems and point out the reasons (usually aimed at convenience) for the introduction and use of one or other unit. It is also good to note that the electric charge of an electron is considered as negative only conventionally and that the existence of anti-particles follows from the properties of symmetry of physical laws [3, 2, 1].

It is useful to state the fact that at large velocities of the quantum objects (e.g. about **2/3** of the speed of light in vacuum **c**) their masses significantly increase compared to those at rest (**rest + mass** [8]).

Interesting is the history of creation of atomic models (**atomic + models** [7]), their advantages and disadvantages that led ultimately to the model of Rutherford. The latter can not explain why the atoms are stable systems and electrons do not fall onto the nucleus, according to the laws of classical Electrodynamics. Usually this fact is shocking to all audiences and requires more detailed consideration.

It is very difficult to fit to the traditional ideas the **atomic states discreteness** and the nature of **atomic spectra** - in addition to being discrete, their lines are not equidistant and consist of multiples of one basic frequency lines. To understand these features would help the examination of relevant examples - one option is to set the wavelengths of the first three lines in the visible spectrum of the hydrogen atom and to calculate the corresponding frequencies $\nu = c / \lambda$.

The semi-classical – semi-quantum **theory of Bohr** of the hydrogen atom with its postulates and consequent **quantization** of fundamental physical quantities such as radius of the orbit and energy of the electron should also be illustrated with appropriately chosen examples. It is important to consider the negative sign of the **bound state energy** [6] of the electron.

The corpuscular - wave nature of light and the main characteristics of **photon** - especially the **zero rest mass** - also pose problems. As is known, the phenomena which found their explanation in the wave theory are interference, diffraction and polarization, while in other phenomena such as **heat emission**, **photoelectric effect** and **effect of Compton** light behaves like a beam of particles - photons. Moreover – it is necessary to emphasize that this duality (**wave-particle duality**) is inherent to all micro-particles, and is not only physical but also a philosophical problem. It is difficult to imagine the photon as an object with such properties, which on top of that we are not able to observe directly. In this connection it is worth paying particular attention to the **wavelength of the de Broglie** (**matter wave**) and its dependence on the mass of the particle, and the experimental confirmation of the presence of typical wave phenomena in beams of elementary particles, marking the beginning of electrongraphy and neutrongraphy.

In examining the laws of heat emission it is difficult to perceive such quantities as **emissivity** and **absorptance**, respectively **spectral** and **total emissivity** and **absorptance** – they should be well clarified. A large percentage of students find it difficult to answer the question what determines the color of objects even on the exam. For some of them, the concept of **black body** remains very uncertain. The same goes for the famous problems named **ultraviolet catastrophe** and **thermal death of the Universe** although they have been properly clarified during the lectures.

Atomic and Nuclear Physics provide a good opportunity to reveal the role of conservation laws for physical quantities **energy, linear momentum, angular momentum, electric charge** - for example when considering the external photo effect, the effect of Compton, at deriving the **Rutherford formula**. Unfortunately, many students believe that the **threshold frequency** of the photo effect is always in the red end of the spectrum. Especially useful in this case are the tables containing the threshold frequency and the **work function** data for different metals.

Interesting is the reaction of the student audience to the interpretation of the **spin** of electron as an internal degree of freedom inherent to all micro-particles and resulting from the relativistic wave equation of Dirac, which should not be associated with rotation around their own axis. In this regard it is worth considering the internal degree of freedom of **quarks**, fantastically named **color;** the **s-strange, c-charm, b-bottom, t-top, u-up and d-down quarks**. In comparison, even their fractional with respect to **e** electric charge doesn't seem so strange. On this background, the valid for all three **angular momenta - orbital, spin and total** - relation with the corresponding quantum number **(**e. g. $\left|\vec{j}\right| = \sqrt{j(j+1)}\hbar$**)** in a combination with appropriate examples does not seem so strange and even the precession of $\vec{l}$ and $\vec{s}$ around $\vec{j}$ seems more natural. All this shouldn't be perceived as an abstract and unnecessary theory - therefore it is important to describe the experiments proving the **discrete orientation** of the mechanical and **magnetic momenta** (**space quantization**).

Some students can't reproduce correctly the ranges of the electron state **quantum numbers**. The **Periodic table** of chemical elements provides a good opportunity for self-control and self-knowledge through solving concrete problems – for example the way of occupation of the **electron shells** and **sub-shells**. An interesting topic for reflection gives the **Pauli exclusion principle**, inherent to **fermions**. A suitable form of examination in this case is a test.

Especially beneficial is the topic of **X-rays and spectra**. Besides a thorough examination of their applications in various fields, a strongly positive effect has the observation of predictive nature of the **law of Moseley** for the frequency of the **characteristic X-ray radiation** in dependence of the atomic number **Z**, thanks to which the existence of more than 90 chemical elements has been predicted.

NUCLEAR SYSTEMS - ARENA OF STILL UNCLARIFIED STRONG INTERACTION

Although the lectures on Nuclear Physics follow these on Atomic Physics, they also pose a number of interesting questions to lecturers and students. At the outset it is necessary to distinguish between the names of objects **neutron**, **neutrino** and **nucleon**, which are often surprisingly replaced one by another.

Considerations of the **high nuclear density** and the lack of sharp borders and center of the nuclei, which seem contrary to the classical idea of core, impress the audience and these facts should be approached carefully.

Surprising turns also the fact that, like electrons in the shell the nucleons in the core also have quantum mechanical momenta that are being summed according to the same (seeming very strange) vector rules. Confusing is the presence of an extra degree of freedom - **isospin**, through which the electrically neutral and positively charged nuclear particles such as **neutron** and **proton**, can be treated as states of a single particle-**nucleon** with different isospin projections. This shows once again that nuclear forces are quite different from the electric ones.

It is difficult to get the nature of the **mass defect** and of the **binding energy**, which can be well understood in the light of the possible nuclear and thermonuclear reactions (**fission and fusion reactions**).

Nuclear interaction is very intense and quite different from the other known interactions in nature. Quite disturbing for the audience are the **charge independence**, the **non-central** and **exchange** nature of **nuclear forces**. The virtual nature of **π-mesons** is difficult to perceive. It is necessary to trace out briefly the historical facts accompanying the theoretical prediction of the nuclear field quant by Yukawa and the following registering of mesons in cosmic rays by Powell and Occhialini twelve years later. This is an appropriate illustration of the power of theory in modern Physics.

Undoubtedly, the lack of accurate analytical expression for nuclear forces makes very strong impression on students, expecting perhaps some kind of modification of the laws of Newton and Coulomb for gravitational and electrostatic forces, respectively. The model description of nuclear systems by a set of parameters with values specified through comparison with the experiment is an alternative approach. Without considering each of the up-to-date **nuclear models** in detail, their classification should be clarified. It is good to emphasize that each model explains only particular properties of nuclei.

Radioactivity is a topic that is usually met with great interest. The **law of radioactive decay** looks like the known laws of **light** and **X-rays absorption**. Against this background, the **half-life time $T_{1/2}$** (**decay period**), the **mean life time τ** and their relation to **decay constant λ** seem to be understood quite naturally.

α- and **β- decay** give a good opportunity to assimilate the knowledge not only in Atomic and Nuclear Physics but also in Chemistry. Particularly striking is the **tunnel effect** (**tunneling**) in **α-**decay as a phenomenon alien to classical Physics, but possible in the quantum world. **β- decay** is a good illustration of the importance of the energy conservation law - its apparent violation has led to the theoretical prediction of **neutrino**. More difficult is to comprehend the idea of transforming neutrons into protons and vice versa, which explains the **β^- -** and **β^+ - decay**.

It seems that most impressive in terms of **linear and angular momentum, energy and electric charge conservation laws** are **γ- radiation** and the possibility of creation of **electron - positron pairs** and the reverse process - their **annihilation**.

The topic of **nuclear reactions** as a manifestation of the strong interaction provides an interesting opportunity to consider the meaning of the concept of **channels of the reaction**. Besides the well-known conservation laws, here are also valid conservation lows concerning the **number of nucleons**, **parity** and **isospin**. It is useful, except the general formulation, to consider proper examples of different types of nuclear reactions. This section provides good opportunities for students testing. With definite interest is being met the **(n, p)** - reaction in which atmospheric nitrogen is converted into **β^- -** activated carbon with a very large half-life, which reaction has given the basis to **radiocarbon analysis** and the possibility of dating archaeological finds.

Special attention should be paid to the topics of **nuclear fission and fusion** which are examined in detail in all textbooks.

CONCLUSIONS

In this work is stated an opportunity for self-education of students of teaching specialties Physics and Informatics and Chemistry and Informatics. This approach has the following advantages over the traditional lecture training [5]:

- Moving towards student - centered learning
- Accentuation on the managerial role of the lecturer
- Individual training
- Use the maximum capacity of all students
- Learning how to study Atomic and Nuclear Physics, instead of only present in class during lectures
- Building skills for active learning in which students demonstrate their individuality, learning orientation and style
- Each student is dynamically self-developing by demonstrating his own learning products (artifacts)

This work is part of a project, which highlights the student-centered learning of Atomic and Nuclear Physics. The list of concepts can be used in the preparation of objective **online** tests. They would provide the tutor with an automatic statistics for individual performance of students (Blackboard platform [10]). The list can be modified, for example by eliminating those concepts which are not a serious problem for a group of students.

With the annexation of Bulgaria to the European Union, after becoming a member of the Atlantic one, the English language becomes a necessity. Inevitably escalates the need for basic computer literacy and acquiring skills for solving practical problems using the computer (e.g. http://cnets.iste.org/). The above-described method involves the joint efforts of lecturers in Physics, Computer science and English. The training of the twenty first century is inevitably interdisciplinary.

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НЯКОИ ПРОБЛЕМИ ПРИ ОБУЧЕНИЕТО ПО АТОМНА И ЯДРЕНА ФИЗИКА

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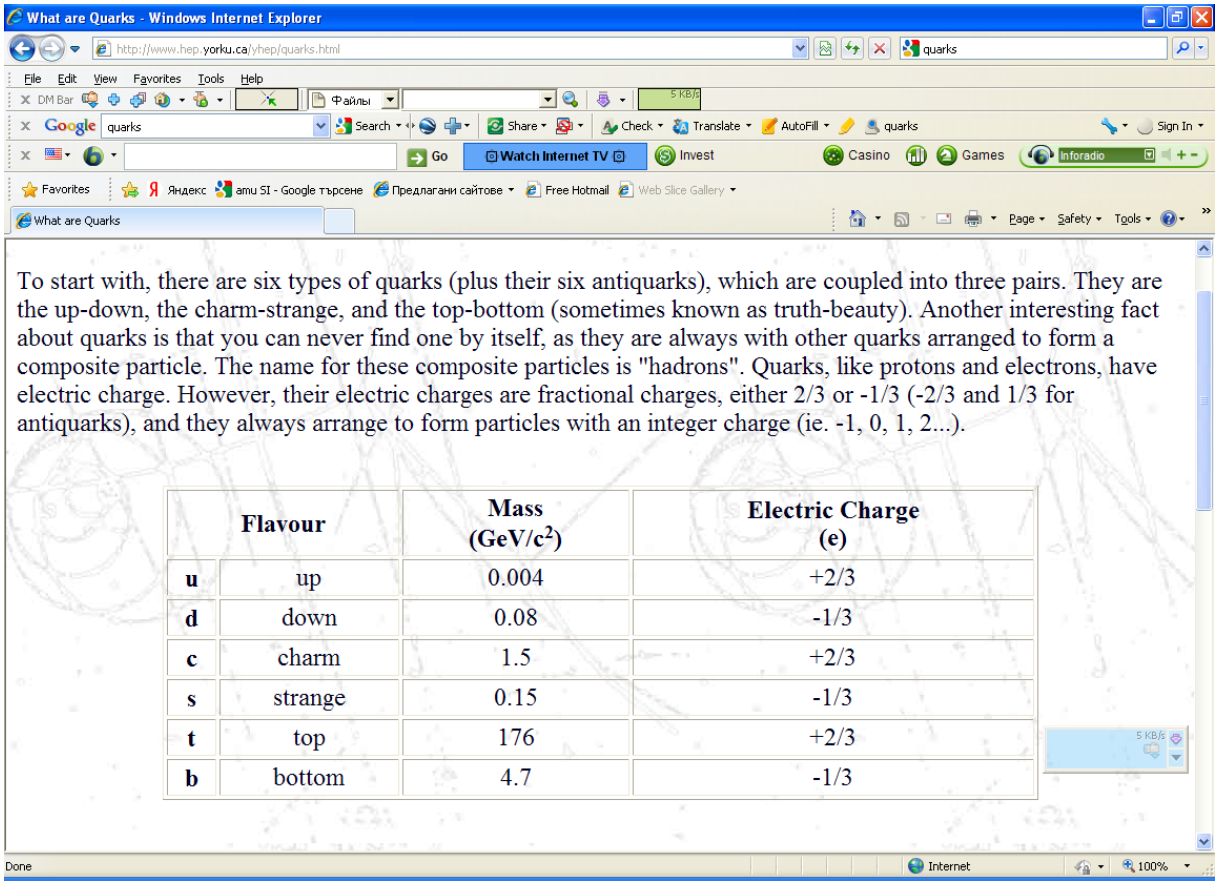
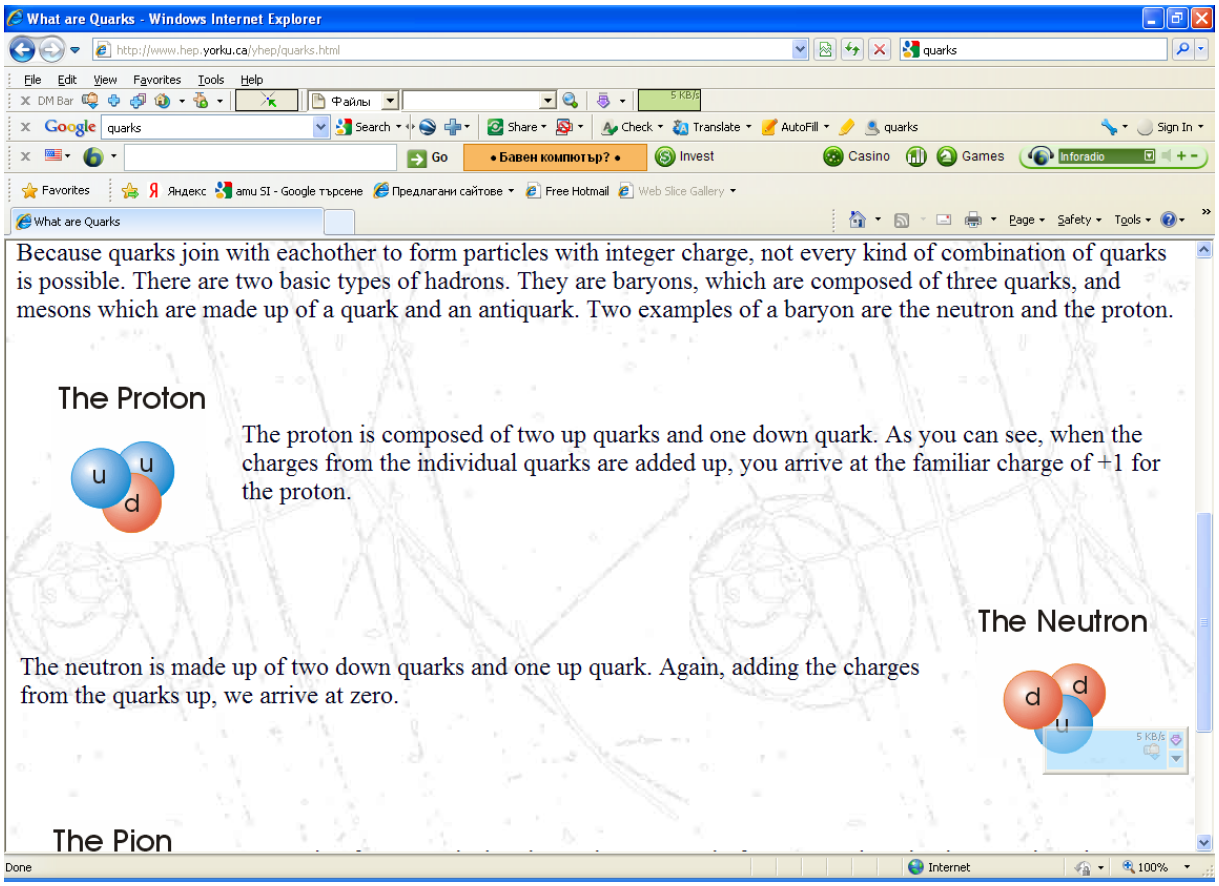
Резюме: *В тази работа са изложени някои специфични проблеми, възникващи в процеса на обучение по Атомна и ядрена физика както в специализираните университетски курсове, така и в курсовете по Обща физика и Обща химия и се предлага преход от лекционно към студентски центрирано обучение.*

Ключови думи: *обучение по атомна и ядрена физика, обучение онлайн*

APPENDIX: A part of students Power Point presentation devoted to quarks





DETERMINING THE LATERAL OSCILATIONS NATURAL FREQUENCY OF A BEAM FIXED AT ONE END

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Technical University of Gabrovo

Abstract: *A method for determining the transverse vibrations of a beam fixed at one end has been discussed. During the laboratory exercise, students explore the relationships between quantities and compare experimental and theoretical results. A relationship between the disciplines of Physics and Noise and Vibration, which further motivates the students after they find out that each subject is important for the learning process, has been shown.*

Keywords: *beam, transverse vibrations, modulus of elasticity.*

INTRODUCTION

Oscillation processes play an important role in engineering. According to their physical nature oscillations can be divided into mechanical, thermal and electrical. As it is well known, the following types of oscillations can be further distinguished - free continuous oscillations, freely dying oscillations, induced oscillations, parametric oscillations, self-excited oscillations, etc. Regardless of their type they are defined by the same physical laws and properties. Quite frequently oscillation processes in engineering are a sum of free oscillations, which makes the study of the latter extremely important in practice. Such oscillations are the lateral oscillations of a beam, a bar or a strip fixed at one end. These oscillations are used not only in engineering but also in some musical instruments like harmonica, xylophone and tuning fork [1].

EXPOSITION

The goal of the laboratory exercise for the students is to extend their knowledge of oscillation processes by learning a method of determining the natural frequencies of free, lateral oscillations of a beam fixed at one end; to create graphs to demonstrate the relationship between the natural oscillations and the length and thickness of the beam; to compare the theoretical and experimental curves.

The lateral oscillations of a beam are normally caused by the elastic bending strains. They are defined by a partial-differential equation. For the solution of the equation to be one-valued the respective initial and boundary conditions are used. The differential equation of free lateral oscillations of straight prismatic beams with distributed mass is worked out by using dynamic force analysis [2, 3, 4]. It is known from theory that the differential equation of the elastic line is as follows:

$$EI\frac{\partial^2 y}{\partial x^2} = M_b \qquad (1)$$

where I is the geometric inertia moment of the beam; E – modulus of elasticity; $y=y(x,t)$ - deflection, M_b – bending moment.

The dependency

$$q = \frac{\partial^2 M_b}{\partial x^2} \qquad (2)$$

is used when spread load with intensity $q(x,t)$ is present.

With free lateral oscillations the intensity of the lateral oscillations is determined by the apparent forces

$$q = S\rho\frac{\partial^2 y}{\partial t^2} \tag{3}$$

where S is the cross sectional area, ρ – the density of the material.

The condition of a prismatic beam is S=const and I=const. Double differentiating of (1) in relation to x and comparing (1), (2) and (3) results in

$$\frac{EI}{S\rho}\frac{\partial^4 y}{\partial x^4} + \frac{\partial^2 y}{\partial t^2} = 0 \tag{4}$$

Equation (4) defines free lateral oscillations of a straight prismatic beam. It is a linear, homogenous, partial-differential equation with constant coefficients. Its solution is of the type:

$$y(x,t) = X(x).T(t) \tag{5}$$

where *X(x)* is a function, depending on x; *T(t)* is a function, depending on t.

The displacement and the angle of inclination at the built-in end are equal to zero. The following boundary conditions are derived:

$$X(0) = 0 \quad \text{and} \quad \frac{\partial X}{\partial x}(0) = 0 \tag{6}$$

for the built-in end

$$X(\ell) = 0 \quad \text{and} \quad \frac{\partial X}{\partial x}(\ell) = 0 \tag{7}$$

for the free end.

For the natural frequencies of the lateral oscillations of a beam fixed at one end the following expression is derived:

$$f_i = 0{,}046(2i-1)^2\frac{\pi^2 h}{4\ell^2}\sqrt{\frac{E}{\rho}}, \qquad i = 1, 2, 3, 4, \tag{8}$$

where h is the thickness of the beam and ℓ is the length of the beam.

