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С А Д Р Ж А Ј

ОРИГИНАЛНИ НАУЧНИ ЧЛАНЦИ

Татјана М. Дошеновић, Стојан Н. Раденовић
Примена Ансаријевог метода у генерализацији неких резултата из теорије непокретне тачке (преглед) 261-280

Вадим Л. Хајков
Примена програма Mathcad у математичком моделовању и рачунарској симулацији основног проблема спољне балистике цевне артиљерије 281-303

Леонид И. Гречихин
Формирање проводљивости код полупроводника п-типа и н-типа 304-321

Бобан П. Бонџулић, Бобан З. Павловић, Владимир С. Петровић
Анализа перформанси објективних мера процене квалитета слика и видеа са потпуним референцирањем 322-350

Јан Дрозд, Зденек Фласар, Лудек Рак
Аспекти умањивања ефеката напада импровизованом експлозивном направом у возилу 351-365

ПРЕГЛЕДНИ ЧЛАНЦИ

Комлен Г. Лаловић
Преглед патента: уређај за гаранцију идентитета на основу биометрије отиска прста..... 366-379

Милосав Н. Мајсторовић, Рајко М. Терзић
Архитектура организације као приступ за развој информационих система 380-398

СТРУЧНИ ЧЛАНЦИ

Алекса С. Срданов, Радиша Р. Стефановић, Нада В. Ратковић Ковачевић, Александра М. Јовановић, Драган М. Миловановић
Метода „спољашње спирале” за решавање линеарног система са великим бројем непознатих..... 399-414

Михаило Р. Мрдак
Пренос топлоте и брзине честица плазме на честице праха у плазма-спреј процесу на атмосферском притиску 415-430

Милан Р. Радосављевић
Примена малих и микрокогенерационих постројења 431-445

САВРЕМЕНО НАОРУЖАЊЕ И ВОЈНА ОПРЕМА 446-464
Милош М. Јевтић, Драган М. Вучковић

ПОЗИВ И УПУТСТВО АУТОРИМА..... 456-481

С О Д Е Р Ж А Н И Е

ОРИГИНАЛЬНЫЕ НАУЧНЫЕ СТАТЬИ

Татьяна М. Дошенович, Стоян Н. Раденович
Применение метода Ансари в обобщении ряда результатов в рамках теории неподвижной точки: обзор 261-280

Вадим Л. Хайков
Математическое моделирование и вычислительный эксперимент при оценке внешней баллистики ствольной артиллерии средствами программы Mathcad ... 281-303

Леонид И. Гречихин
Формирование p-, n-проводимости в полупроводниках 304-321

Бобан П. Бонджулич, Бобан З. Павлович, Владимир С. Петрович
Анализ характеристик объективных показателей оценки качества фотографий и видео на основании базы данных 322-350

Ян Дрозд, Зденек Фласар, Лудек Рак
Аспекты снижения последствий подрывов автомобилей, совершенных с помощью самодельных взрывных устройств 351-365

ОБЗОРНЫЕ СТАТЬИ

Комлен Г. Лалович
Обзор патента: устройство идентификации личности по биометрическому отпечатку пальца 366-379

Милосав Н. Майсторович, Райко М. Терзич
Архитектура организации как доступ к развитию информационных систем 380-398

ПРОФЕССИОНАЛЬНЫЕ СТАТЬИ

Алекса С. Срданов, Радиша Р. Стефанович, Нада В. Раткович Ковачевич, Александра М. Йованович, Драган М. Милованович
Применение метода «внешней спирали» при решении систем линейных уравнений с большим количеством неизвестных 399-414

Михаило Р. Мрдак
Передача тепла и скорости частиц плазмы частицам порошка в процессе плазменного напыления при атмосферном давлении 415-430

Милан Р. Радосавлевич
Применение малых и микро-когенерационных установок 431-445

СОВРЕМЕННОЕ ВООРУЖЕНИЕ И ВОЕННОЕ ОБОРУДОВАНИЕ 446-464
Милош М. Йевтич, Драган М. Вучкович

ПРИГЛАШЕНИЕ И ИНСТРУКЦИИ ДЛЯ АВТОРОВ РАБОТ 456-481

C O N T E N T S

ORIGINAL SCIENTIFIC PAPERS

Tatjana M. Došenović, Stojan N. Radenović
Ansari's method in generalizations of some results in the fixed point theory: Survey 261-280

Vadim L. Khaikov
Mathematical modeling and computer simulation of a basic problem of tube artillery external ballistics by means of the Mathcad software 281-303