For the first three natural frequencies of the lateral oscillations of a beam fixed at one end the following expression is derived

$$f_1 = 0{,}046\frac{\pi^2 h}{4\ell^2}\sqrt{\frac{E}{\rho}}, \tag{9}$$

$$f_2 = 0{,}046\frac{9\pi^2 h}{4\ell^2}\sqrt{\frac{E}{\rho}}, \tag{10}$$

$$f_3 = 0{,}046\frac{25\pi^2 h}{4\ell^2}\sqrt{\frac{E}{\rho}}. \tag{11}$$

Scheme of the experiment and tasks

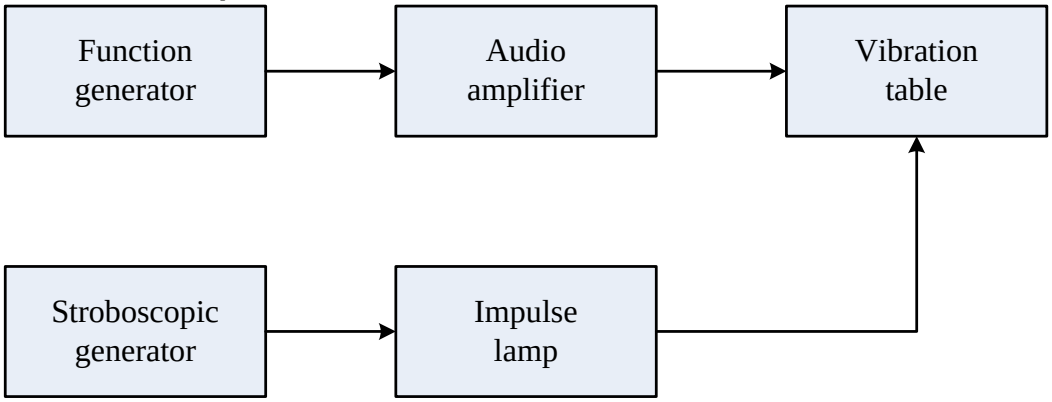

Fig.1. Scheme of the experiment

The sample is fixed on the vibrating table and the frequency of oscillations is changed by function generator while the beam begins to vibrate with maximum amplitude – until a resonance is achieved. The frequency of the blink of the pulse lamp of the stroboscopic generator changes until the image of the beam becomes stationary. Then the frequency is given from the stroboscopic generator.

The following tasks are to be accomplished:

1. To determine the relationship between the natural oscillations of a beam fixed at one end and its length – $f_{exp} = f(\ell)$ and to check it with the theoretical relationship $f_{theor} = f(\ell)$.

The students are to determine the relationship either for the first, or the second or the natural frequency following the instructions of the teacher.

Example: Determine the relationship $f_1 = f_1(\ell)$ for the first natural frequency of a steel beam with the following characteristics:

modulus of elasticity $E = 3{,}12.10^{11}$ N/m^2;
density $\rho = 7{,}74.10^3$ kg/m^3;
thickness $h = 2{,}80$ mm.

Experimental results:

Table 1

ℓ, mm	265	250	235	220	205	190	175	160
f_{1e}, Hz	29,1	32,7	37,0	42,2	48,6	56,5	66,6	79,5
f_{1t}, Hz	28,7	32,3	36,5	41,7	48,0	55,9	65,9	78,8

Example: Determine the relationship $f_1 = f_1(\ell)$ for the first natural frequency of a synthetic resin- bonded paper beam with the following characteristics:

modulus of elasticity $E = 2{,}19.10^{10}$ N/m^2;
density $\rho = 1{,}294.10^3$ kg/m^3;
thickness $h = 3{,}00$ mm.

Experimental results:

Table 2

ℓ, mm	265	250	235	220	205	190	175	160
f_{1e}, Hz	20,3	22,8	25,8	28,4	33,8	39,4	46,3	55,4
f_{1t}, Hz	19,9	22,4	25,4	28,9	33,3	38,8	45,7	54,7

The results (Table 1 and Table 2) show that the experimental dependence $f_1 = f_1(\ell)$ for a beam of steel and synthetic resin- bonded paper hardly differs from the theoretical.

Fig. 2 presents graphs of the dependence $f_1 = f_1(\ell)$ for steel and synthetic resin-bonded paper.

According to the formulae (9) for determination of the frequency one gets that it is higher for steel in comparison with that for synthetic resin-bonded paper - $(\frac{E}{\rho})_{st} > (\frac{E}{\rho})_{sr}$

That dependence is confirmed from the experimental results, too.

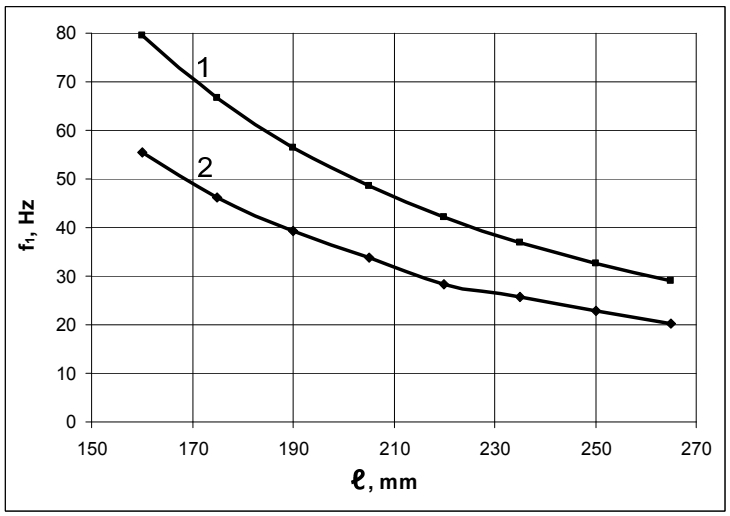

Fig.2. Graphs of the experimental dependence $f_1 = f_1(\ell)$: 1 – for steel; 2 – for synthetic resin- bonded paper.

2. To determine the relationship between the natural oscillations of a beam fixed at one end and its thickness – $f_{exp} = f(h)$ and to check it with the theoretical relationship $f_{theor} = f(h)$.

The students are to determine the relationship for the first, or the second or the natural frequency either following the instructions of the teacher.

Example: Determine the relationship $f_1 = f_1(h)$ for the first natural frequency of a steel beam with the following characteristics:

modulus of elasticity $E = 3{,}12.10^{11}$ N/m^2;
density $\rho = 7{,}74.10^3$ kg/m^3;
length $\ell = 250$ mm.

Experimental results:

Table 3

h, mm	2,20	2,40	2,60	2,80	3,00	3,20	3,40	3,60
f_{1e}, Hz	25,0	27,2	29,4	31,7	34,1	36,4	38,6	40,9
f_{1t}, Hz	25,4	27,7	30,0	32,3	34,6	36,9	39,2	41,5

Example: Determine the relationship $f_1 = f_1(h)$ for the first natural frequency of a synthetic resin- bonded paper beam with the following characteristics:

modulus of elasticity $E = 2{,}19.10^{10}$ N/m^2;
density $\rho = 1{,}294.10^3$ kg/m^3;
length $\ell = 250$ mm.

Experimental results:

Table 4

h, mm	2,20	2,40	2,60	2,80	3,00	3,20	3,40	3,60
f_{1e}, Hz	16,1	17,5	19,0	20,6	22,1	23,5	25,1	26,5
f_{1t}, Hz	16,4	17,9	19,4	20,9	22,4	23,9	25,4	26,9

The results (Table 3 and Table 4) show that there is good correlation between experimental and theoretical results of dependence $f_1 = f_1(h)$ for steel and synthetic resin-bonded paper beams.

Fig. 3 presents graphs of the dependence $f_1 = f_1(h)$ for steel synthetic resin- bonded paper.

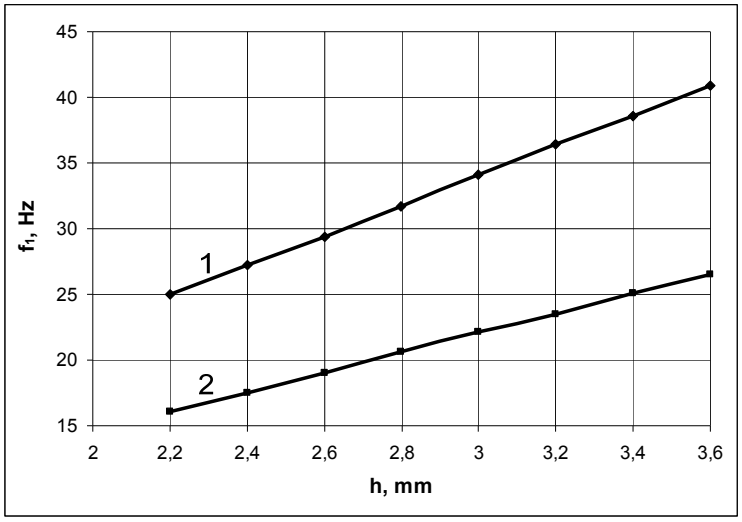

Fig.3. Graphs of the experimental dependence $f_1 = f_1(h)$:
1 – for steel; 2 – for synthetic resin- bonded paper.

Students use beams made of the following materials: steel, copper, aluminum, acrylic resin, synthetic resin- bonded paper and laminated fabric.

Combining a particular natural frequency with a particular material will make it possible for the teacher to assign individual tasks to the students.

CONCLUSION

This exercise demonstrates the relationship between engineering disciplines as well as the important role of continuity in the training of postgraduate engineers. For example in their lectures and seminars in Physics they have studied oscillation processes in spring pendulum, mathematical pendulum and liquid oscillations in a U-shaped tube. In the discipline Noise and Oscillations they study more complex oscillation processes, such as free lateral oscillations of a beam fixed at one end.

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ОПРЕДЕЛЯНЕ НА СОБСТВЕНИТЕ ЧЕСТОТИ НА НАПРЕЧНИ ТРЕПТЕНИЯ НА ГРЕДА, ЗАПЪНАТА В ЕДИНИЯ КРАЙ

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Резюме: *Разгледан е метод за определяне на собствените напречни трептения на греда, запъната в единия край. По време на лабораторното упражнение студентите изследват връзки между величините и сравняват експерименталните и теоретичните резултати. Показана е взаимовръзка между дисциплините „Физика” и „Шум и вибрации” , което допълнително мотивира студентите след като разберат, че всеки отделен предмет е важен за цялостния учебен процес.*

Ключови думи: *греда, напречни трептения, модул на еластичност*

AN INNOVATIVE APPROACH TO INFORMATICS TRAINING FOR CHILDREN

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Abstract: *The paper presents our attempt to construct an innovative approach to Informatics teaching, which has been designed especially for pupils up to 5-th grade. The rationale and main ideas of the approach, based on Comparative analysis, are briefly described. An example illustrates the feasibility and usefulness of the proposed method for a given real-life situation. Finally, some intentions for further research and experimental work are shared.*

Keywords: *Extra-curricular Informatics teaching, Competitive programming, Multi-criteria decision making, Comparative analysis*

INTRODUCTION

European politicians have recognised that education and training are essential to the development of today's knowledge society and economy. The EU's "ET2020" strategy states the main goal of school education – to reflect the changing needs, equipping the new generation with useful basic knowledge, skills and competencies, together with properly defined and developed fundamental attitudes and values [8]. In this strategy Informatics and Information technologies are among the areas, mentioned as key ones.

Unfortunately, for lower secondary schools in Bulgaria (and in most European countries), Informatics is not a compulsory subject. There are no officially published and approved curriculum and educational standards. In order to make possible training of pupils at this age, the Bulgarian National commission for extracurricular activities on Informatics created a curriculum, comprising 15 themes. These themes are studied only in different out-of-class courses, comprising lectures and practical exercises. Students, attending such courses, have to learn a number of basic algorithms and how to write programs for them in a given programming language, mostly C++. But defining the scope and content of curriculum is only the first step. Especially for instructors of pupils up to 5-th grade, Informatics teaching is still a great challenge, because of the lack of well developed and validated pedagogical approaches and methods, ensuring smooth and efficient training process.

The current paper presents our vision about a systematic approach to Informatics training of children. Part 2 introduces the rationale and the basic ideas on which the approach has been built. Part 2.1 describes briefly the method of Comparative analysis, and Part 2.2 - its possible use for Informatics teaching. In Conclusion some ideas for further research and practical work have been given.

AN APPROACH TO INFORMATICS TEACHING

On the base of analysis of the current state and our experience gained in the field, we reach the understanding that the above mentioned directives for school education in Informatics can be accomplished successfully through a new, non-standard approach. Searching for some science-based and innovative solutions, we decided to introduce the so-called CCC approach, meant to be:

- Constant – to apply a systematic rather than ad-hoc approach, following a consistent and long-term strategy;

- Continuous – to start with some procedural regulations and their use for a few selected activities in teaching and only after their successful adoption to move to other ones;
- Correct – based on some already validated methods, techniques and best practices.

From pragmatic point of view, the first and the second principles cover some managerial aspects and describe ***how*** we have to apply a number of appropriate methods. So the crucial factor for the success of this approach is ***the choice*** of methods to be used - in accordance with the third principle and taking into account the specifics of Informatics training for children in this age group.

Next follows a brief description of one universal and validated method – the Comparative analysis. We are going to show how it can be used, independently or through integration with another method, thus forming a pair of mutually complementary and compatible ones.

1. Comparative Analysis

Generally speaking, the Comparative analysis (CA) shares the main objectives and methods of the theory of multiple criteria decision making [1], but in expanded form so as to specify and use them systematically in a selected application area.

The detailed description of CA can be found in [3]. Here we want to present only a piece of information, necessary for understanding the CA method usage.

The method of CA is a study of the quality content of a set of homogeneous objects and their mutual comparison so as to select the best, to rank them or to classify each object to one of the predefined quality categories.

At the beginning of CA use, we have to identify objects in the selected application area, worth to be studied. ***Object*** can be any item under consideration. Being in a given state, the object posses specific q*uality content*, described and evaluated by its *model*. The modelling goal is to obtain a *quantitative measure of object quality* on the base of some user-oriented quality factors through their decomposition into measurable characteristics in one or more levels.

Two main players participate in the process of CA usage – Analyst and Customer. The ***Analyst*** is responsible for models construction and for accomplishing the whole CA procedure, developed for the problem, which has been defined by the Customer. Depending on the Customer's role, the stated problem and the current moment, a ***case*** should be opened to determine the *context* of the desired comparative analysis, described by the following six elements:

case = {View, Goal, Object, Competitors, Task, Level}

The ***View*** describes the Customer's role and the perspective from which the comparative analysis will be performed. The ***Goal*** can be to *characterize*, to *evaluate*, to *predict* and *any other* – defined by the Customer. The ***Object*** represents the item under consideration. According to the stated Goal, the instances of the objects to be compared are included in the set C of ***Competitors***. The CA ***Task*** can be *Selection* (to find the best), *Ranking* (to obtain a completely ordered list), *Classification* (to define the appropriate quality category for each object) or *any combination of them*. The depth ***Level*** defines the overall *complexity* of the CA and depends on the importance of the problem under consideration and on the resources needed for its implementation.

2. CA application for Informatics teaching

In order to apply the CA in this area some basic objects (trainee, syllabus, topic and problem) and a number of additional objects (instructor, contest, parent, textbook, learning material, external evaluator, etc.) have been identified in [2]. Next we will describe briefly

only the derivative model for the object 'trainee', most suitable for our current research goals.

Trainee is a student up to 5-th grade, attending an extracurricular course so as to acquire knowledge and skills necessary to be successful in Competitive programming.

In order to create the trainee model, we have to identify some pupil's individual characteristics, which are worth to be evaluated and, if possible, systematically developed. The basic considerations about student's profile for Informatics training have been described in detail in [2] and are shown in Fig.1

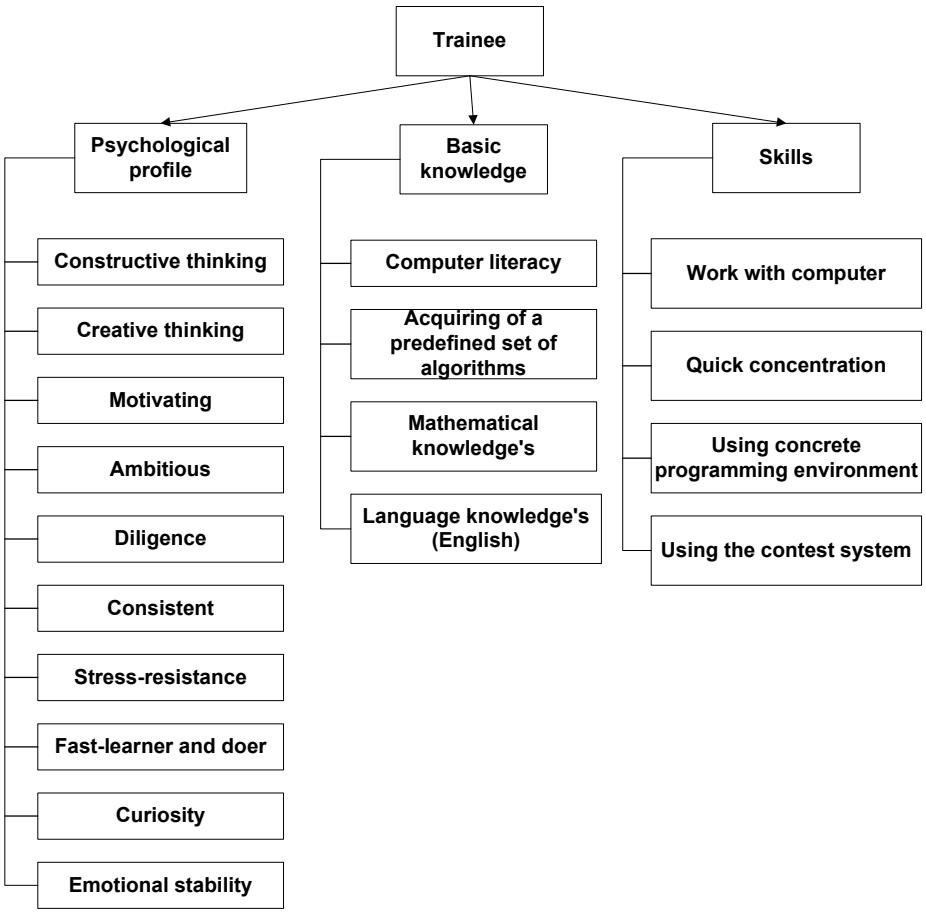

Fig.1 A model for object "Trainee"

For any defined case, involving the object Trainee, we can construct a derivative model, comprising the distinguishing trainee's characteristics, which are valuable for that case.

As an example, let's present the quality characteristic ***motivation*** from pedagogical perspective, describing its significance, influencing factors and ways for increasing its role.

From psychological point of view, the *motivation* assures the power for well organized, goal-oriented teaching. A motivated child accepts easier the burden of acquisition of different in volume and complexity information, which should be further processed - understood and memorized. A few factors can influence the motivation. The external factors can be a short-term (participation and good performance at incoming competition) or long-term – preparation for the future professional career in the field of software industry. An internal factor can be curiosity and search for intellectual satisfaction from the process of revealing the secrets of Informatics and programming. Our experience and discussions with colleagues show, that for the pupils at this age the motivating factors

have more narrow scope and are connected with some concrete goals, like:

- to participate and to be a winner in a competition;
- to learn how to work in a given programming environment;
- to become a proficient in algorithm construction and writing nice programs for it;
- to develop an aesthetic approach to programming, based on smart and sophisticated tricks, search for optimized solutions, etc.

Many participants in such extracurricular forms manage to preserve the created fascination from programming during their whole life.

Therefore, the instructor should try to find which motivating factors are valid for a particular student and to make an attempt to use them properly, in accordance with the defined teaching objectives at the moment. Creating and maintaining the proper level of motivation is very important especially when a new knowledge has to be acquired. The lecturing plan should be carefully designed so as all consecutive steps (provoking the interest, introduction, explanation, examples of usage, etc.) to be performed in a proper and effective way.

Beside the motivation, many other trainee's characteristics can be defined as ones, worth to be evaluated and developed on purpose during the process of training, namely *competitiveness*, *stress-resistance*, *curiosity*, *flexibility*, *emotional stability, self discipline, risk-taking, reflectiveness, hard-working, etc*.

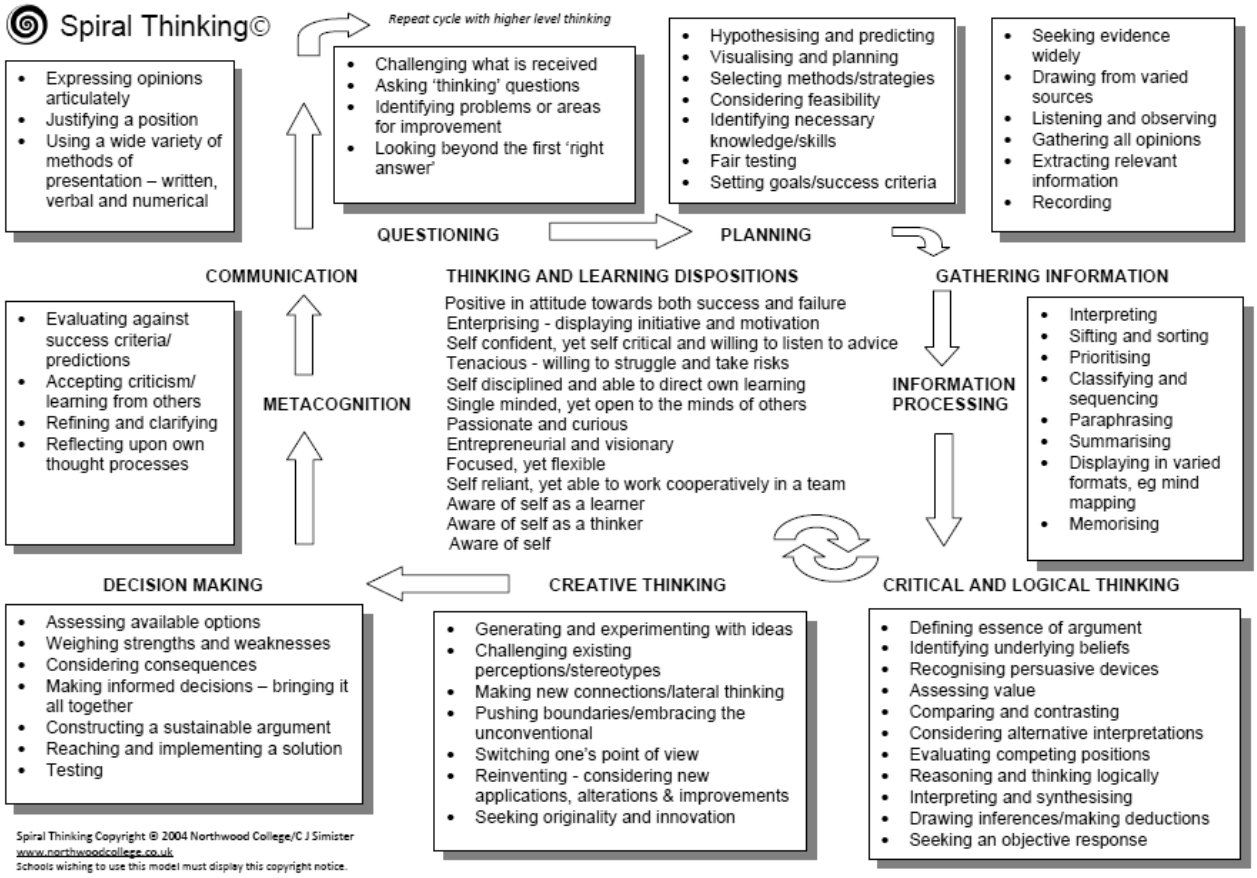

Fig.2 Spiral Thinking ©2004: C. J. Simister/Northwood College

From methodological point of view, really excellent results can be achieved by unifying the efforts of teachers with different background. The Informatics teachers can adopt a few techniques and methods, proposed especially for children in this age group and developing some significant for programming abilities. For example, the Comparative

analysis, introduced here, can be applied together with the method of Spiral Thinking (see Fig.2). Our impression is that the CA can support most of the basic activities, identified as significant in this approach.

There is a number of other Thinking and Learning Skills Teaching approaches, developed for children up to 14 years [5,6]. On the base of teaching materials from these books, many important for Informatics students' quality factors can be further decomposed so as to facilitate their objective evaluation within the CA. Adopting the Spiral Thinking method [5], we can receive a description of some main abilities through a number of sub-abilities and skills, as shown in the Table 1.

Factor: Critical and logical thinking	**Factor: Creativity**
• Defining essence of argument • Identifying underlying beliefs • Recognizing persuasive devices • Assessing value • Comparing and contrasting • Considering alternative interpretations • Evaluating competing positions • Reasoning and thinking logically • Interpreting and synthesizing • Drawing inferences/making deductions • Seeking an objective response	• Generating and experimenting with ideas • Challenging existing perceptions/stereotypes • Making new connections/lateral thinking • Pushing boundaries/embracing the unconventional • Switching one's point of view • Reinventing - considering new applications, alterations and improvements • Seeking originality and innovation

Table 1. Main abilities through a number of sub-abilities and skills

Different cases can be defined in order to support the decision making in some crucial for the training moments. Each case should be constructed by the joint efforts of the Analyst and a Customer, who can be an instructor, a parent, the principal of school, etc. The analysed situation can be related with an event (e.g. internal or external competition, final exam, programming duel) or with a specific didactic goal. For example, a case can be opened so as to evaluate the quality of a written program on the base of a set ot user-defined criteria (reliability, correctness, maintainability) or/and on the base of compliance with some recommendations for good programming style.

After a proper CA implementation, the obtained CA results can be used for accomplishing the very modern nowadays "participatory" education as:

- inventing different stimuli to increase student's motivation;
- keeping a personal record for achievements and defining some individual take-home assignments;
- rescheduling the syllabus, changing not only the content and time devoted to the basic themes, but also the didactic methods, used to present them.

3 Example

In order to prove the feasibility and usefulness of the CA, let's consider a real-life situation, for which the proposed in [3] procedure will be accomplished. Next follows a brief description of this step-wise procedure, demonstrating how we can apply the CA for a defined situation.

Step 1. ***Pre-analysis*** – description of a problem, for which the CA method seems useful.

During the teaching process a number of milestones can be defined, when an evaluation of the overall trainee's performance should be made. For example, before a

contest (regional or national) the instructor can organize an internal qualification test so as to select the participants, representing the group.

Step 2. *Preparation* – the elements of the defined case are:

View – instructor's;

Goal – assessment of the current students' level so as to rank them according to the acquired knowledge, proved skills, and demonstrated performance;

Object – a trainee, enrolled in a programming course;

Competitors – other trainees from the same group and one "virtual" trainee, presented by threshold values of the quality characteristics under consideration.

Task – ranking the trainees;

Level – high.

Step 3. Construction - building an object model, corresponding to the quality content appropriate for the situation.

For that case we choose characteristics, split into two groups: psychological traits and programming knowledge and skills, namely:

A) Psychological characteristics

F1 – motivation, $w_1 = 0,13$;

F2 – constructive thinking, $w_2 = 0,12$;

F3 – stress-resistance, $w_3 = 0,13$;

F4 – the ability for fast concentration and keeping its high level during the whole contest, $w_4 = 0,12$.

Б) Programming knowledge and skills

F5 – theoretical knowledge, $w_5 = 0,15$;

F6 – ability to apply the known algorithms for solving a new problem, $w_6 = 0,18$;

F7 – ability to understand and realize the essence of a problem with a long and not completely formalized description, $w_7 = 0,05$;

F8 - prerequisite knowledge in Mathematics, $w_8 = 0,05$;

F9 – additional knowledge about programming environments and operating systems, and skills to use them, $w_9 = 0,07$.

The assigned weights are exemplary and can be changed, depending on the context – e.g. the moment of evaluation, the type of the incoming competition, the average performance of the group till now, etc.

Step 4. Execution - Carrying out the CA task

We estimate the current overall "shape" of a trainee so as to determine his/her rank.

Trainee/ factors	**F1 (0,13)**	**F2 (0,12)**	**F3 (0,13)**	**F4 (0,12)**	**F5 (0,15)**	**F6 (0,18)**	**F7 (0,05)**	**F8 (0,05)**	**F9 (0,07)**	**Total**
virtual	2	2,5	1,5	1	2,5	1,5	1,6	1	1	***1,72***
1	2,5	1	2	1,5	2,25	2	1,3	0,5	0,7	***1,721***
2	3	2	1	1	2,5	2	1	1	0,5	***1,75***
3	1	0,5	0	0,5	2	0,5	1	1	2	***0,88***
4	0,5	0	2	0,5	1,7	1	1,4	0,5	1	***0,985***
5	0	1	0,3	0,3	1,8	4	1,8	1	2	***1,465***

Table 2. Models results after implementation a test

After each evaluation (by test, quiz, take-home assignment, contest, etc.) the results

are saved in a table with rows for trainees and columns for factors). The first row comprises data about the "virtual" student with some appropriately defined threshold values. After this step, the results for a group of 5 students are shown in Table 2.

Step 5. Completion - analysis, interpretation and drawing conclusions from the results.

Trainee	virtual	2	1	5	4	3
Total score	*1,72*	*1,75*	*1,721*	*1,465*	*0,985*	*0,88*

After sorting by the Total score, the trainees will be ranked in the following way:
I – trainee 2, II – trainee 1, III – trainee 5, IV – trainee 4, V – trainee 3.

Some conclusions about the current "shape" of each trainee can be made so as to make possible planning some future instructor's actions, like selecting the best participants for incoming contest, extra training on some stumbling blocks, assigning additional tasks for trainees with poor results and so on.

CONCLUSION

According to the research results, which have been obtained till now, the proposed innovative approach seems to be general-purpose, flexible enough to reflect the peculiarities of different context of Informatics training for children and last, but not least, feasible.

Future research work in this area will be to expand the existing object models both in variety and scope. The complete application of the approach is planned for extracurricular training on Informatics for the next academic year. We hope that such real-life experiments will enrich the set of useful principles, procedures and CA cases, thus improving the approach as a whole.

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ЕДИН НОВАТОРСКИ ПОДХОД КЪМ ОБУЧЕНИЕТО ПО ИНФОРМАТИКА НА ДЕЦА

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Резюме: *Статията представя опита ни да конструираме иновативен подход към обучението по информатика, предназначен за деца до 5 клас. Основанията ни за разработване и ключовите идеи на подхода, базиран на Сравнителен анализ, са представени накратко. Приведен е пример, илюстриращ осъществимостта и полезността на предлагания метод за дадена реална ситуация. Накрая са споделени някои намерения на авторите за по-нататъшна изследователска и експериментална работа.*

Ключови думи: *Извънкласно обучение по Информатика, състезателно програмиране, многокритериално вземане на решения, сравнителен анализ*

USING WEB BASED TECHNOLOGIES ON TRAINING IN XHTML

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***Abstract**:* The worldwide trend of innovative technologies entering all spheres of life is observed also in the educational field. Introducing interactive training boosts the learning process and it becomes easier, faster and more interesting for comprehension. This paper focuses on issues related to GSM technology, WAP applications and the usage of HTML, XHTML and CSS. It presents a website developed for training in XHTML

***Keywords**:* XHTML, Web based Technologies, Web based Training

INTRODUCTION

The information in the World Wide Web is a virtually unlimited resource for satisfying the needs of communication, information and knowledge. It is of high performance, immense amount and actuality – three main parameters which define information as a reliable ally. Through the Web, FTP and e-mail people get to know the latest news, the innovation booms in Science and Technologies, etc [2].

GSM technology allows short messages, news, etc. to be easily conveyed to the user. Data transfer is carried out by two protocols for wireless data transfer, i.e. the Short Message Service (SMS) and the Wireless Application Protocol (WAP). So, side by side with the development of ordinary phone services in the wireless digital telephones, a parallel process of developing the possibilities for text communication is running, providing a continually growing priority of text data transmission.

The Protocols, used for the needs of maintenance and operation of telecommunication appliances, devices and information servers, are the *Telnet* (in recent years, the *ssh* – secure shell – telnet protocol with connection encryption to avoid transmission of unprotected along the communication channel passwords and other important information) and the *HTTP* (web interface with administration functions for controlling interactively the communication device by means of keys and menus in the web browser environment). They enable the configuration and control of network-connected routers, switchers, commutation appliances and devices (modems, access servers, ISDN devices), web servers, servers for databases and many other types of structural units, ensuring the operation of the communication network or the data transfer net.

Nowadays the fast developing technologies and the mobile services continual drop of prices provoke the expanding usage of mobile devices (cell phones, PDA, etc., generally called mobile terminals). The number of cell phones' users keeps on increasing, challenged by new services and technologies like Internet, MMS, etc. incorporated in mobile devices.

Distinguished from personal computers (PCs), mobile terminals are characterized with specific features: small screens, unstable communication connection, and mostly of the type 'operated with one hand'. WAP is the protocol for effective transmission of data to the users of mobile devices. It is suitable for application in all standard wireless networks: CDPD, CDMA, GSM, PDC, PHS, TDMA, FLEX, ReFLEX, iDEN, TETRA, DECK *DataTAC, Mobitex,* etc. The language for creating pages on mobile phones is the *Wireless Markup Language* (WML). The information in it is organized in cards and packs. The table below shows the comparative characteristics of WML and HTML [1, 3, 5,8].

WAP/WML	HTTP/HTML
Interactive environment for applications	Documents(information) presentation
Specialized mobile devices supporting micro browsers	For PCs in networks with stable communication channels
The content is presented with short specific menus structured in cards and packs	The content consists of text and graphic pages without strict technical limits of the amount
WML cards consist of visible content and controlling directives for replacement of a current card (by the user)	HTML pages consist of visible and controlling symbols (and expressions)

WAP applications include access to distributed databases, banking, entertainment, message exchange. An essential part of the communication implementation is fulfilled by the WAP switches (protocol convertors). They are the linking unit between Internet and the pocket wireless devices. WAP switches may be the property of the mobile operator, the Internet Service Provider (ISP), or the owner of the website with WAP or WML content. More reliable protection is provided by an operator-based WAP server. The limitations for working on mobile terminals are mainly owed to their weaker parameters in comparison with those of the traditional PCs. Mobile terminals incorporate a low-efficient processor, less memory capacity (ROM and RAM), limited electric power, low resolution and small screen size, non-conventional input device [4,6,7].

All these disadvantages impose the creation of applications with specific features. In principle, after a WAP application is being developed, it can be transferred to a mobile phone and seen how it runs, but as the work is rather impeded, mobile devices' emulators have been developed. With their help the applications' tests are considerably speeded up and the designing process is facilitated as a whole.

HTML, XHTML and CSS

For consolidation of HTML platform so that it is built upon efficiently, the standardization organization W3C created the EML (*Extensible Markup Language).*

XML resembles HTML – completed with tags, attributes and values. It is a standard for developing other languages. XML can be used, for instance, to create a language for documents formatting. Such a personal language is equipped with tags containing specifications of the actual data.

When the XML tag specifies data, the latter becomes accessible for other tasks as well. A software program can be developed to retrieve only the necessary information, incorporate it to the data of another resource and the combined result can be presented for other purposes.

To facilitate the operation of XML programs for synthetic analysis *(parsers)*, XML requires a careful usage of uppercase and lowercase letters, quotes, closing tags, etc. In addition to that, billions of Web pages written in HTML already exist, and accordingly, millions of servers and browsers for their support.

W3C re-wrote HTML in XML. The new XHTML [1] contains all the technologies of HTML and it can be understood by any browser. Besides, users who know HTML, easily switch on it. On the other hand, the built-in XML's syntax adds power and flexibility and it becomes an ideal basis for the usage of CSS.

Though XHTML and CSS make a strong combination, there is a small disadvantage in browser's support. The addition of extensions is not problematic, but when it concerns a serious and full support of specifications, no browser can manage the task.

However, the prolonged waiting is also not useful. In the A List Aparat online magazine, devoted to the Web designing (http://www.alistapart.com/stories/tohell/), some authors support the cause to create XHTML/CSS-base pages, which look admirable to the standard supporting browsers, and acceptable to the ordinary or old ones.

HTML was magnificent with the specificity that the punctuation might not be adhered to. That extremely facilitated the writing of Web pages.

Some circles of specialists reject HTML and consider that XHTML is the only solution. XHTML is a significant improvement of HTML. It is stricter, very flexible and powerful, and it seems for sure that would be supported in the future; the possibility of extensions will meet various needs. Nevertheless, if there is no need to satisfy all, but just to publish a simple page, then better use HTML.

There are three standard trends in both HTML and XHTML: transitional that allows the usage of rejected tags; *frameset* allowing the usage of rejected tags and frames; *strict* that forbids the usage of rejected tags. These constructive trends can be applied in different CSS's versions but the chosen combination depends on several factors.

CHOOSING HTML, XHTML or CSS

There are several principles for making the proper choice:

- The larger amount of data in the site, the more advisable is the usage of CSS and XHTML. The first one facilitates the application, editing and updating within the site formatting, while the second component helps creating the structure of the page, ensuring its continual existence.
- Many companies and state agencies set out the condition Web pages to be in correspondence with definite requirements, which ensure adequate access to people with physical limitations. In that case the designer should follow the strictness of the XHTML and the CSS formatting.
- Big commercial sites, which aim at reaching as many customers as possible, can choose the transitional trend of XHTML applying the advantages of some rejected tags for universal support, while banking is laid upon the sustainability of XHTML. These types of sites probably will pass to the more powerful CSS with the increase of the support necessities.
- Small or personal sites are likely to refer to the advantages of the easy-to-apply syntax in HTML combined with the might of the CSS formatting, and the partial usage of rejected tags, if necessary.

HTML and XHTML definitely share one and the same lexis with insignificant syntax differences. When a statement is valid for both XHTML and HTML, the abbreviation (X)HTML is applied.

CSS is incorporated into the specifications of (X)HTML as a natural extension and at the same time as a specific instrument.

WEB-BASED TRAINING IN XHTML

The website aims at making XHTML learning easier on the basis of the following key points – availability of diverse lecture material containing graphics and photographs that facilitate the process of knowledge acquisition, and availability of terminological vocabulary providing quick access to the explanation of a concrete term.

Fig. 1 shows the navigation map of the website.

The "Home" page (Fig. 2) provides information on the website concept. The navigation menu is displayed on top of the screen and it is permanently visualized, nevertheless of the user location within the system. The navigation bar consists of six

components, which can be seen in all pages of the application: Home; Lectures; Exercises; Links; Application.

The “Lectures” page (Fig.3) contains the teaching material grouped in topics.

The “Exercises” page (Fig.4) contains information on the required exercises and the software products necessary for their execution. Emulator has been used on developing relevant exercises. The “Files” page (Fig. 5) contains all source codes for conducting the exercises.