Leonid I. Gretchikhin
Formation of p-, n-conductivity in semiconductors 304-321

Boban P. Bondžulić, Boban Z. Pavlović, Vladimir S. Petrović
Performance analysis of full-reference objective image and video quality assessment metrics 322-350

Jan Drozd, Zdenek Flasar, Luděk Rak
Aspects of reducing the effects of vehicle-borne improvised explosive devices 351-365

REVIEW PAPERS

Komlen G. Lalović
Patent overview: Device for fingerprint identity guarantee 366-379

Milosav N. Majstorović, Rajko M. Terzić
Enterprise architecture as an approach to the development of information systems .. 380-398

PROFESSIONAL PAPERS

Aleksa S. Srdanov, Radiša R. Stefanović, Nada V. Ratković Kovačević, Aleksandra M. Jovanović, Dragan M. Milovanović
The method of "external spiral" for solving a large system of linear equations 399-414

Mihailo R. Mrdak
Transfer of heat and speed of plasma particles to powder particles in the plasma spray process at atmospheric pressure 415-430

Milan R. Radosavljević
Application of small and micro cogeneration units 431-445

MODERN WEAPONS AND MILITARY EQUIPMENT 446-464
Miloš M. Jevtić, Dragan M. Vučković

CALL FOR PAPERS AND INSTRUCTIONS FOR AUTHORS 456-481

ОРИГИНАЛНИ НАУЧНИ ЧЛАНЦИ
ОРИГИНАЛЬНЫЕ НАУЧНЫЕ СТАТЬИ
ORIGINAL SCIENTIFIC PAPERS

ANSARI'S METHOD IN GENERALIZATIONS OF SOME RESULTS IN THE FIXED POINT THEORY: SURVEY

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Abstract:

The aim of this paper is to show that the C-class function introduced by A. H. Ansari is a powerful weapon for the generalization of many important results in the theory of fixed points.

Keywords: C class function, Metric space, Cauchy sequence, Common fixed point, Fixed point.

Introduction

With the advent of S. Banach paper (Banach, 1922), the development of the theory of fixed point is moved upwards. A huge number of scientists, for more than 90 years, have managed to generalize Banach contraction principle (Abbas & Jungck, 2008, pp.416-420), (Altun et al, 2010, pp.2238-2242), (Boyd & Wong, 1969, pp.458-464), (Đorić, 2009, 1896-1990), (Geraghty, 1973, pp.604-608), (Amini-Harandi & Emami, 2010, pp.2238-2242), (Hussain et al, 2013),

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(Harjani & Sadarangani, 2009, 3403-3410), (Jachymski, 2011, pp.768-774), (Jungck, 1976, pp.261-263), (Karapinar & Salimi, 2012), (Khan et al, 1984, pp.1-9), (Liu et al, 2015), (Rhoades, 1977, pp.257-290), (Rhoades, 2001, pp.2683-2693), (Radenović & Kadelburg, 2010, pp.1776-1783), (Radenović et al, 2012, pp.625-645), (Salimi et al, 2013), (Samet et al, 2012, pp.2154-2165). In 2014 A. H. Ansari (Ansari, 2014a, pp.373-376), (Ansari, 2014b, pp.377-380) introduced the concept of C-class functions which cover a large class of contractive conditions, see also (Ansari, 2014a, pp.373-376), (Ansari, 2014b, pp.377-380), (Ansari et al, 2017, pp.2657-2673), (Ansari & Chandok, 2016, pp.65-71).

Definition 1 (Ansari et al, 2017, pp.2657-2673) A C-class function is a continuous function $F:[0,\infty)\times[0,\infty)\to R$ such that for any $x, y \in [0,\infty)$, the following conditions hold:

$(C1)$ $F(x,y)\le x$;

$(C2)$ $F(x,y)=x$ implies that either $x=0$ or $y=0$.

An extra condition on F that $F(0,0)=0$ could be imposed in some cases if required. By C we will denote the class of all C- functions.