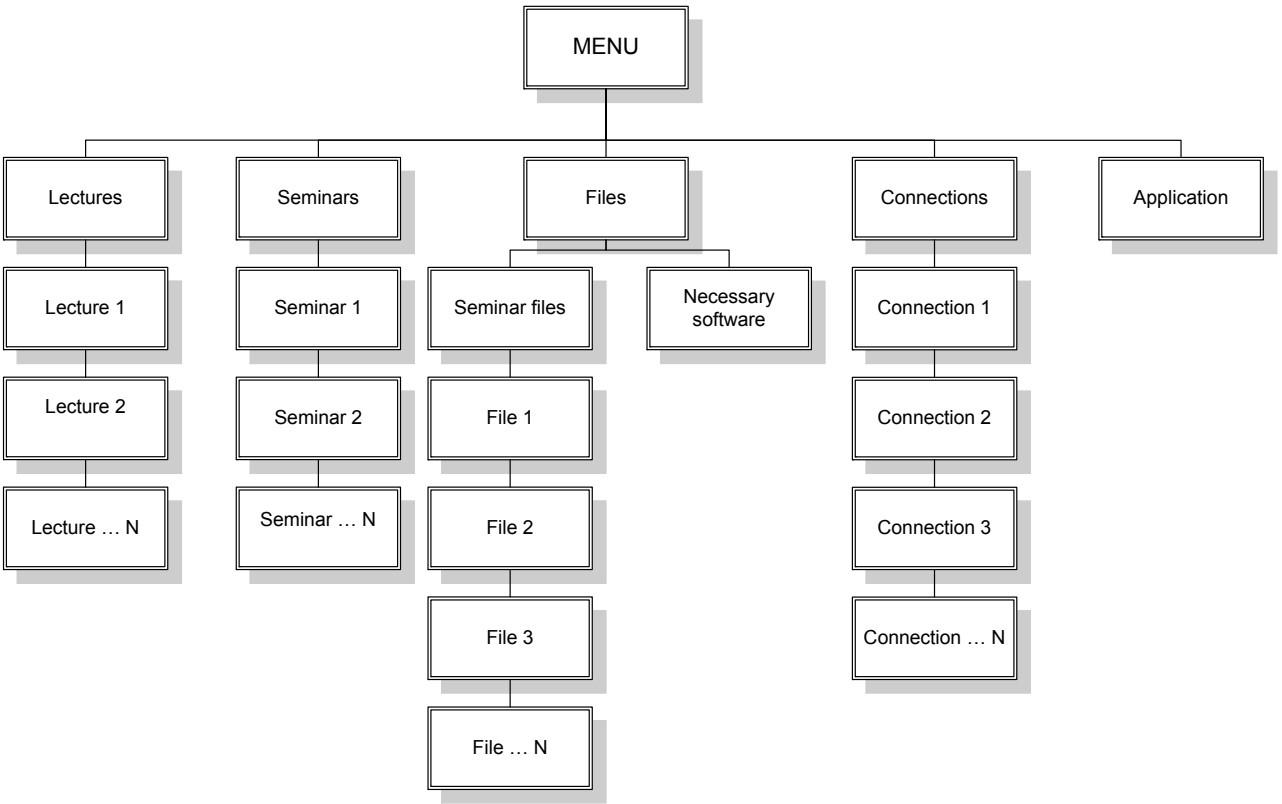

Fig. 1. Navigation map of the site

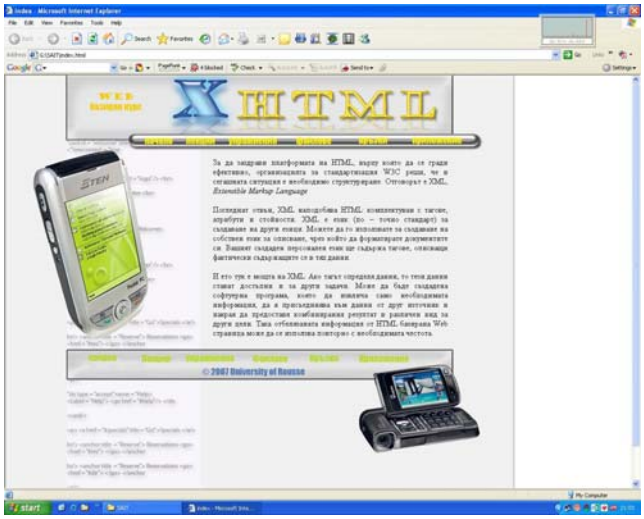

Fig. 2. “Home” page

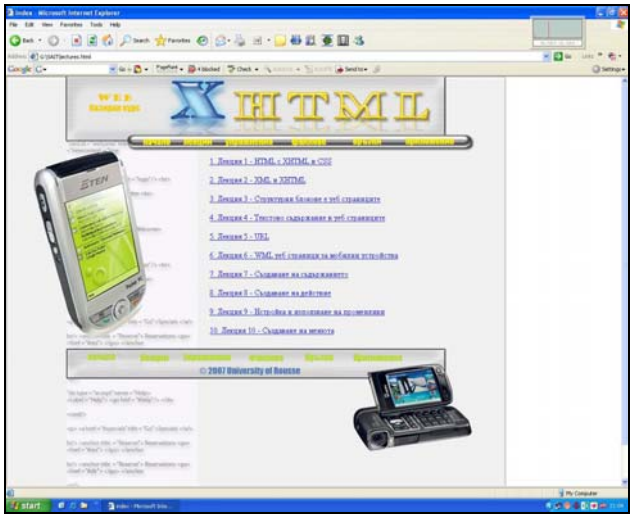

Fig. 3. “Lectures” page

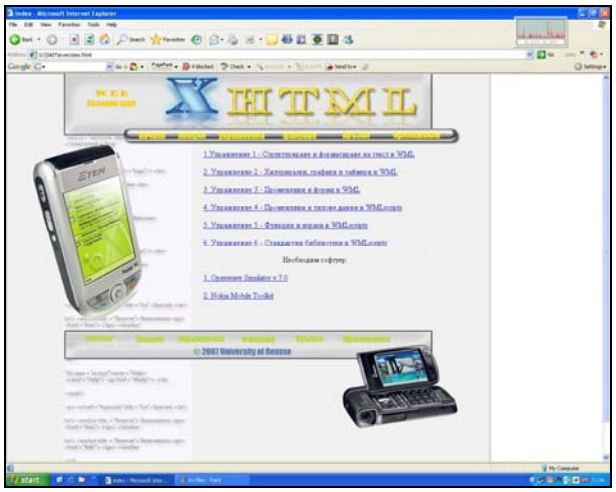

Fig. 4. "Exercises" page

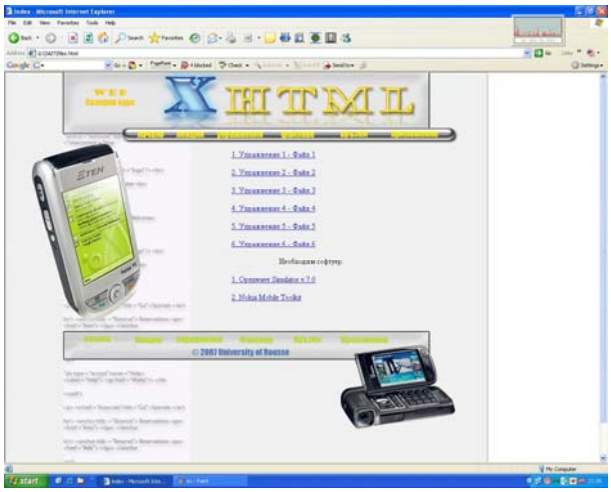

Fig. 5. "Files" page

The "Links" page (Fig. 6) provides information on the references and other useful hints. The “Application” page is shown on Fig. 7.

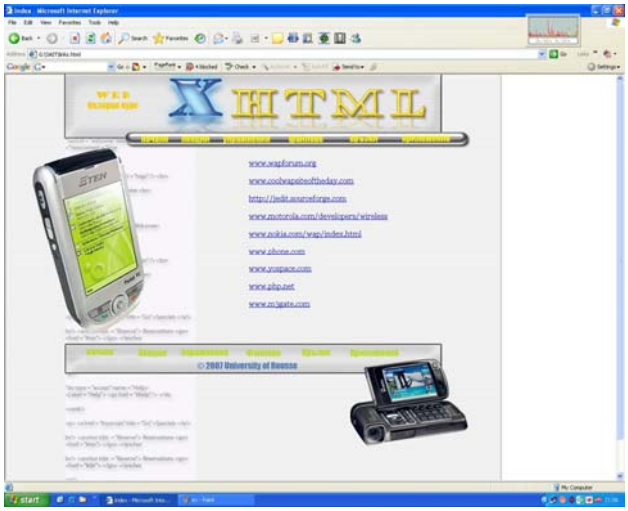

Fig. 6. "Links" page

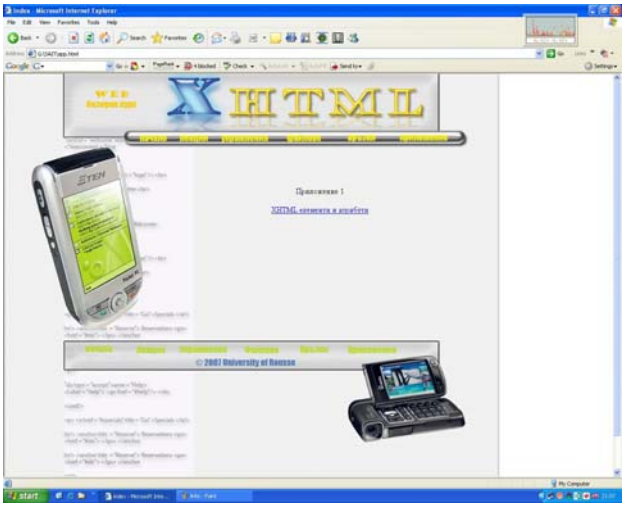

Fig. 7. "Application" page

CONCLUSION

The application that has been created presents the implementation of the basic training trends in XHTML – including theory, exercises, terminological vocabulary and plenty of diagrams, graphics and supplementary text information. The advantages concern the better comprehension of the teaching material, boosted by the interactive communication ant all this encourages the interest and motivation of learners. The website is intuitive and ensures positive and unique learning environment for users.

The application is open – it gives opportunities for supplementing the lessons with practice-oriented videos, as well as animation to the topics in order to add visual effects, aiming to achieve better understanding of the material included in the exercises. The terminology vocabulary may also be extended as it contains indices for the English terms and abbreviations.

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ПРИЛОЖЕНИЕ НА WEB БАЗИРАНИТЕ ТЕХНОЛОГИИ В ОБУЧЕНИЕТО ПО XHTML

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***Резюме**: Общата тенденция за въвеждане на нови технологии във всички сфери се наблюдава и в областта на обучението. Възможността за създаване на интерактивно обучение спомага за по-лесно, бързо и приятно възприемане на учебния материал. В публикацията се дискутират въпроси, свързани с GSM технологията, приложенията на WAP и използването на HTML, XHTML и CSS. Представя се и разработеният сайт за web базирано обучение по XHTML*

***Ключови думи**: XHTML, Web базирани технологии,Web базирано обучение*

HUMAN COMPUTER INTERACTION IN COMPUTER SCIENCE EDUCATION

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***Abstract**: Including Human computer interface as a subject in modern education for Computer Science and related students is of very important. This could be clearly seen from the proposed subjects, curricula and other specialized courses offered at universities in Europe and USA. How is this reflected in the training of students in computer science in Bulgaria? A brief analysis of this issue and related problems, the authors try to give in this article.*

***Keywords**: Human-Computer Interaction, Human-Computer Interface, Education*

INTRODUCTION

Human–computer interaction is the study, planning and design of the interaction between people (users) and computers. It is often regarded as the intersection of computer science, behavioural sciences, design and several other fields of study. There is currently no agreed upon definition of the range of topics which form the area of human-computer interaction. There are some working definitions, that at least permit to get down to the practical work of deciding what is to be taught and one of them is:

Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them [2].

Research in Human-Computer Interaction has been spectacularly successful, and has fundamentally changed computing [1]. Through the past three decades, HCI has progressively integrated its scientific concerns with the engineering goal of improving the usability of computer systems and applications, thus establishing a body of technical knowledge and methodology.

One of the most important fields of Human-Computer Interaction for us is Human-Computer Interface (HCI) and its design.

EDUCATIONAL PURPOSES IN HCI

The objectives, pursued by HCI training, are to teach principles and techniques for design and development both usable and secure systems, but also functional. Emphasis is particularly the project construction and test methods for prototypes' development and evaluation and the psychological aspects of CHMI, too.

Long-term goal of HCI is to develop systems which minimize the barrier between the human model understanding of what is need to get from the computer and the real computer "perception" of the user task. This objective is the basis for building the subject's training.

People, dealing with HCI, are interested in developing new design methodologies, experimenting with new hardware devices, prototyping new software systems, explaining new paradigms of interaction and development of new models and theories of interaction.

To produce easy to use computer system, HCI professionals should:

- Understand the factors (physiological, ergonomic, organizational and social), which determine how people handle and make efficient use of computer technology;

- Apply this understanding in tools and techniques development, that help the designer to provide computer system, suitable for users, so that:
- Achieve efficient, effective and safe interaction with individual and group HCI

HCI IN COMPUTER SCIENCE EDUCATION

Human-computer interaction (HCI) has long been a focal area for innovative, multidisciplinary computing research and development. Ten years after the new millennium began, it is time to ask where this increasingly important field is going. Are the new forthcoming specialists in computer science ready for developing the HCI? Could they improve and appreciate the new interesting and stimulating ideas on the future of our interactions with computers?

How it is done worldwide?

In 1985, the ACM SIGCHI workshop on curricula in HCI (Mantei, 1985) proposed the development of courses in HCI [2]. Since then, numerous individual courses have been developed and instituted in many parts of the world [5]. The main proposed for the curricula courses are shown on Table 1.

Table 1 Course Emphases on the Content of HCI [2]

CONTENT AREAS (course length assumed to be 14 weeks with 42 contact hours total)		CS1: UI Design & Devel.	CS2: Phen & Thy of HCI	PSY1: Psych of HCI	MIS1: Human Aspects of IS
N	**The Nature of HCI**				
N1	(Meta-)Models of HCI	2	2	2	1
U	**Use and Context of Computers**				
U1	Human Social Organization and Work	2	4	4	4
U2	Application Areas	1	1	1	4
U3	Human-Machine Fit and Adaptation	2	2	4	3
H	**Human Characteristics**				
H1	Human Information Processing	1	9	4	1
H2	Language, Communication and Interaction	1	5	2	2
H3	Ergonomics	1	2	1	1
C	**Computer System and Interface Architecture**				
C1	Input and Output Devices	2	0	3	2
C2	Dialogue Techniques	3	0	4	3
C3	Dialogue Genre	1	0	1	1
C4	Computer Graphics	1	0	1	1
C5	Dialogue Architecture	1	0	1	0
D	**Development Process**				
D1	Design Approaches	4	2	4	4
D2	Implementation Techniques	5	2	2	4
D3	Evaluation Techniques	5	6	4	3
D4	Example Systems and Case Studies	3	2	2	4
P	**Project Presentations and Examinations**	7	5	2	4

Table 1 relates the content of HCI and the emphases of each topic for each of four proposed courses. All proposed in the curricula courses could be broadly characterized as either technology oriented (CS1: User Interface Design and Development and CS2: Phenomena and Theories of Human-Computer Interaction) or human oriented (PSY1: Psychology of Human-Computer Interaction and MIS1: Human Aspects of Information Systems). Also they are moving from a general professional/practical orientation (CS1 and MIS1) to one that is more specialized and research oriented (CS2 and PSY1). Also the courses should be specified, depending on the type of students – hardware or software oriented; bachelor, master or PhD etc.

Main courses and their interaction are shown on figure 1.

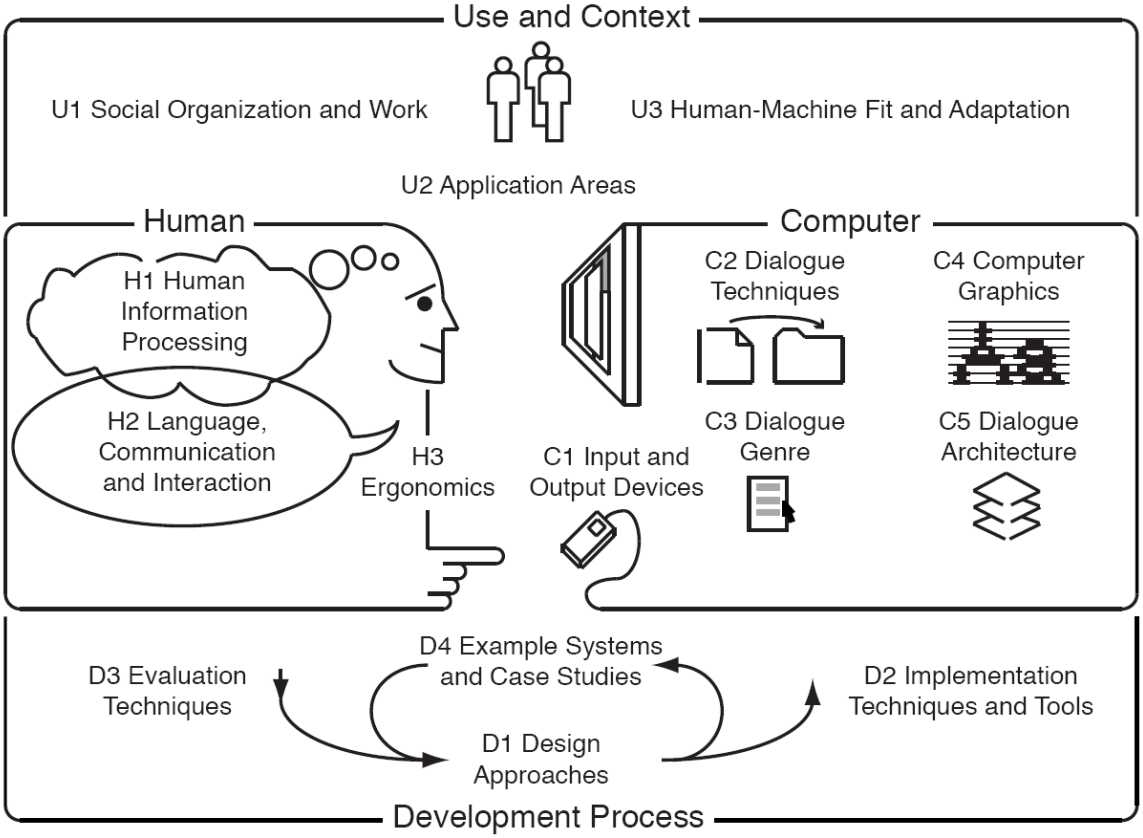

Fig. 1 Human-Computer Interaction

How it is done in Bulgaria?

In our country, the education in Computer science is already well developed. But it is not the same for including HCI in the computer science curricula in different universities.

As could be seen from Table 2, only a few universities have courses, which are oriented only to HCI.

Table 2 HCI courses in some Bulgarian Universities

University	Course Name	Students degree
Sofia University	Human Computer Interface Design	Bachelor Master specific course
Ruse University	Human Computer Interface	Bachelor (compulsory)
Plovdiv University	Principles in user interface construction for Web and Desktop applications	Bachelor (eligible)
Technical University – Varna	Human Computer Interface	Master
University of	Human Computer Interface Design	Bachelor (eligible)

Librarian Knowledge and Information Technology - Sofia		

There are lots of courses, which include parts (or themes) of technical oriented aspects in HCI. But the time and themes are too small and definitely not enough for such huge subject. Normally there are almost no courses, which deal with human aspects of HCI.

WHAT ARE THE MAIN PROBLEMS

Studying HCI in computer science education in Bulgaria, we have found some serious problems, namely:

- luck of appropriate learning systems ready for use – there are lots of systems, which some lecturers made for their own use or purposes [2, 4], but that is not a correct decision;
- luck of experience in biding education, in which the active side has to be the student;
- there are almost no literature in university libraries and all available is in English;
- a wide variety of software systems and interface types developed, which have to be well known, so the systems could be effectively used.

WHAT SHALL WE DO?

The studying subject HCI in the Computer science courses review made, allow making following ***conclusions***:

- Offered subject is actual and useful.
- Studying HCI corresponds to update level in sufficient stage, but the time and themes devoted to it in lectures are not enough.
- Preliminary students' knowledge in the field of interface models development is still very low.
- Students' language training is not good enough.

and some ***recommendations***:

- Force studying of interface models development, which are in the base of design useful software systems.
- Familiarizing students in using on-line materials, so they will keep abreast of the time and follow the novelty and tendencies in software development.
- At chance to increase the time, spend in learning business models designing principles.

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ОБУЧЕНИЕТО ПО ЧОВЕКО-МАШИНЕН ИНТЕРФЕЙС В ОБЛАСТТА НА КОМПЮТЪРНИТЕ НАУКИ В БЪЛГАРИЯ

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Русенски университет „Ангел Кънчев"

***Резюме**: Включването на човеко-машинния интерфейс като дисциплина в съвременното образование на студентите от специалност Компютърни науки и свързаните с тях е доста важно. Това може ясно да се види от предложените учебни дисциплини, учебни програми и различни специализирани курсове, предлагани в университетите в Европа и САЩ. Как е отразено това в обучението на студентите в областта на компютърните науки в България? Кратък анализ на състоянието на този въпрос и свързаните с него проблеми, авторите се опитват да дадат в настоящата статия.*

***Ключови думи**: Човеко-машинно взаимодействие, Човеко-машинен интерфейс, Обучение*

COMPUTER – BASED CONCEPTUAL MAPPING FOR FACILITATION OF CREATIVE AND MEANINGFUL LEARNING IN THE COURSE OF "MULTIMEDIA SYSTEMS AND TECHNOLOGIES"

Valentina Voinohovska

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***Abstract**: Constructivism implies that every learner must construct her/his own knowledge structure, or cognitive structure, through her/his own efforts. Knowledge structures are built primarily through meaningful learning, not by rote learning or simply memorizing information. This paper illustrates an approach of using computer – based concept mapping tool that facilitates creative and meaningful learning and helps organizing and representing knowledge.*

***Keywords**: concept map, constructivism, computer – based, meaningful learning, quality of education*

INTRODUCTION

Last few years were marked by rapid technological advances and deep changes in many aspects of human activity. Such changes have stimulated much discussion about the role and processes of education, and about the role of information and communication technology (ICT) in teaching and learning.

The new standards identify several higher – order thinking skills and digital citizenship as critical for students to learn effectively for a lifetime and live productively. These areas include the ability to:

- Demonstrate creativity and innovation;
- Communicate and collaborate;
- Plan strategies to guide inquiry, make research, locate, organize, analyze, evaluate, synthesize and ethically use information from a variety of sources and media;
- Think critically, solve complex, multidisciplinary, open-ended problems, and take decisions;
- Use technology effectively and productively;
- Evaluate and select information sources and digital tools based on the appropriateness to specific tasks;
- Process data and report results;
- Making innovative use of knowledge, information and opportunities to create new products.

In order to meet the expectations of students who live in a technology - rich environment, the classroom must provide interactive opportunities which motivate and allow them to focus on learning [10, 14, 15]. Visual learning techniques include the use of digital technology to create diagrams, such as concept maps and webs, and use graphs, charts and images for analyzing and communicating information.

CONCEPT MAPS ESSENTIALS

Information visualization is a broad topic. Advances in technology and in understanding of cognition and perception have lead to new techniques and methods for visualizing information [6]. Workshops, symposiums, and conferences are frequently held on information visualization.

Knowledge visualization however, is a relatively new area for research. Novak proposed that the basic elements of knowledge are concepts and relationships between concepts are propositions. Concepts are defined as "records of events or objects,

designated by a label" [8]. Propositions consist of two or more concept labels connected by a linking relationship that forms a semantic unit [7]. According to many researchers using these propositions, we construct new knowledge by linking new concepts to our previous knowledge.

Structuring knowledge with visual representations during study time has the following advantages:

- Students easily recognizes visual symbols;
- Less text facilitates a word, phrase, or general idea scanning;
- Visual representation allows for general understanding;
- Students make abstract ideas visible and concrete;
- Reorganization of student's knowledge;
- Provide structure for thinking, writing, discussing, analyzing, planning and reporting;
- Explicit description of concepts and their interrelationships;
- Deep processing of knowledge, which promotes better remembering and retrieval and the ability to apply knowledge in new situations;
- Relating new concepts to existing concepts and ideas, which improve understanding and interpretation.

Concept mapping is a powerful learning technique consistent with constructivist learning theory. Constructivists [8, 11] theorized that the individual learner acquires knowledge by linking new information with past experiences to create a personal process for meaning – making. In constructivist learning, students are involved in knowledge construction and not knowledge absorption.

With the fundamental goal of fostering learning Novak [8] proposed that concept maps embody constructivist theory. Through constructivist approaches learners actively build their own knowledge, rather than adapting the teacher's interpretation of the world. In constructivist environments where students use concept mapping tools, learners are actively engaged in reflecting on their interpretation of the external world and constructing meaningful learning [3, 4].

Novak's experiences in using concept maps to help guide student learning were highly positive. They were supported by Vygotsky's [12] ideas of the importance of social exchanges in learning. Another idea that was supported is Vygotsky's concept of "Zone of Proximal Development" (ZPD). Vygotsky's studies showed that there was a level of cognitive development that allowed a learner to advance in understanding of a given domain of knowledge without coaching, and a higher level of understanding beyond which the learner cannot advance without coaching. He called this range of understanding the Zone of proximal Development.

Concept maps have been shown to be an effective for the education as tool for evaluation, displaying students' prior knowledge, summarizing what has been learned, note taking, planning, scaffolding for understanding, establish educational experiences, improving affective conditions for learning, teaching critical thinking, supporting cooperation and collaboration, and organizing content [2].

By concept mapping, students can learn meaningfully. In Ausubel's view, to learn meaningfully, students must relate new knowledge (concepts and propositions) to what they already know. He proposed the notion of an advanced organizer as a way to help students link their ideas with new information or concepts and claimed that new concepts can be incorporated into more inclusive concepts or ideas during learning. Jonassen, Peck, and Wilson [5] argued that meaningful learning has the following features:

- Active – learners interact with an environment and manipulate the objects in that environment, observe the effects of their interventions and construct their own interpretations;

- Constructive – learners integrate new interpretations with their prior knowledge;
- Intentional – learners articulate their learning goals, what they are doing, the decisions they make, the strategies they use, and the answers that they find;
- Authentic – learning tasks are real-world problems;
- Cooperative/collaborative – learners work in groups.

A concept map is a way of representing relations between ideas, images or words. Each word or phrase is connected to another and linked back to the original idea, word or phrase. Concept maps are a way to develop logical thinking and study skills, by revealing connections and helping students see how individual ideas form a larger whole.

Concept maps are flexible. They can be made simple or detailed, linear, branched, radiating, or cross-linked:

- Linear concept maps - one concept or event leads to another.
- Hierarchical concept maps represent information in a descending order of importance - the key concept is on top, and subordinate concepts are below.
- Spider concept maps - basic theme in the center of the map and sub-themes surround the main theme.
- Cross – linked maps - descriptive word or phrase and identify the relationship with a labeled arrow.

In a “well constructed” concept map [1]:

- Each pair of concepts, together with their joining linking phrase, can be read as an individual statement or proposition that makes sense;
- Concepts and linking phrases are as short as possible, possibly single words;
- The structure is hierarchical and the root node of the map represents the topic of the map.

Figure 1 shows an example of a concept map that describes the structure of concept maps and illustrates their characteristics.

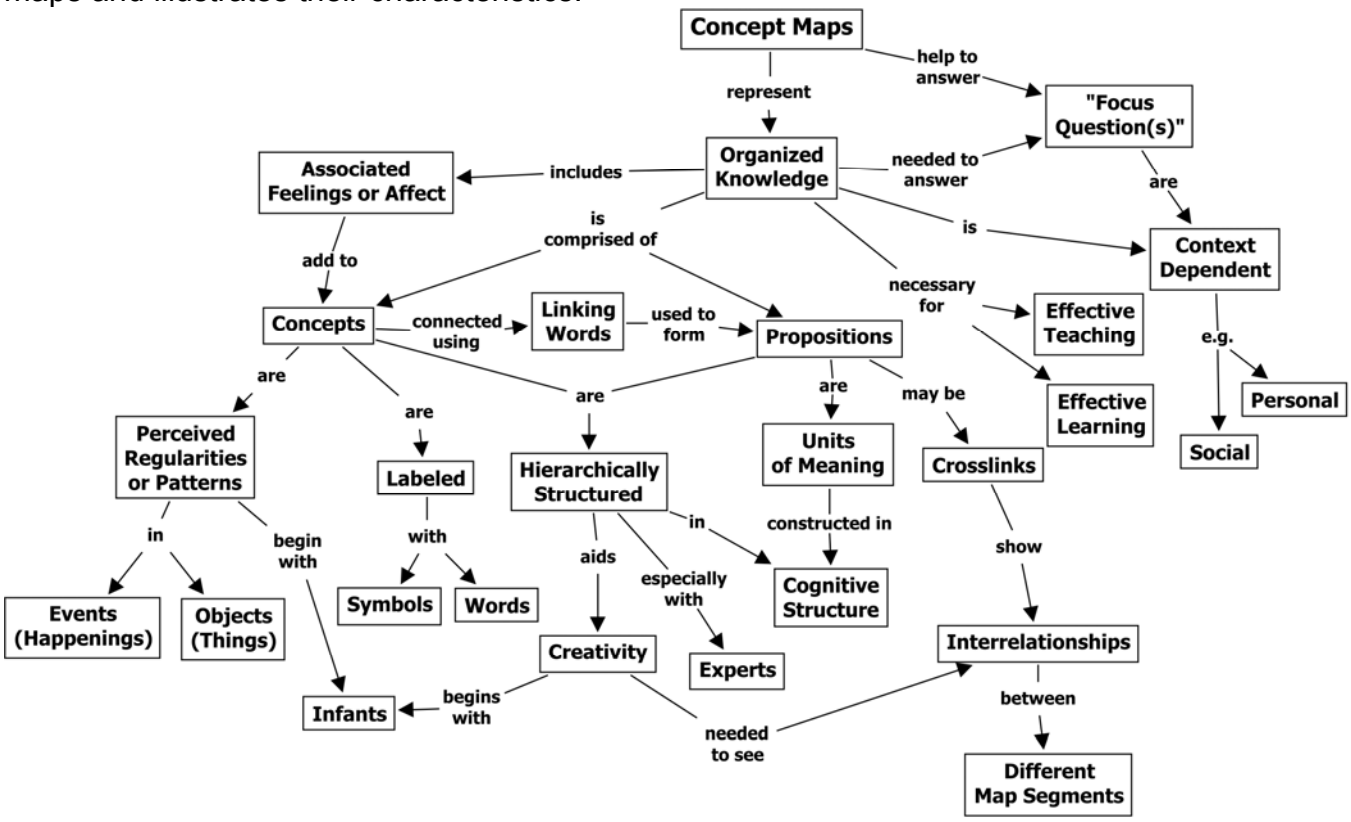


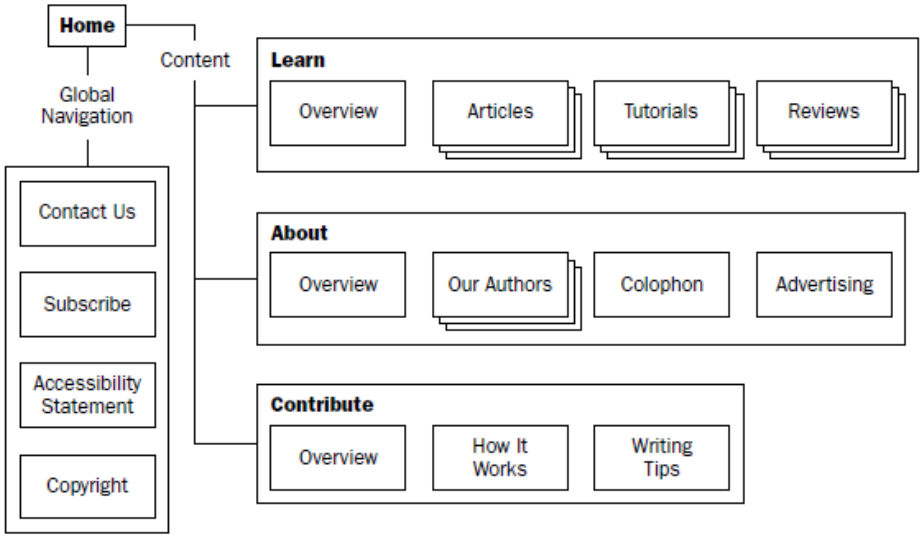
Figure. 1. A concept map showing the key features of concept maps [9].

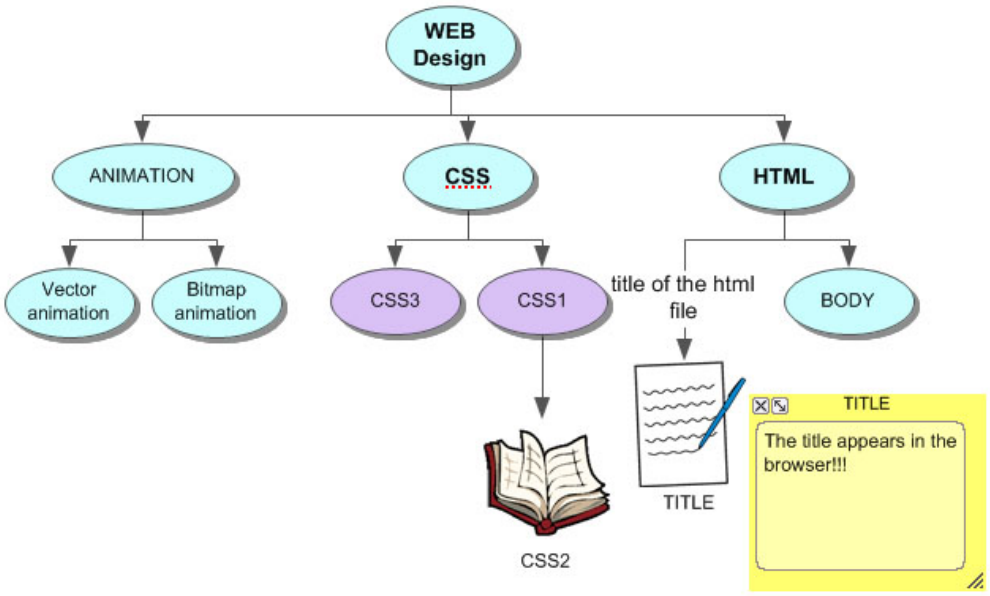
COMPUTER – BASED CONCEPT MAPPING STRATEGIES

In the course "Multimedia Systems and Technologies" students create visual models that facilitate creative thinking and help them organize, analyze, evaluate and present information by using computer – based concept mapping tool.

1. Visualize and develop ideas with graphical organizers and diagrams

- Brainstorm and capture ideas, clarify thoughts;
- Represent ideas visually using symbols, add new topic and subtopic;
- Use links to present relationships between ideas;
- Rearrange and connect ideas easily by replacing the branches;
- Add text or text phrases to links to explain relationships;
- Use different colors, shapes, patterns, shadows, fonts and styles to differentiate their ideas;
- Arrange diagrams into different tree charts;

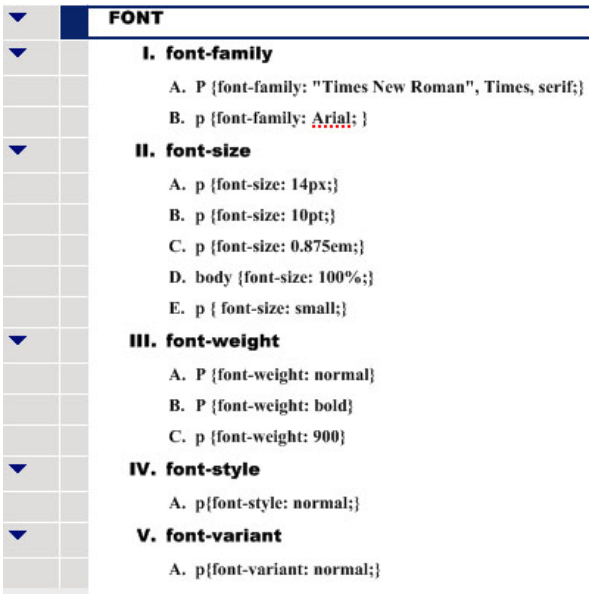


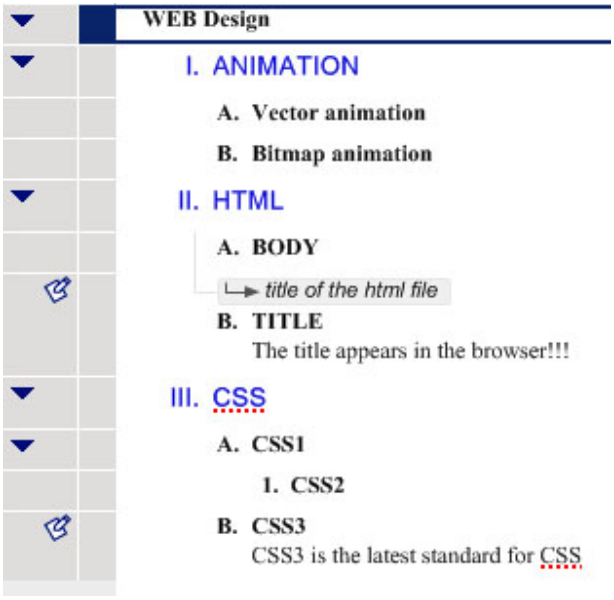


2. Plan and organize written work

- Capture ideas and information;
- Hide and show levels of detail to see the big picture or all of the content;
- Transfer the outline to word processor for formatting and finish the written work;

- Rearrange topics by dragging;
- Transform notes and paragraphs into individual topics to reorganize information easily and quickly;
- Plan projects and track ideas;
- Add topics at different levels;





3. Present Knowledge

Students present their work, on the basis of the content they have already developed. The collected information is expanded in presentations.

- Develop presentation using the content they have already have;
- Use professional themes to create visually appealing presentations. Customize themes to personalize them by adding graphics and changing background colors, fonts, and bullet styles;
- Add graphics from computer and Internet;
- Add video and sound files;
- Add speaker notes to slides;
- Use slide transitions;
- Print slides in various formats;

4. Engage Students with Collaborative Learning

Students actively engage in learning by collaborating on group projects, share documents, and receive guidance from the teacher during the entire process.

- Collaborate on group projects and sharing information to create collective knowledge;
- Share documents for review and suggestions. Adding comments directly into documents without overwriting original text, so students can see suggestions and respond with revisions to improve the quality of work;
- Share completed work with other students.

CONCLUSION

Effective education programs include a wide range of learning activities: selected readings, Internet searches, project work, report preparation and presentation, drawings, video presentations, collaborative research, and other activities. The study shows

knowledge visualization as an effective technique for teaching and learning. The use of modern computer – based mapping tool, an integration of knowledge and information visualization has the potential of impacting the management of knowledge, information, and education.

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КОМПЮТЪРНО – БАЗИРАНО СРЕДСТВО ЗА СЪЗДАВАНЕ НА ПОНЯТИЙНИ КАРТИ С ЦЕЛ ПОДПОМАГАНЕ НА ТВОРЧЕСКОТО И СЪДЪРЖАТЕЛНОТО УЧЕНЕ В КУРСА ПО „МУЛТИМЕДИЙНИ СИСТЕМИ И ТЕХНОЛОГИИ”

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***Резюме**: Според теорията на конструктивизма всеки обучаем самостоятелно трябва да конструира своята собствена структура от знания. Структурата от знания се изгражда предимно чрез съдържателно учене, а не с учене на изуст и само запоняне на информация. В тази статия е описан подход за използване на компютърно – базирано средсво за създаване на понятийни карти, което насърчава творческото и съдържателно учене на студенте и им помага за организиране и представяне на знанията им.*

***Ключови думи**: понятийна карта, конструктивизъм, съдържателно учене, компютърно – базиран, качество на обучението*

AN EDUCATIONAL TOOL FOR NOVICE PROGRAMMERS

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***Abstract**: The paper investigates the characteristics of novice programmers, their difficulties in introductory programming courses. There are described variety aspects of programming – too many reasons for novices' overwhelming and de-motivation. The significant role of visualization environments and algorithm animation tools is presented. It is underlined that the provision of a useful and accurate mental model and algorithm making abilities will positively influence a novice's success in programming. A tool design for algorithm animation and its learning aids are presented.*

***Keywords:** Computer Science, Algorithm Animation, Algorithm Visualization Tools, Novice Programmers*

INTRODUCTION

Data structures and algorithms are important foundation topics in computer science education. Students deal with algorithms in many computer science courses. For instance, in computer graphics, students learn objects rendering algorithms, in networking, they study algorithms that solve networks track congestion, and in database, they learn algorithms that search or sort data. Accordingly, teaching algorithms is a common activity that takes place in many computer science classes. However, algorithms are often hard to understand because they usually model complicated concepts, refer to abstract notions, describe complex dynamic changes in data structures, or solve relatively difficult problems. Consequently, teaching algorithms is a challenging task that faces instructors and requires a lot of explaining and illustrating. Therefore, teaching aids other than conventional are needed to help students understand algorithms better [6]. The ability to realize graphic representations faster than textual representations led to the idea of using block schemes to describe the behaviour of algorithms to learners.

DIFFICULTIES IN LEARNING PROGRAMMING

Learning to program is generally considered hard, and programming courses often have high dropout rates [10]. Educational research has been carried out to recognize the characteristics of novice programmers and to study the learning process and its connections to the variety aspects of programming. Let explore these issues more closely.

CHARACTERISTICS OF NOVICE PROGRAMMERS

By definition, novice programmers lack the knowledge and skills of programming experts. Several different separating factors have been studied in the literature and were also reviewed by Robins et al. [11]. Common features for novices seem to be that they are limited to surface knowledge of programs and generally approach programming "line by line", rather than at the level of bigger scope. Novices spend little time in designing and testing their algorithm. When necessary, try to correct their mistakes with small local fixes instead of more thoroughly reformulations [2]. The knowledge of novices tends to be context specific rather than general [3], and they also often fail to apply correctly the knowledge they have obtained. In fact, an average student does not usually make much progress in an introductory programming course [2]. This was also noticed by the study of McCracken et al. [5], who noticed serious deficiencies in student's programming skills in introductory courses. This supports the empirical observations of many teachers; programming novices often fail to recognize their own deficiencies. Also the personal

properties of the students affect their performance. Mathematical or science abilities seem to be related to success at learning to program [4, 7]. In an introducing course, different student behaviours in confronting a problematic situation can be recognized. Perkins [9] named two main types novices: stoppers and movers. In problematic situation stoppers simply stop and abandon all hope of solving the problem on their own, while movers keep trying, modifying their algorithm and use feedback about errors effectively. There are also extreme movers, "thinkers", who cannot track their work, make changes more or less randomly, and like stoppers do not progress very much in their task. There are effective and ineffective novices, i.e. students who learn without excessive effort and those who do not learn without inordinate personal attention [11]. Naturally, students' personal learning strategies and motivation affect their success in learning programming strategies. Robins et al. [11] stated that "Given that knowledge is (assumed to be) uniformly low, it is their pre-existing strategies that initially distinguish effective and ineffective novices". Prior knowledge and practices can also be a major source of errors, especially when trying to transfer a step-by-step problem-solving solution directly from a natural language into a program [13]. The differences between the natural language and a programming language could easily cause problems.

VARIETY ASPECTS OF PROGRAMMING

Learning programming contains several activities, e.g., learning the language features, algorithm design, and algorithm comprehension. Typical approach in textbooks and programming courses is to start with declarative knowledge about a particular language. However, studies show that it is important to bring also other aspects to the first programming courses. Several common deficits in novices' understanding of specific programming language constructs are presented in Soloway and Spohrer [13] and collected also by Pane and Myers [8]. For example, variable initialization seems to be more difficult to understand than updating or testing variables.

However, the main source of difficulty does not seem to be the syntax or understanding of concepts, but rather basic algorithm planning [11]. It is important to distinguish between programming knowledge and programming strategies [1]. Winslow [14] noticed that students may know the syntax and semantics of individual statements, but they do not know how to combine these features into valid algorithms. Even when they know how to solve the problem by hand, they have trouble translating it into an equivalent algorithm.

Students have often great difficulties in understanding all the issues, relating to the execution of a program. Students have difficulties in understanding that each instruction is executed in the state, which has been created by the previous instructions.

There is often little correspondence between the ability to write a program and the awareness to read one. Programming courses should include them both. In addition, some basic test and debugging strategies should be taught [14]. Robins et al. [11] suggest that one more issue that complicates the learning of programming is the distinction between the mental model as it was intended, and the program model as it actually is. There are often mistakes in the design and bugs in the code. Also in working life, programmers face daily the need to understand a program that is running in an unexpected way. This requires an ability to track code to build a mental model of the program and predict its behavior. This is one of skills that could be developed by emphasizing algorithm comprehension and debugging strategies in the programming courses.

We can generalize that it is clear that novices are burdened by having to learn so many new things in introductory programming courses. This leads to an overwhelming perception of incapability and uphill struggle in a large proportion of novices. Their self-

esteem may be getting defeated before they have even reached base subjects. Whilst syntax might be a difficulty for novices, it is evident that the more pressing issue is the deficiency in their problem solving and algorithm construction skills. Novices can understand the individual concepts of programming in isolation but have significant difficulties putting them together in order to express a problem's solution. The provision of a useful and accurate mental model and algorithm making abilities will positively influence a novice's success in programming.

THE ROLE OF ALGORITHM ANIMATION AND VISUALIZATION TOOLS IN NOVICE PROGRAMMERS INTRODUCTORY COURSES

Algorithm visualization and animation tools are designed to make visible aspects of programming often hidden from the programmer. As such they are capable of promoting "low-level" models of algorithm features such as models of execution. They can reinforce a model of an algorithm execution by explicitly showing how the execution of a statement affects the program state and hence the environment in which the following statement is executed.

Computerized aids that reinforce mental models and reliable algorithm construction of the programming process are far more appropriate for novice programmers than commercial environments [12]. There are many environments aimed novice programmers learning improvement. These tools provide some benefit, but it is clear that these ideas can be improved upon. If the features of these tools were usefully enhanced, extended and combined, it might prove to be more beneficial to novice programmers.

FLOWCHARTS

Flowcharts have traditionally been used to visualise algorithm structures and are a very appropriate visualisation form for novices. They are easy to learn, can be easily understood with little or no prior training and provide the novice with an accurate mental model of an algorithm and its components. Furthermore, flowcharts aid the processes of abstracting a problem into a solution and the transition between problem specification and syntactical solution.