Example 1 (Ansari et al, 2017, pp.2657-2673) The following functions belong to the class C:

1. $F(x,y)=x-y.$
2. $F(x,y)=mx,$ for some $m\in(0,1).$
3. $F(x,y)=\dfrac{x}{(1+y)^r}$ for some $r\in(0,\infty).$
4. $F(x,y)=\dfrac{\log(y+a^x)}{1+y}$, for some $a>1.$
5. $F(x,y)=(x+l)^{(1/(1+y)^r)}-l$, $l>1,$ for $r\in(0,\infty)$.
6. $F(x,y)=x-\dfrac{y}{k+y}.$
7. $F(x,y)=x-\varphi(x),$ where $\varphi:[0,\infty)\to[0,\infty)$ is a continuous function such that $\varphi(t)=0$ if and only if $t=0.$
8. $F(x,y)=\sqrt[n]{\ln(1+x^n)}.$

We start this section with the following definitions and notions:

Definition 2 (Ansari, 2014b, pp.377-380) A mapping $F:[0,+\infty)^2 \to R$ has a property C_F, if there exists an $C_F \geq 0$ such that

$(C_F 1)$ $F(x,y) > C_F$ implies $x > y$;

$(C_F 2)$ $F(y,y) \leq C_F$, for all $y \in [0,+\infty)$.

For more examples of $C-$class functions that have the property C_F see (Ansari, 2014b, pp.377-380) Here we announce the following three examples

a) $F(x,y) = x - y, C_F = r, r \in [0,+\infty)$;

b) $F(x,y) = x - \frac{(2+y)y}{1+y}, C_F = 0$;

c) $F(x,y) = \frac{x}{1+ky}, k \geq 1, C_F = \frac{r}{1+k}, r \geq 2.$

Let Ψ denote the class of all functions $\psi:[0,\infty) \to [0,\infty)$, Φ denote the class of all functions $\phi:[0,\infty) \to [0,\infty)$ and F elements of C satisfying the following conditions:

(i) ψ is non-decreasing and continuous;

(ii) ϕ is non-decreasing and continuous;

(iii) $\psi(t) - F(\psi(s),\phi(s)) > 0$ for all $t > 0$ and $s = t$ or $s = 0$.

The condition (iii) generalizes (2.3) from (Karapinar & Salimi, 2012, p.9).

Definition 3 *(*Ansari et al, 2017, pp.2657-2673*) A subclass of type I is a function $H: R \times [0,\infty) \to R$ if it is continuous and*

$s \geq 1$ implies $H(1,t) \leq H(s,t)$ for all $t \in [0,\infty)$.

Example 2 (Ansari et al, 2017, pp.2657-2673) We have the following functions of the subclass of the type I:

- $H(s,t) = (t+l)^s$, $l > 1$,
- $H(s,t) = (s+l)^t$, $l > 1$,
- $H(s,t) = st^n$, $n \in N$,

- $H(s,t)=st,$
- $H(s,t)=t,$
- $H(s,t)=\frac{s+1}{2}t,$
- $H(s,t)=\frac{2s+1}{3}t,$
- $H(s,t)=\left(\frac{\sum_{i=0}^{n}s^{n-i}}{n+1}\right)t,$
- $H(s,t)=\left(\frac{\sum_{i=0}^{n}s^{n-i}}{n+1}+l\right)^{t},\ l>1.$

Definition 4 (Ansari et al, 2017, pp.2657-2673) We say that the pair (F,H) is an upclass of the type I if $F:[0,\infty)\times[0,\infty)\to R$ is continuous, H is a function of the subclass of the type I and satisfies:

(1) $0\le x\le 1$ implies $F(x,y)\le F(1,y)$

(2) $H(1,y_1)\le F(x,y_2)$ implies $y_1\le xy_2,$

for all $x,y,y_1,y_2\in[0,\infty)$.

Example 3 (Ansari et al, 2017, pp.2657-2673) Below are listed the functions of the upclass of the type I, for all $s\in R,\ t,y\in[0,\infty)$, $x\in[0,1]$:

- $H(s,t)=(t+l)^{s},\ l>1, F(x,y)=xy+l,$
- $H(s,t)=(t+l)^{s},\ l>1, F(x,y)=(1+l)^{xy},$
- $H(s,t)=st^{n}, F(x,y)=x^{n}y^{n},$
- $H(s,t)=st, F(x,y)=xy.$

Definition 5 (Ansari et al, 2017, pp.2657-2673) We say that the pair (F,H) is a special upclass of the type I if $F:[0,\infty)\times[0,\infty)\to R$ is continuous, H is a function of the subclass of the type I and satisfies:

(1) $0\le x\le 1$ implies $F(x,y)\le F(1,y)$

(2) $H(1,t)\le F(1,y)$ implies $t\le y$,

for all $y,t\in[0,\infty)$.