Studies of flowchart-based animation tools have shown that by animating a flowchart, we can further its effectiveness and offer a concrete model of execution by demonstrating the interaction between algorithm components.

Our work benefits are directed to algorithm animation and block scheme advantages, usefully extend and combine in an application with learning aids. We suppose that in this way we will decrease variety problems in introductory programming courses and diminish the mental models level of abstraction.

A TOOL DESIGN FOR ALGORITHM ANIMATION

This research presents a novice-programming tool. It is aimed at facilitating the imperatives first approach to teaching introductory programming. This tool improves on existing approaches by combining multiple forms of animation with algorithm variables visualization features and the manually animation of flowcharts. It allows the user to construct a wide range of algorithms, involving variables, assignment, decisions, and looping. It is these basics that underpin the core problem solving aspects of imperative programming. However, knowledge of these concepts provides important skills, useful for developing process logic in any programming paradigm. The designed tool focuses on using flowcharts to develop visual solutions to basic programming problems. This provides the user with an accurate mental model of the algorithm structures. It provides the facility to animate its algorithms and visualises the effect each algorithm statement has on any

variables. The animation features and interaction with the visual representation reinforce student understanding of both the visual solution and algorithm statement flow. The tool allows the user to focus on the problem solving aspects of algorithm constructing whilst, minimising all other distractions. This has been achieved by eliminating the necessity of writing complex and confusing syntax and reducing the learning curve associated with professional development environments. These distractions cloud the problem solving processes at the heart of programming; minimising their impact reduces the cognitive overload that inhibits the algorithm construction abilities of many novices.

Our tool's user interface is simple and has a main working area of visualization for the flowchart design. There is learner support, providing for block context depended information entering. This tool's feature ensures user's mistake avoidance. The remaining areas of its user interface contain the controls to construct, animate, save and load flow charts, as well as perform other useful commands.

A flow chart creation

In the tool users can create an algorithm by interacting only with the flowchart and do not have to trouble themselves with entering large amounts of complex and confusing syntax. To add a component to a program, the user simply selects it from a component toolbar and clicks on the relevant part of the flowchart. The component is defined and if successful, gets added below the component selected (shown in figure 1). If the user makes an error during the component definition, they are presented with an accurate and meaningful error message.

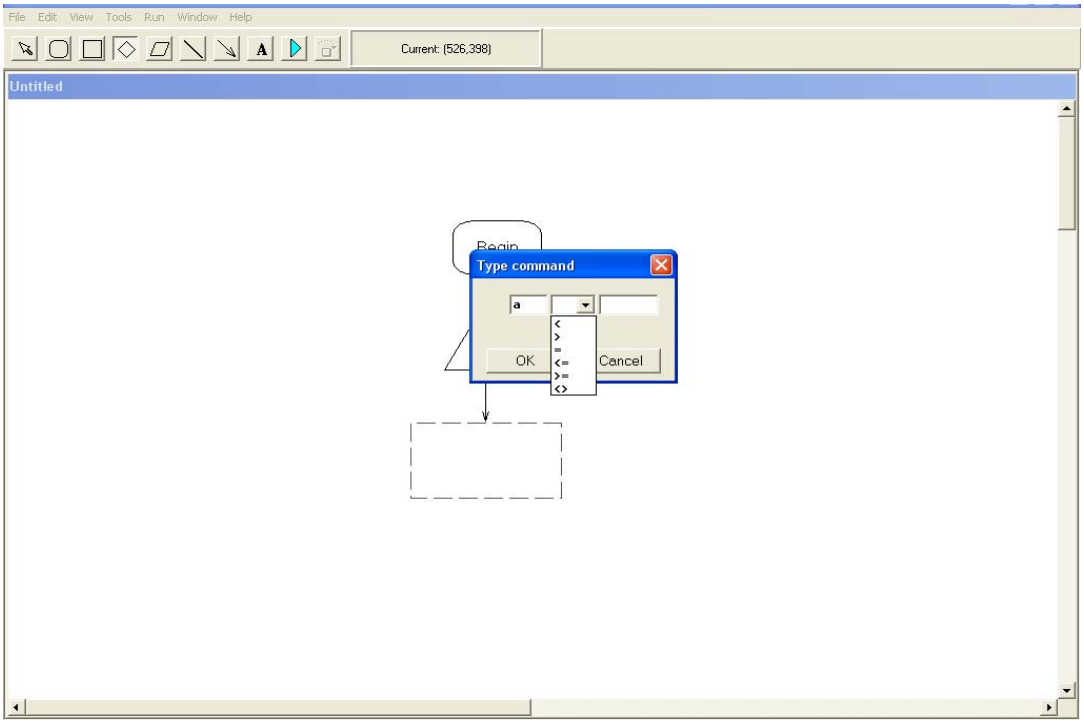

Figure 1. The Tool's User Interface

Variable handling

The values of algorithm variables are visualised in the window "Variables". This window is visible during algorithm execution/animation the variable inspector allows the user to observe in real time the effect each algorithm statement has on the data used.

Algorithm animation

The tool improves on the capabilities of the static flowchart by animating its

flowcharts to show an algorithm in action. The animation features emphasise algorithm flow concepts and the interaction between algorithm components in the flowchart representation. Combining this with the variable inspection features provides the user with an accurate and concrete model of a working algorithm.

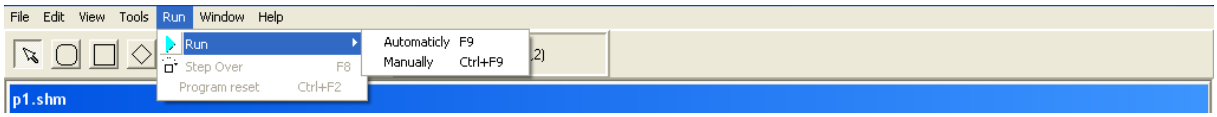

Figure 2. User Opportunities for Algorithm Visualization

The learner has two opportunities to visualize the algorithm action: automatically and step by step - manually (figure 2). In the first mode only the input variables' values are entering and the final result is shown (figure 3). This mode provides a feature for quick algorithm correctness testing. The step by step animation of a flowchart is achieved by tracing through the flow of an algorithm, highlighting each flowchart component and viewing relevant effect of its execution in real time by the variables' window. When a cyclic or conditional construction is reached, the flow in algorithm is diverted appropriately, based on the result of the logical expression it contains.

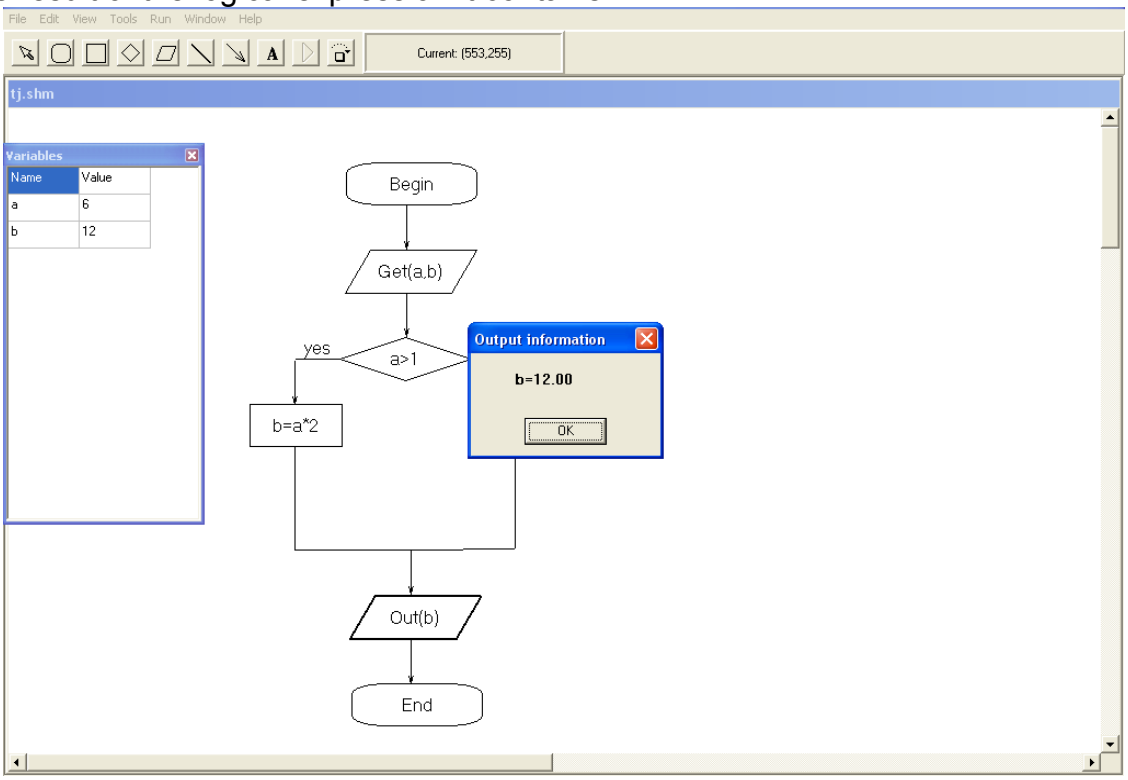

Figure 3. Variable Window and Output Result

Conclusions and future work

Future plans are to combine the use of the tool with a well-defined teaching pedagogy and online learning environment. Currently, the used pedagogy is based on operational approach theories of learning development [15] and it will being investigate. Of particular interest are the solving problems principles of this classroom teaching pedagogy. However, this idea is still in the initial stages of development and much more work is needed. Firstly, further research is needed to refine the ideas regarding this teaching pedagogy and how it can best be used to aid in the delivery of the introductory concepts of programming. Secondly, an online learning environment that fully exploits the capabilities of our algorithm animation tool and the pedagogy needs to be researched, designed and

built. Modification of the tool will also be needed to further its use with respect to these proposals.

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СРЕДСТВО ЗА ОБУЧЕНИЕ НА НАЧИНАЕЩИ ПРОГРАМИСТИ

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Резюме: *Статията разглежда особеностите на начинаещите програмисти, техните затруднения във въвеждащите курсове по програмиране. Обърнато е внимание на многоаспектността на материала и причините, поради които начинаещите го намират за труден, непреодолим и се демотивират. Представено е положителното въздействие на средите за визуализация и анимация на алгоритми. Статията подчертава важността начинаещите да усвоят умения за съставяне на коректни и ефективни алгоритми, за да постигнат успех в програмирането. Представено е средство за подпомагане на начинаещите програмисти да преодолеят трудностите и да изградят умения за съставяне на алгоритми.*

Ключови думи: *Компютърни науки, Алгоритми, Начинаещи програмисти, Анимирано представяне на алгоритми*

A COURSE FOR PROMOTING STUDENT'S VISUAL LITERACY

Valentina Voinohovska

Angel Kanchev University of Ruse

***Abstract**: Rapidly evolving technology is changing the way people throughout the world work. It offers unlimited possibilities for creativity and collaboration. Today's environment is highly visual - television, web sites, video, and images, computer screens, signs, symbols, books, magazines, movies, and even body language provide visual messages. Visual information and technology literacy are core components of 21st century educational practice. This paper presents a training course which aims to promote the visual, information and technological literacy of students in the course of desktop publishing.*

***Keywords**: visual literacy, information literacy, technology literacy, information technology, education*

INTRODUCTION

It is difficult these days to find any industry in which knowledge workers do not need significant visual, technology and information literacy skills. The *en*Gauge report on 21st-century skills define literacy as the ability to use "digital technology, communications tools, and/or networks to access, manage, integrate, evaluate, and create information in order to function in a knowledge society".

- Visual literacy may be defined as the ability to recognize and understand ideas conveyed through visible actions or images, as well as to be able to convey ideas or messages through imagery [1];
- Information Literacy is defined as "a set of abilities requiring individuals to recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information." [3];
- Technology literacy is defined as the ability to responsibly use appropriate technology to communicate, solve problems, and access, manage, integrate, evaluate, and create information to improve learning in all subject areas and to acquire lifelong knowledge and skills in the 21st century [2].

Peoples have used images to express meaning for thousands of years ago. With the emergence of new information and communication technologies, the idea of educating people for visual literacy arises. During 1960s John Debes introduces the term "visual literacy" and, with a group of academics, hosted the first national conference on the topic. This group after that grew into the International Visual Literacy Association, which held an annual conference and supports a Web portal with links to resources, teaching materials and publications.

There is strong connection between visual literacy and emerging technologies. EDUCAUSE, a leading association, whose mission is to advance higher education by promoting the intelligent use of information technology, has made visual literacy an important part of its agenda. Another international consortium of academics and technologists is the New Media Consortium. The annual report produced by EDUCAUSE and the New Media Consortium, shows how new information and communication technologies will influence higher education.

Visual literacy is related with constructivist learning through the role of individual learner acquiring knowledge by linking new information with past experiences to create a personal process for meaning – making and by interacting with the environment [7]. Technology, particularly the graphical user interface of the World Wide Web, requires skills

for reading and writing visually in order to derive meaning from what is being communicated.

Visual images are becoming the prevalent form of expressing information in the learning and teaching resources, delivered across a range of media and formats [6]. Visual image predominates to the text. The widespread use of images means that visual literacy is crucial for obtaining information, constructing knowledge and building successful educational outcomes. Visual literacy supports a comprehension of visual communication. A lack of awareness of visual literacy affects student's ability to be able to communicate effectively. By understanding the basic principles of visual literacy, learners can produce images that communicate in a more efficient ways.

Visual literacy is the ability to understand, create, and use visual images. Associated with visual literacy are:

- Visual thinking - the ability to transform thoughts, ideas, and information into all types of pictures, graphics, or other images that help communicate the associated information.
- Visual communication - pictures, graphics, and other images are used to express ideas and to teach students. In order to be effective visual communication, the receiver must be able to construct meaning from seeing the visual image.
- Visual learning - process of learning from pictures and media. Visual learning includes the construction of knowledge by the learner as a result of seeing the visual image.

VISUAL LITERACY COMPETENCY STANDARDS

The Visual Literacy Competency Standards were collaboratively written by the members of the Visual Literacy Standards Task Force (VLTF), using the Information Literacy Competency Standards as a foundational document. In March 2010, the ACRL Information Literacy Standards Committee gave support to the ACRL Image Resources Interest Group's (IRIG) proposal to develop Visual Literacy Competency Standards. The first public draft of the Standards was distributed in February 2011 [4]:

1. The visually literate student determines the nature and extent of the visual materials needed:
   - Defines and articulates the need for an image;
   - Identifies a variety of image sources, materials, and types;
2. The visually literate student finds and accesses needed images and visual media effectively and efficiently
   - Selects the most appropriate sources and retrieval systems for finding and accessing needed images and visual media;
   - Conducts effective image searches;
   - Acquires and organizes images and source information;
3. The visually literate student interprets and analyzes the meaning of images and visual media
   - Identifies information relevant to an image's meaning;
   - Situates an image in its cultural, social, and historical contexts;
   - Identifies the physical, technical, and design components of an image;
   - Validates interpretation and analysis of images through discourse with others;
4. The visually literate student critically evaluates images and their sources
   - Evaluates the aesthetic and technical characteristics of images
   - Evaluates the effectiveness and reliability of images as visual communications
   - Evaluates textual information accompanying images
   - Makes judgments about the reliability and accuracy of image sources

5. The visually literate student uses images and visual media effectively
   - Uses images effectively for different purposes
   - Uses technology effectively to work with images
   - Uses problem solving, creativity, and experimentation to incorporate images into scholarly projects
   - Communicates effectively with and about images
6. The visually literate student designs and creates meaningful images and visual media
   - Produces images for a range of projects and scholarly uses
   - Uses design strategies and creativity in image production
   - Uses a variety of tools and technologies to produce images
   - Evaluates personally created image products
7. The visually literate student understands many of the ethical, legal, social, and economic issues surrounding the creation and use of images and visual media, and accesses and uses visual materials ethically
   - Understands many of the ethical, legal, social, and economic issues surrounding images and visual media
   - Follows ethical and legal best practices when accessing, using, and creating images
   - Acknowledges image creators and sources in projects and presentations

PROMOTING VISUAL, INFORMATION AND TECHNOLOGY LITERACY

To produce quality images for print, web, and video, students need to understand essential graphic design principles and the process of creation of digital images [5]. In this course, students learn the basics of visual design, photography and image composition and use:

The purpose of the curse is to demonstrate methods and techniques for integrating and teaching new literacy needs in the classroom:

- Visual literacy: The course will cover the students' ability to use, construct, analyze and communicate visual information. After the study students will acquire practical skills in graphic design, photography, print and layout design, and production. Students work with real – world projects that help them better understand the essential of visual design. They work in teams or individual. The projects contain activities that require students to share the ideas, to give and receive peer review comments and to rework their products
- Information Literacy: The course will demonstrate students' abilities to apply information to high – level problem solving and engage in analytical and critical thinking. In addition, the students' will demonstrate the ability to determine the extent of information needed, access and use information effectively and efficiently, evaluate information and its sources critically, and understand the access and use information ethically and legally.
- Technology literacy
  - Using digital camera and scanner;
  - Using powerful photography tool for complex image selections, realistic painting and drawing, retouching, image correction, color and tone control, image editing and enhancement, etc.;
  - Using powerful tool for precise control over typography and built – in creative tools for designing, create sophisticated page layouts for publishing, interactive PDF documents that include video and sound documents, SWF documents complete with interactivity, animation, sound, and video;
  - Using powerful tool for vector drawing;

- Using text editor.

The course is divided into the following parts:

Part 1 – Work with images and photography

- Organizing and managing images - managing files and using file – naming conventions, understanding file formats, resolution, and file size, understanding techniques used to create visual hierarchy;
- Image source, copyright issues and fair use guidelines;
- Color enhancement and retouching techniques - color correction and effects;
- Principles of image composition;
- Analyzing and critiquing photographs;
- Using a digital camera too learn the basic of photography;
- Scanning images;
- Working with authoring tool for image editing (Adobe Photoshop) - working with various file formats, retouching photos, adjusting brightness and contrast, levels and colors, cropping, resizing, and straightening images, transforming and combining multiple images.

Part 2 – Create logo

- Investigating logos;
- Selecting file formats;
- Understanding and employing design principles;
- Understanding and employing color theory - color modes, color management;
- Creating and editing graphical elements and illustrations;
- Communicating and presenting design decisions;
- Sketching a logo;
- Working with authoring tool for managing and organizing graphics elements and illustrations (Adobe Photoshop).

Part 3 – Create Business cards

- Evaluating and analyzing business cards;
- Understanding different print formats;
- Applying principles of print design;
- Sketching a business card;
- Creating an original work;
- Presenting a design layout to a group;
- Planning strategies to guide inquiry;
- Working with authoring tool for precise control over typography and built-in creative tools for designing, publishing documents for print (Adobe Indesign).

Part 4 – Create advertisements

- Understanding different file formats;
- Analyzing and evaluating advertisements;
- Planning strategies to guide inquiry;
- Sketching advertisements;
- Balancing graphics and text;
- Designing for emphasis and usability;
- Creating an original work.
- Working with authoring tool for precise control over typography and built-in creative tools for designing, publishing documents for print (Adobe Indesign) - formatting text (kerning, tracking, scaling, etc.), combining graphic and text, using layers, placing objects, placing text over images

Part 5 – Create brochures
- Analyzing and evaluating brochures;
- Understanding sustainable design principles;
- Designing interactive Tri-fold layout brochure;
- Presenting designs to the group;
- Creating compelling brochure content;
- Giving and receiving peer review comments;
- Improving the product;
- Working with authoring tool for precise control over typography and built-in creative tools for designing, publishing documents for print (Adobe Indesign) – working with frames, placeholder text, columns, character and paragraph styles, wrapping text around objects, applying effects to text, placing objects on page, creating shapes and borders, creating interactive documents

Part 6 – Create newsletters
- Analyzing newsletters;
- Accessing, evaluating, and synthesizing content from multiple sources;
- Collaborating with other students;
- Designing a nameplate;
- Using design techniques to differentiate content and to provoke interest;
- Designing multi-column and multi-page layouts;
- Incorporating color and layout consistently;
- Integrating imagery and text;
- Providing clear navigation;
- Working with authoring tool for precise control over typography and built-in creative tools for designing, publishing documents for print (Adobe Indesign) – creating templates, using objects from the library, creating multi-page spreads, transforming objects, managing text flow between frames and columns, adding page numbers, import text from text editor;
- Working with authoring tool for vector drawing (Corel Draw) – working with the interface, drawing in perspective, comparing vector and bitmap images, using stroke, fill, polygons and paths.

Part 7 – Create portfolio
- Planning and conducting research strategies;
- Understanding and practicing lifelong career skills - job research skills and presenting skills;
- Defining the goals and uses of a portfolio
- Organizing and managing content;
- Designing consistent pages;
- Creating a Web Photo Gallery (Adobe Photoshop);
- Working with authoring tool for creating a portfolio (Adobe Indesign)

CONCLUSION

The purpose of this paper is to present a course for promoting new literacy needs in the classroom. Pilot project is planned for academic year 2011-2012. Assessment will include components such as evaluation of skills in visual, information and technology literacy, a survey about student's learning outcomes, collecting examples of student work for further comparative analysis, and review. After the pilot, the experiences and findings will be used to further improvements of the curriculum.

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КУРС ЗА ПОВИШАВАНЕ НА ВИЗУАЛНАТА ГРАМОТНОСТ НА СТУДЕНТИТЕ

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***Резюме**: Бързо развиващите се технологии променят начина, по който хората работят предоставяйки неограничени възможности за креативност и сътрудничество. Средите за работа днес са високо визуални. Телевизията, уеб сайтовете, видеото и изображенията, компютърните екрани, знаците, символите, книгите, филмите и дори езика на тялото имат специални послания. Визуалната, информационната и технологичната грамотност са основните компоненти на съвременната обучаваща практика. Тази статия представя курс на обучение, който е насочен към подобряване на визуалната, информационната и технологичната грамотност на студентите в курса по предпечатна подготовка.*

***Ключови думи**: визуална грамотност, информационна грамотност, технологична грамотност, информационни технологии, обучение*

TEACHING AND LEARNING MATHEMATICS BASED ON GEOGEBRA USAGE

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Abstract: *The paper presents conditions and results of studies which determine the necessity of using computer technology, particularly GEOGEBRA in teaching and learning of mathematics.The results of a pilot study are presented concerning the attitudes of teachers in mathematics from Ruse for deeping learning of GEOGEBRA and its future application in teaching and learning processes. The study includes the training of 16 teachers in mathematics from different schools.*

Keywords*: GEOGEBRA, teacher education, mathematics.*

INTRODUCTION

The development of the technological postindustrial societies in countries like USA, Japan, Korea, Iceland and others, creates the need of skills for learning throughout the entire life, based on knowledge and skills in using computer and information technologies.

The preparation of teachers in mathematics, which is to be in compliance with the modern need of the public, demands the development of skills for appropriate usage of modern day technologies in the study of mathematics. Influenced by companies like CASIO, who develop educational software, researchers in the field of teaching and learning mathematics, math teachers in schools and lecturers at universities pointed their attention to the usage of:

- Numerical and graphical calculators;
- Computer Algebra Systems (CAS), aimed at simulations with symbolical expressions like Derive, Maple, Matematica;
- Dynamical Geometry Software (DGS), based on the relations between geometrical objects like Cabri and Sketchpad.

In the process of using them the two formats CAS and DGS are being perfected and turned into comfortable products, which are easily used to solve a variety of mathematical problems – the forms of CAS contain possibilities for visualizing mathematical objects and ratios and DGS contain elements of algebra representation.

The software GEOGEBRA [3] combines many of the possibilities of the two formats CAS and DGS, for instance the equations and coordinates of points can be entered directly, graphically with the mouse or algebraically through the entering of algebraic values. Analogically the functions can be defined algebraically and then altered dynamically by changing the graphic.

The training of teachers in Bulgaria in using GEOGEBRA in teaching mathematics corresponds with the public educational goals.

THE BENEFITS OF USING CAS & DGS

Research in the usage of CAS & DGS as tools in teaching mathematics shows them as a base for developing theoretical models aiming the usage of technologies in the study of mathematics. For instance, the K. Ruthven model is created on the basis of a study on the application of CAS systems in teaching mathematics [11]. The research confirms the usage of technologies in the learning process:

- Increasing sufficiently the effectiveness of content performance;
- Helps the creation of good learning conditions for students in the classrooms.

Another research of K.Ruthven [12] on the role of digital technologies and resources in the improvement of processes of testing skills concluded that these technologies help to:

- Increase the speed and efficiency in presenting the academic material;
- Make the presentation more diverse and interesting;
- Provide conditions for changing the way of learning – introduction of elements of games, fun and excitement;
- Motivate and stimulate the students to learn.

The research of A.Carle, D. Jaffee and D.Miller shows that the usage of computer based technologies increases the motivation of the students for achieving higher goals [1].

The number of studies aimed at the usage of DGS in the learning process of mathematics is increasing. Jahn, A. & J. Salazar study the possibilities of exploring three-dimensional geometry using a dynamic geometry environment [4]. S.Soury-Lavergne studies the deductive reasoning, based on dynamic geometry using of CABRI 3D [13].

The researcher V. Kokol-Volich determines the possibilities of GEOGEBRA for the early development of geometrical concepts [6].

The project of P. Kenderov „Innovation in Studying Mathematics on an European Level“ [17] is aimed at forming basic knowledge in the usage of information technologies in the study of mathematics.

The rapid spread and development of GEOGEBRA verifies its efficiency in the teaching of mathematics [15].

On one hand it’s important the teachers and the pupils to develop themselves as users of CAS & DGS technologies, with which they can create new knowledge, solve tasks, simulate processes, prove hypotheses, explore objects, develop models. On the other hand, the students must also use CAS & DGS technologies in the right time, in the right conditions for the correct learning and disciplinary objectives.

GEOGEBRA USAGE IN TEACHING AND LEARNING MATHEMATICS

GEOGEBRA was designed by M. Hohenwarter at the University of Salzburg, Austria [3]. It connects the basic principles of mathematics study and those of usage of computer technologies in the education process. GEOGEBRA uses dynamic geometry, algebra and elements of mathematics analysis. With it an user can create:

- constructions of points, vectors, circle segments, segments, etc.;
- functions which later can be dynamically changed by the usage of a mouse.

The most important characteristics of GEOGEBRA is its ability for a dual presentation of objects: every string in the algebraic window output has its correspondent value in the geometrical one and vice versa.

GEOGEBRA is mathematical software and its features can be studied in the process of learning mathematics.

GEOGEBRA is freeware software, it does not require licensing, and this is one of the main reasons for its fast spreading and usage across schools and universities.

Many people believe that GEOGEBRA can be a motivating factor in the process of teaching mathematics and a useful tool for students throughout their education.

GEOGEBRA is suitable to be used for:

- research activity, where it is used on the basis of combining facts, experimenting with certain combinations, results analysis and hypothesis suggesting, creating models, confirming or withdrawing a hypothesis;
- simulations which aim to analyze possible solutions and many other..

The main purposes of the "Fibonacci - Disseminating Inquiry-Based Science and Mathematics Education in Europe" [16] project are the following ones:

- to vastly include the research method that is based on the usage of CAS&DGS and in particular on GEOGEBRA in the process of teaching mathematics and natural science;
- to help the creation and development of centers for qualification and pre-qualification for currently practicing teachers so that they start using the research method in teaching mathematics and natural sciences;
- to create materials and manuals for GEOGEBRA usage in the process of teaching mathematics.

Publications and studies that study different software products, including GEOGEBRA, can also be found on the European Virtual Library of Mathematics (EVLM) [14]. EVLM is a database of theoretical study materials, relevant case studies and information on software products, which help gaining knowledge and abilities to implement it in both the processes of teaching and studying mathematics.

Gaining knowledge to work with GEOGEBRA when teaching is a necessary step in the development of the professional qualification of teachers in mathematics.

EXAMPLE OF CURRICULUM CONTENT FOR LEARNING GEOGEBRA

After an analysis on the usage of CAS & DGS as a mean for rising the efficiency of the learning process and the need to enrich the standard methods of mathematics teaching, a National Programme for Development of School Education and Preschool Education since 2006 to 2015 was created [9]. The aforementioned Programme is designed to encourage the integration of ITC technologies in education systems.

The main benefits of the Programme are connected with:

- enlargement and enrichment of the sphere of study by means of interactive methods and strategies for teaching and studying;
- improvement of the existing static forms of study materials and creation of dynamic (multimedia) materials, which integrate image, sound, animation and text;
- usage of electronic and multimedia study materials through education process.

The integration of educational mathematics software is set towards the development of abilities for effective knowledge management but not towards providing knowledge of the technology itself.

The expectations are set towards a positive change in both teachers and students' attitudes to the usage of ITC technologies in the process of mathematics teaching and studying and towards the development of students' abilities to create and work independently in an integrated approach towards the educational process.

The process of every study material unit development (lesson, problem, solution, analysis etc.) based on GEOGEBRA integration in mathematics teaching is connected with:

- an analysis of the basics of the national standards for curriculum in mathematics;
- determining the areas and subjects which allow integration of new knowledge and skills;
- determination and argumentation of deductive work technologies and the active methods of education;
- determining the routine and the creative cognitive activities of students;
- determining the tasks to be individually or cooperatively performed by the persons who studies and their teachers;
- others.

On the basis of the aforementioned the need of qualification and pre-qualification of teachers and lecturers which is aimed at updating their knowledge arises [9].

There are four main stages of gaining knowledge and skills to use and integrate GEOGEBRA in mathematics teaching. Those four stages are:

- First stage: Forming interest in the software by presenting its characteristics (main menus, submenus, tools) and mathematical problems, which require simplified geometrical drawings and constructions. A short manual is written to explain and instruct on this stage.
- Second stage: Teaching how the basic commands to be used through the development of samples added to the main education content Beginners manual creation, which contains all commands along with relevant examples, GEOGEBRA, drawing short sample math problems with the participation of the students.
- Third stage: Students' working independently on creating study materials by using GEOGEBRA. Results presentation in front of a suitable and relevant audience. Website's creation containing study materials and manuals and guides for advanced learners.
- Forth stage: Teaching based on methods for teaching and learning mathematics by using GEOGEBRA. Knowledge showing and testing in a real study process and results evaluation by experts from the GEOGEBRA Institute, Ruse, Bulgaria.

As a summary, studying GEOGEBRA by students in mathematics requires forming and developing knowledge for creating and using study resources in the educational process.

PILOT STUDY ON LEARNING GEOGEBRA

Public expectations guide the efforts of researchers to study:

- The role of technology in teaching, for example, to increase motivation to learn [1, 10].
- Benefits of integrating technology in teaching [5];
- Critical points in mathematics [5] and others.

However, there are studies which show that:

- Many trainers are convinced of the necessity and benefits of implementing technology in teaching, but do not use them [8];
- Many learners use technology to record lectures and instructions for exercises, etc... However, not for effective teaching [3].

These results, on one hand, and the offer of the senior expert in mathematics and informatics in RIO Ministry of Education and Science Mrs. Diana Milanova, to organize training on learning GEOGEBRA, on the other hand, directed me to conduct a pilot study.

The main objective of the research study was the attitude of teachers in mathematics from Ruse to the thorough study of geometric software GEOGEBRA and its future application in teaching and learning of mathematics.

Current tasks for achieving the objective are:

- To implement the first stage model for studying GEOGEBRA as a convenient tool in learning mathematics.
- To explore the views of participants on the thorough study of GEOGEBRA for the development and use of educational resources in mathematics.

The study involved 16 teachers of mathematics and students from fifth to twelfth grade from different types of schools: Secondary Schools, High School in European

Languages, German Languages School, Vocational School in Electrical and Electronic Engineering.

Students were motivated to participate in such training for several reasons:

- There are many GEOGEBRA institutes that distribute this software vault, organize scientific and practical conferences, develop and disseminate educational materials on algebra, geometry, etc....
- In 2010 training on GEOGEBRA was conducted by a team of the Fibonacci project.

Research Methodology:

1. Quick guide was developed with technical characteristics of GEOGEBRA, instructions for installing the product, main menus, sub menus, tasks with simple drawings.
2. A system of tasks was developed for opportunities to integrate GEOGEBRA as a tool for visualization and simulation in teaching specific mathematical topics to support the formation of knowledge and skills of students.
3. A questionnaire was developed relevant to the purpose and objectives of the study.

The survey results are as follows:

How useful was your training in GEOGEBRA (Fig. 1)?

Did the training fulfill your expectations (Fig. 2) ?

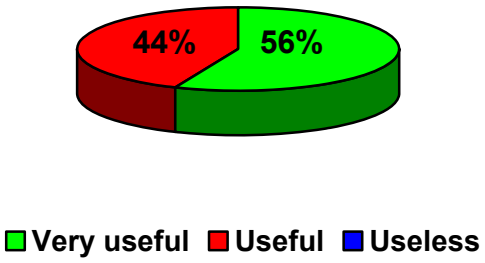


Figure 1

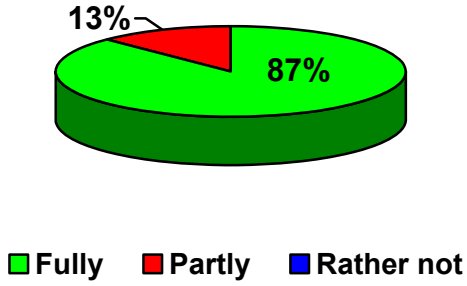


Figure 2

To what extent do you feel prepared after the training (Fig. 3)?

What is the probability after the training to use the acquired knowledge and skills (Fig.4)?

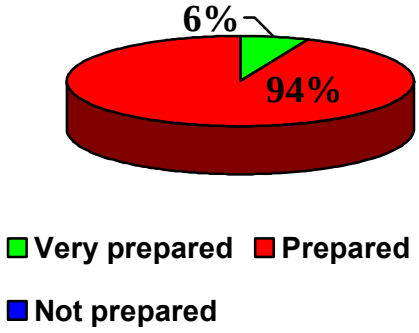


Figure 3

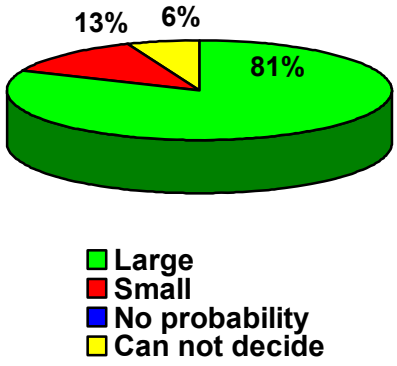
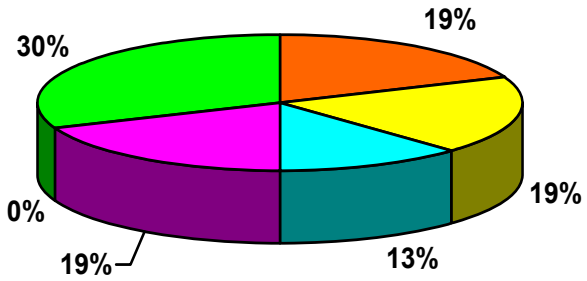


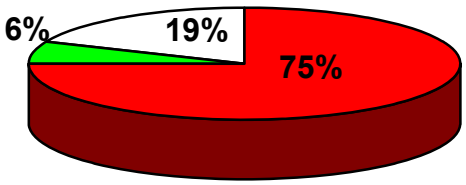
Figure 4

What skills did you acquire as a result of the training?



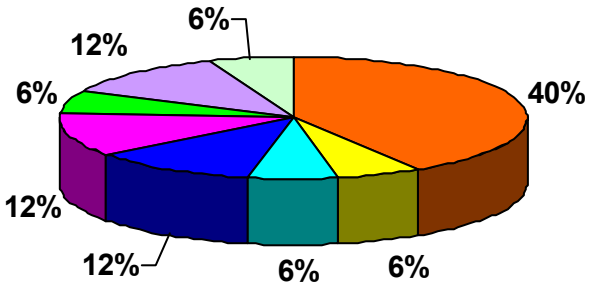
- Skills to create figures.
- Skills to introduce algebraic expressions.
- Skills constructs
- Skills for plotting functions.
- No special skills.
- Can not decide.

Do you think you need additional training?



Yes No Can not decide

What is your general impression of the training, in which you participate?



- Very good
- Excellent
- Positive
- I am satisfied.
- I like it. It is available.
- On good level.
- I would like sequel.
- The hours to be synthesized in two days.

CONCLUSIONS

The pilot study shows that:

- All participants are actively involved in learning software GEOGEBRA and believe that it is useful for their activities.
- The training motivates participants to continue their education, although 94% of them think they are prepared for its application in mathematics;
- The participants wish to develop their knowledge and skills to a level of development and implementation of educational resources in teaching and learning of mathematics with GEOGEBRA.

Therefore, it is necessary to be prepared training materials in GEOGEBRA as a basis for the teaching of students - future teachers of mathematics and for the qualifications of the existing teachers in mathematics teaching and learning mathematics using GEOGEBRA.

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ПРЕПОДАВАНЕ И УЧЕНЕ НА МАТЕМАТИКА, БАЗИРАНИ НА GEOGEBRA

Магдалена Методиева Петкова, докторант

Русенски университет „Ангел Кънчев”

Резюме: *Статията представя условията и резултатите от изследвания, които определят необходимостта от използване на компютърни технологии, в частност GEOGEBRA, за преподаване и учене на математика. Представени са резултатите от пилотно изследване на отношението на учители по математика от гр. Русе към задълбочено изучаване на геометричния софтуер GEOGEBRA и бъдещото му прилагане в преподаването и ученето на математика. Изследването включва обучение на 16 учители по математика от различни видове училища за изучаване на GEOGEBRA.*

Ключови думи*: GeoGebra, учители, математика.*

MOSEM 2 PROJECT - LEARNING ELECTROMAGNETIC PHENOMENA AND SUPERCONDUCTIVITY BY INTEGRATION OF DATA ACQUISITION, DATA VIDEO, MODELLING, SIMULATION AND ANIMATION

Nadezhda Nancheva

Angel Kanchev University of Ruse

Abstract: *The MOSEM 2 project aims to promote lifelong learning in physics and pedagogy for science teachers at the upper secondary level through offering a range of modelling tools based on existing commercial and non-profit solutions, as well as the outcomes of previous Leonardo related projects. It seeks to extend the minds-on experiments and materials from the twin project MOSEM by adding a set of computer aided activities covering a series of topics in Electromagnetism and Superconductivity. The new activities will integrate different ICT technologies: data acquisition, data video, modelling, simulation and animation.*

Keywords: *Data acquisition, data video, modelling, simulation and animation, vocational training, upper secondary school, physics teachers, superconductivity, electromagnetism*

INTRODUCTION

Europe lacks competent physics teachers what is driving a negative feedback loop that hinders recruitment of good candidates – students learning to become teachers – that could possibly turn the trend. This situation is ongoing at both national and European levels, as has been documented by several studies and conferences in recent years. The MOSEM 2 project, funded by European Commission, aims to contribute to changing this situation in a positive way by promoting lifelong learning in physics and pedagogy for science teachers at the upper secondary level through offering a range of modelling tools based on existing commercial and non-profit solutions, as well as the outcomes of previous related projects. Development in 2009 - 2010 is followed by testing and revisions in 2010 - 2011, and finished versions will be ready by the end of the project.

The MOSEM 2 project builds on the foundations of several collaborations in national and/or European projects, most recently the MOSEM and SUPERCOMET 2 projects, which are the direct sources of the ideas for the MOSEM 2 consortium. The partnership behind the project proposal consists of leading European physics educators with a proven track record of collaboration in previous projects, as well as being frequent contributors at international conferences for physics education. The project has 30 partners in 11 countries (Austria, Belgium, **Bulgaria**, Czech Republic, France, Italy, Netherlands, Norway, Poland, Spain, UK), 9 universities, 2 foundations and Simplicatus AS will develop the project deliverables. Testing and dissemination is carried out with 13 upper secondary schools and 8 valorisation partners. **University of Ruse** and **English Language School "Geo Milev"** present Bulgaria in the project. The MOSEM 2 project aims to improve physics teaching through use of data-logging, models and simulations combined with online learning modules containing animations, textual descriptions and media files (videos, photos, etc.) and will contribute to innovation in scientific curricula of the European schools, in particular by offering educational paths that show how it is possible to reconstruct classical physics in a modern perspective, developing new teaching/learning strategies and methodologies and using materials, tools based on multimedia and ICT.

The tangible results of the MOSEM 2 project include new contents for the existing and internationally used electronic learning environment offered to participating schools and teachers. The new materials combine mathematical models, simulations and video analyses of simple thought-provoking tabletop experiments, supported by electronic and printed materials comprising additional videos, animations and text. Specially developed

teacher seminars allow the participants to experience these resources and pedagogical methods to facilitate active learning, building on the outcomes of SUPERCOMET 2 and MOSEM. Additionally, MOSEM 2 will improve the previous outcomes of SUPERCOMET 2 and MOSEM by adding a quantum-mechanical explanation of the physics behind superconductivity, by courtesy of leading researchers in this exciting field of physics. The MOSEM 2 project will augment the experiments and materials from the twin project MOSEM by developing a set of models and simulations covering a series of topics in electromagnetism and superconductivity, and creating a collection of real-life data in the form of pictures, videos, and data-acquisition activities. This is supported by a teacher seminar and a printed teacher guide for lifelong learning.

This paper shows some examples of the project outcomes which are only a small portion of the material under development. The subject used as an illustration – **magnetic field in Helmholtz coils** - has been chosen to present differences in approaches to the same phenomena and indicate advantages and disadvantages of methods/tools (modelling, simulation and data acquisition).

ICT TOOLS USED IN THE PROJECT

MOSEM 2 project focuses on `constructional`category ICT tool [4] for constructing new information and understanding. The strands relevant to science within this category are: Data acquisition, Video analysis, Modelling, Animations/Simulations and Data processing. All these ICT tools should be integrated to enhance student understanding. Different ICT methods can be combined to give complementary insights.

1. Data acquisition

MOSEM 2 data-acquisition activities are created to encourage student to control and measure real physical phenomena by collecting data from equipment connected to the computer or from analyzing real movie showing a physics situation. To gather and elaborate data students use Coach 6 educational environment [7], interface and sensors. In such a way connection between real computer aided experiments, simulation and modelling of the same phenomena is realized. This creates a consistent way of learning/teaching from a constructivism point of view.

The main learning benefits of data-acquisition activities are:

- Computer equipped with interface and sensors becomes an universal measurement instrument
- The rate of data collection is available over a wide range of time and sampling frequencies
- Presenting data while being collected allows making immediate observation of the data
- Encourages critical thinking skills (more time for exploration/analysing results)
- Promotes active learning (student investigations).

Figs. 1 and 2 show screen shots of real, easy to perform experiments, created with Coach 6 program. The program is widely used throughout Europe as a comprehensive system which integrates tools for computer measurement and control, video-measurement and modelling. The program provides an environment allowing simultaneous use of a variety of tools: explanatory text, images, videos, graphs, tables, displays, models and programs. It is an authoring system that enables creating multimedia activities [3]. Two experiments are presented as an example: **Experimental verification of Ohm`s law** (Fig.1) and **Magnetic field inside/around solenoid** (Fig.2). Students are asked to complete the experimental equipment with Coach 6. In the first experiment a current-voltage characteristic of different resistors is studied [6]. Students use voltage and current sensors to measure a voltage across the resistor and a current carried through the resistor. From process-

ing the measurement data they determine the resistance R. During the measurement the power is gradually varied from 0 to 12 V.

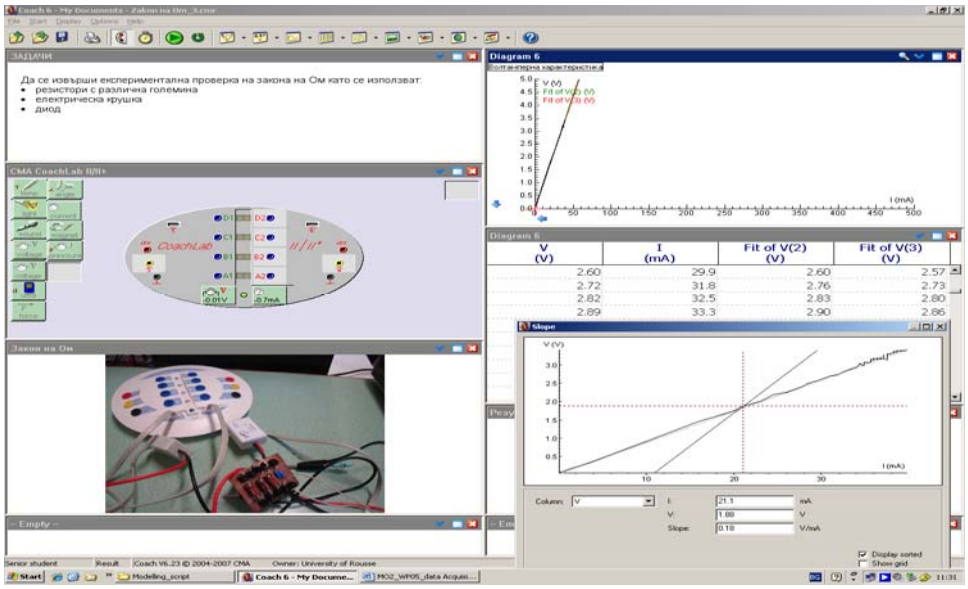

Fig.1. Screen shot showing experiment “Experimental verification of Ohm`s law”

In the second experiment a magnetic field inside/around solenoid is studied [5]. Magnetic sensor connected with Coach 6 system is situated in solenoid with current. During the measurement the power is gradually varied from 0 to 6 V. From processing the measurement data the relation between magnetic induction and current is obtained. Students will be able to change the magnitude of electrical current in the loop and the position of magnetic sensor inside and outside the solenoid. The result did not depend on the precise placement of the sensor inside the solenoid, indicating that the magnetic field is constant inside the solenoid. Inside the coil the field is very uniform, and the field from a solenoid is essentially identical to the field from a bar magnet.

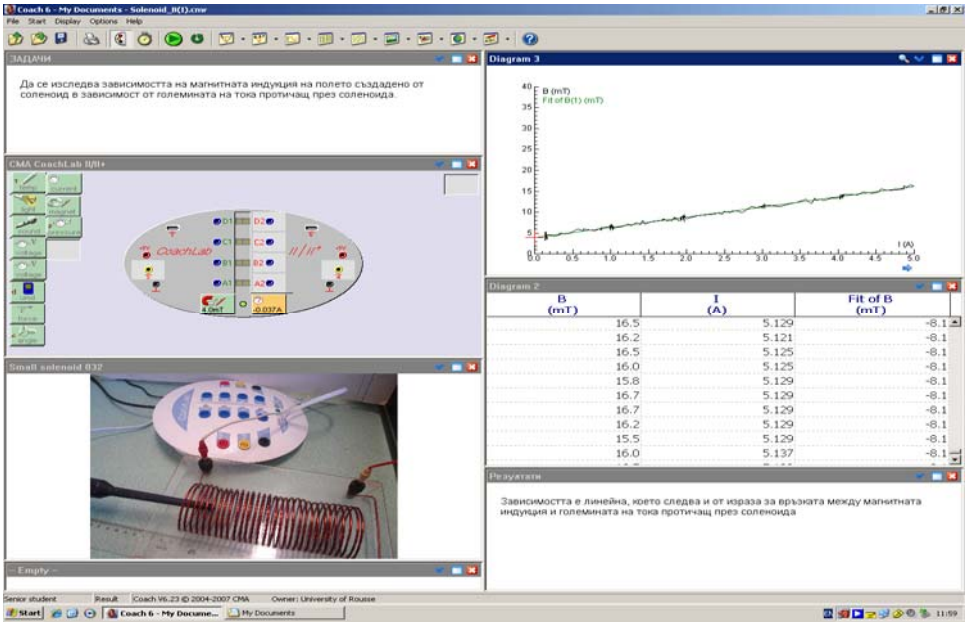

Fig.2. Screen shot showing experiment “Magnetic field inside/around solenoid”

The magnetic field generated in the centre, or core, of a current carrying solenoid is essentially uniform, and is directed along the axis of the solenoid. Outside the solenoid, the magnetic field is far weaker.

2. Data video experiments

Data-video experiments allow making measurements of position and time of moving objects on digital video clips or images. During the measurements the data are collected in the form of points (manually, or automatically by point tracking). The possibility of synchronizing graphs with the video frames help students to bridge the concrete visual display of a motion event and its abstract graphical representation. Students can make their own video of an experiment. In case the video recording is difficult to arrange then student can perform an experiment and then analyse video of already recorded experiment in Coach Activity.

Fig. 3 shows screen shot of real experiments **"Measurement of the magnetic field with a compass needle".** The learning objectives in this experiment are:

- To measure the magnetic field of a magnet B_M in the units of horizontal component of the Earth's magnetic field B_E
- To understand that a magnitude of a magnetic field of a magnet varies with distance from the magnet
- To determine empirically the relation between the magnetic field of a magnet and the distance from the magnet

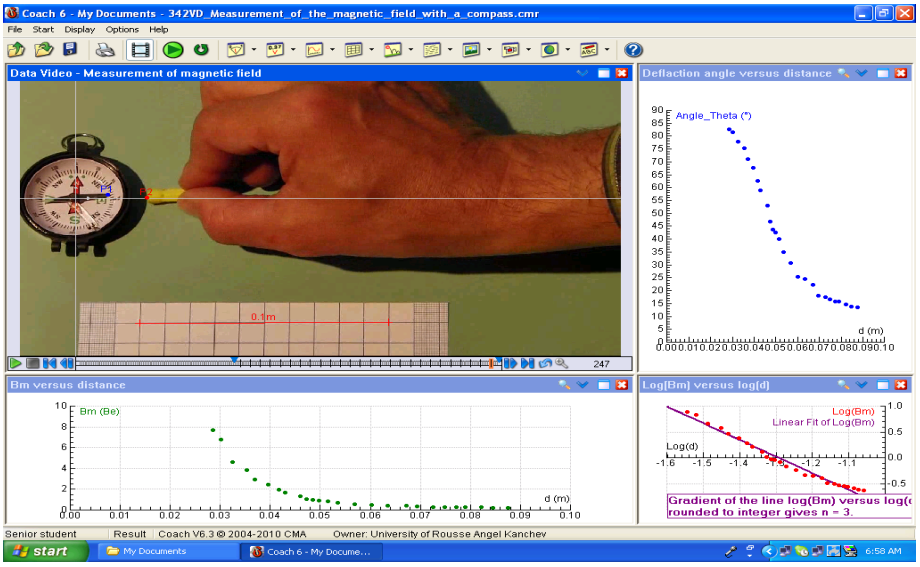

Fig.3. Screen shot showing experiment "Magnetic field of compas needle"

3. Modelling

In Modelling experiments students can create, explore or use computer models of dynamical changing systems.The main learning benefits of modelling are:

- Allows to solve complex and realistic problems, not just limited to ideal situations
- Helps to enhance student's theory building abilities (model visible to students)
- Model structure is easy to modified allowing trying different modeling ideas
- Allows to compare the theoretical models with experimental results (data acquisition, video measurement)

A key feature of modelling activity is the process of editing and altering a model to study the change of behaviour. Students can use the model to test their theories and knowledge about a phenomenon. MOSEM 2 modelling activities are assigned to make

students understand how things work by having them actually work with the model, combining physics, math, and technology. To achieve the goals we favour modelling whenever the complexity of the model can be reasonably understood by average high school students. Coach 6 tools demand low programming skills but involve profound knowledge of physics including advanced equations.

As an example of modelling the experiment **"Magnetic field in Helmholtz coils"** is presented (Fig.4). A Helmholtz pair consists of two identical circular magnetic coils that are placed symmetrically one on each side of the experimental area along a common axis, and separated by a distance d equal to the radius R of the coil. Each coil carries an equal electrical current flowing in the same direction. The learning objectives are:

- To analyse magnetic field B generated by a pair
- To use the given model for simulation

The experiment with Helmholtz coils is a good example for integrating of different ICT tool – data acquisition and modelling.

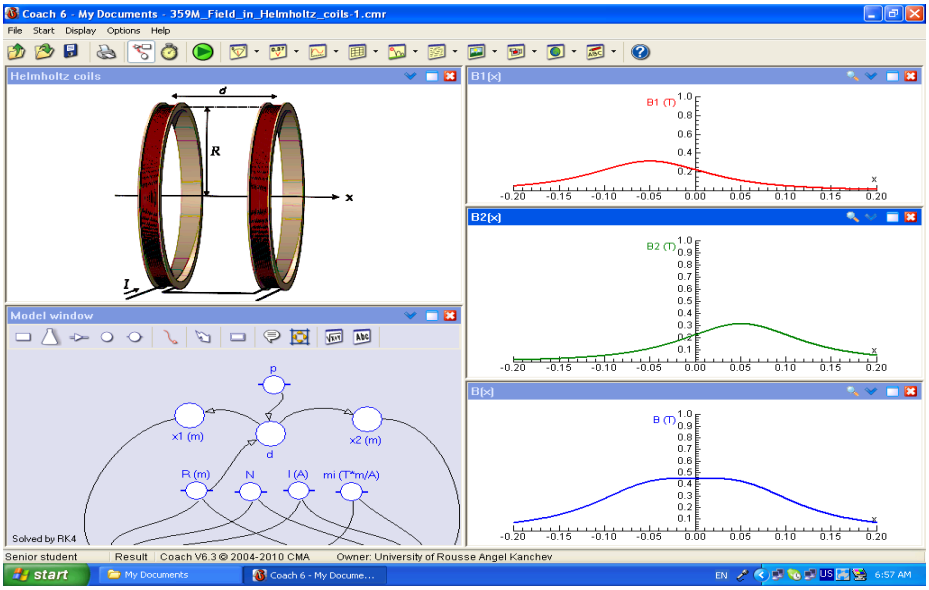

Fig. 4 .Screen shot showing modelling of magnetic field in Helmholtz coils

4. Simulation

A simulation is called a computer program that uses an internal model to produce data and visualization, as accurate as possible, of a simulated phenomenon. In addition to a number of important attributes of a simulation the one intended for educational purposes should be quantitatively right, interactive and allows changing parameters. Student primarily work with a simulation – this way teacher makes the student explore a phenomenon by running the computer program with different parameters and/or initial conditions, and analyze/visualize the quantitative outcomes of the program. For preparing MOSEM 2 simulation activities Easy Java Simulation (EJS) has been used [1, 2]. The ESJ is a free, Java modelling and authoring tool designed for creation of interactive computer simulations of scientific phenomena. These simulations can be used in computer laboratories with students to explain better difficult concepts, to let students work with the simulations or (for more advanced students) even create their own simulations. EJS has been created by Francisco Esquembre and is a part of the Open Source Physics project [2]. EJS has been designed to help a person who wants to create a simulation to concentrate most of his/her time in writing and refining the algorithms of the underlying scientific model, and to dedicate the minimum possible amount of time to the programming techniques [1].

The program EJS allows creating simulations which requires a model of a high complexity (considered to be too difficult to be understood by a student therefore not suitable for modelling activity). EJS has been used because it leverages the creation and inspection of programs as compared to pure programming. In the project a collection of ready-to-use interactive EJS experiments will be developed.

Fig.5 presents screen shot from EJS 3D showing a simulation of experiment **"Magnet falling through copper tube"**. The user may rotate a set-up looking at from different perspectives. An induced current in a copper tube is visualized in the form of red dots when a magnet is falling down the tube. There is also a metal ball falling nearby the setting to show the difference in the behaviour of these two objects. As the variables of the model are calculated in a real time the appropriate graph are presented along. Using EJS tools one can see and modify a model behind the simulation introducing changes to its variables. Teachers and teacher trainers will be able to use EJS experiments developed in the project directly or, by using EJS program, to modify them according to their own needs.

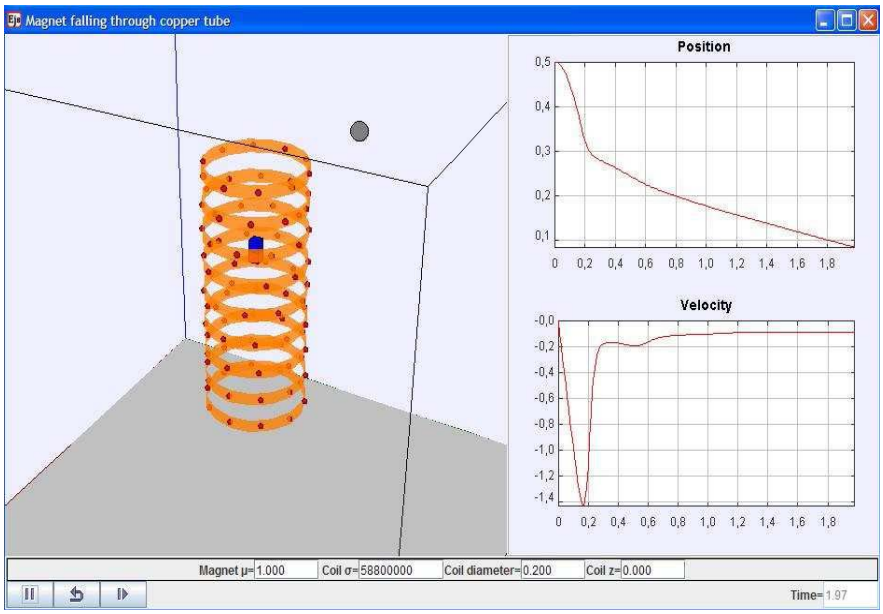

Fig.5. Screen shot from EJS 3D showing a simulation of magnet falling through copper tube.

5. Animation

There is a number of publications discussing different aspects of animations as a tool in computer based learning. In the MOSEM 2 project an animation is called a computer visualization or video (broadly moving images created with the use of computers) that displays a phenomenon without a real computation behind it. The main learning benefits of animation are:

- Comparing representations in order to get a better understanding of the more abstract ones
- Getting a better understanding of the relation between variables
- Better mechanism for self correction (debugging tool)
- Easier to use for poor-skilled students

The heart of an animation is a model, program or sensor data – the 'engine' which contains all the rules and formulas. Besides many entirely described attributes of an animation made for the educational purposes the content should be correct and animation easy to run. Students begin their work with watching such an animation – in that case teacher encourages learners by asking them to sit down and watch a nice, qualitative visualization, which explains by itself, thanks to visual clues 'how things work'. Educational activities as-

sociated with the animation are limited however. Creating MOSEM 2 animation based activities we use SUPERCOMET flash animations or especially shot videos, where a first visualization helps to introduce a topic or increase students' interest in it. The collection of such animations is available at website: http://online.supercomet.no. Animations can be created with the Coach 6 system too.

SUPPORT MATERIALS

Support materials developing in the project consist of ready-to-use electronic and printed resources for the different outcomes of the entire project – models, simulations, videos, date acquisition exercises, etc. – and various teacher seminar oriented documents – how-to-explanations, descriptions of different types of exercises, subject related booklets etc. All types of support materials will be freely available on the project resources and majority of them will be published in a form of Teacher Guide. Its main intension is to outline the pedagogical rationalism for using MOSEM 2 outcomes and suggest effective ways of using them in the classroom, as a part of everyday teaching, in stand-alone mode and in combination with experimental kits and multimedia tools. The Teacher Guide is an integral part of Teacher Seminar and is a central part of a project support materials. Moreover it consists of basic information about the physics of electromagnetism and superconductivity as well as shows possibilities for evaluation of the work.

TEACHER SEMINAR

In general a teacher seminar does not only transfer knowledge to teachers but can aim at different goals and at different levels of teachers' professionalism. For MOSEM 2 it is planned to develop two types of seminars:

- the first one, in which teachers are considered as learners very much like students are considered in a traditional classroom, so they follow guidelines strictly and therefore remain intellectually passive in the sense that they only absorb ideas. This is assigned to follow up evaluated strategy to "motivate" teachers for using the materials and presents usability and value of educational materials.
- . the second one, in which teachers are considered as managers and builders of their professionalism and is based on equality between all participants including the teacher trainer. Crucial for this type of seminar is interaction and discussion, along with good preparations by both – the participants and the teacher trainers – therefore project materials are good bases on which the process is initialized.

The responsibility to choose the exact format of a seminar to attend will be left to participants. The implementation – approach, activities, teaching style, learning materials for students, assessment and evaluation – will be presented, but final decision when and how to use them will be left to the individual participating teacher.

CONCLUSION

Within the MOSEM 2 project we advocate the attendance at a teacher seminar prior to using animations, simulations, modelling and data-acquisition. The seminar will address both subject knowledge and alternative conceptions and in addition will offer pedagogic approaches to the material in electromagnetism and superconductivity. All of this takes place in a supportive environment with an emphasis on developing both the participants and the presenter. The authors expect the results of MOSEM 2 project to spread like rings in water across borders, based on the international collaboration of the project and a planned online community connecting teachers in different countries. Different type of meetings including conferences will be used to share experience, teaching materials and methods. This will not only help to improve physics teaching in certain organizations but also will allow building language skills and cultural understanding. The part of materials and texts in Bulgarian has been prepared by the author of this paper and has been presented during teacher` seminars organized in Ruse and Shumen, following by teachers' and students` evaluation [5], organized in the English Language School in Ruse. All mate-

rials developed by participants in the projects SUPERCOMET 2, MOSEM and MOSEM 2 can be seen on sites: http://online.supercomet.no and http://mosem.eu free.

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The MOSEM^2 (MOdelling and data acquisition for continuing vocational training of upper secondary school physics teachers in pupil-active learning of Superconductivity and ElectroMagnetism based on Minds-On Simple ExperiMents) project is supported by the European Commission under the Leonardo da Vinci, Transfer of Innovation programme, project number: NO/08/LLP-LdV/TOI/131.013.

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ПРОЕКТ MOSEM 2 - ИНТЕГРИРАНЕ НА РЕАЛНИ ЕКСПЕРИМЕНТИ, ВИДЕОАНАЛИЗ, МОДЕЛИРАНЕ, СИМУЛАЦИИ И АНИМАЦИИ ПРИ ИЗУЧАВАНЕ НА ЕЛЕКТРОМАГНИТНИТЕ ЯВЛЕНИЯ И СВРЪХПРОВОДИМОСТТА

Надежда Нанчева
Русенски университет „Ангел Кънчев"

***Резюме*:** Предлаганата работа представя проекта MOSEM 2 и малка част от материалите, разработени в рамките на проекта. Представените примери демонстрират различни педагогически подходи – реален експеримент, видеоанализ, моделиране, симулации - при изследване на електромагнитни явления и свръхпроводимост.

Ключови думи: *Реални експерименти, видеоанализ, моделиране,симулации и анимации, повишаване квалификацията на учители по физика, обучение по физика, електромагнетизъм, свръхпроводимост.*

* The experiments presented in Fig.3 and Fig.4 have been developed by team from Amstel Institute – Netherlands.

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- *Leave a blank line under Header - Font Size 14;*
- Title should be short, no abbreviations, no formulas or special symbols - Font Size 14, centered, Bold, All Caps;
- *One blank line - Font Size 14;*
- Name and surname of author(s) - Font Size: 12, centered, Bold;
- *One blank line - Font Size 12*;
- Name of place of work - Font Size: 12, centered;
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- abstract – no formulas - Font Size 10, Italic, 5-6 lines ;
- keywords - Font Size 10, Italic, 1-2 lines;
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4. At the end of the paper the authors should write:

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- Name and surname of the author(s);
- abstract; keywords.

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6. Figures (black and white), made with some of the widespread software, should be integrated in the text.

7. Tables should have numbers and titles above them, centered right.

8. Reference sources cited in the text should be marked by a number in square brackets.

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