Example 4 (Ansari et al, 2017, pp.2657-2673) The following functions are a special upclass of the type I, for all $s\in R,t,x,y\in[0,\infty)$:

- $H(s,t)=\left(t^k+l\right)^{s^n}$, $l>1$, $F(x,y)=x^m y^k+l$,
- $H(s,t)=\left(s^n+l\right)^{t^k}$, $l>1$, $F(x,y)=(1+l)^{x^m y^k}$,
- $H(s,t)=s^n t^k$, $F(x,y)=x^p y^k$,
- $H(s,t)=st$, $F(x,y)=xy$.

Remark 1 (Ansari et al, 2017, pp.2657-2673) Every pair (F,H) of the upclass of the type I also belongs to the class of a special upclass of the type I, but converse is not true.

Assertions similar to the following lemma were used (and proved) in the course of proofs of several fixed point results in various papers (Radenović et al, 2012, pp.625-645).

Lemma 1 (Radenović et al, 2012, pp.625-645) Let (X,d) be a metric space and let $\{x_n\}$ be a sequence in X such that

$$\lim_{n\to\infty} d(x_n,x_{n+1})=0.$$

If $\{x_n\}$ is not a Cauchy sequence, then there exist $\varepsilon>0$ and two sequences $\{m_k\}$ and $\{n_k\}$ of positive integers such that $n_k>m_k>k$ and the following sequences tend to ε^+ when $k\to\infty$:

$$d(x_{m_k},x_{n_k}),\ d(x_{m_k},x_{n_k+1}),\ d(x_{m_k-1},x_{n_k}),\ d(x_{m_k-1},x_{n_k+1}).$$

Definition 6 (Abbas & Jungck, 2008, pp.416-420) Let f and g be self maps of a set X. If $\omega = fx = gx$ for some $x \in X$, then x is called a coincidence point of f and g, and ω is called a point of coincidence of f and g. The pair f, g of self maps is weakly compatible if they commute at their coincidence points.

Proposition 1 (Abbas & Jungck, 2008, pp.416-420) Let f and g be weakly compatible self maps of a set X. If f and g have a unique point of coincidence $\omega = fx = gx$, then ω is the unique common fixed point of f and g.

Main results

Previously described functions attracted the attention of authors and now there are various generalizations of the results from the fixed point theory, not only in a metric space, but also in the partial metric spaces, metric like-spaces, G-metric spaces,...(Ansari, 2014a, pp.373-376), (Ansari, 2014b, pp.377-380), (Ansari et al, 2017, pp.2657-2673), (Isik et al, 2015, pp.703-708), (Ansari & Chandok, 2016, pp.65-71). In this paper, we will present some of these results. Also, we shall prove some new results, which generalize already known ones, by using the $C-$class functions introduced recently by A.H. Ansari (Ansari, 2014a, pp.373-376), (Ansari, 2014b, pp.377-380). In this review paper, we will use only *C*-class functions.

Our first (probably new) result is the following:

Theorem 1 Let (X, d) be a complete metric space. Suppose that the mappings $f, g : X \to X$ satisfy the following condition

$$\psi(d(fx, fy)) \leq F(\psi(d(gx, gy)), \phi(d(gx, gy))) \tag{1}$$

for all $x, y \in X$ where $\psi \in \Psi, \varphi \in \Phi$ and $F \in C$. If the range of g contains the range of f and $f(X)$ or $g(X)$ is a closed subset of X, then f and g have a unique point of coincidence in X. Moreover, if f and g are weakly compatible, then f and g have a unique common fixed point.

Remark 2 Putting in (1): $\psi(t)=t, \phi(t)=(1-k)t$, $k\in(0,1)$ and $F(s,t)=s-t$ for all $s,t\in[0,\infty)$ we get a well-known Jungck's result from (Jungck, 1976, pp.261-263). Hence, Theorem 1 is a genuine generalization of the old and important Jungck's result in several directions (see all assumptions in (Jungck, 1976, pp.261-263).

Further, putting in (1): $\psi(t)=t, F(s,t)=\beta(s)\cdot s$ for all $s,t\in[0,\infty)$ where $\beta:[0,\infty)\to[0,1)$ such that $t_n\to 0^+$ whether $\beta(t_n)\to 1^-, g=I_X$ (identity mapping on X), we get a well-known Geraghty type result (Geraghty, 1973, pp.604-608). Hence, Theorem 1 is a new generalization of this old and important result in the fixed point theory in the framework of complete metric spaces.

Proof. Let us prove that the point of coincidence of f and g is unique in the case that it exists. Suppose that ω and δ are two distinct points of coincidence of f and g. From this follows that there exist two points u_ω and u_δ such that $fu_\omega=gu_\omega=\omega\neq\delta=fu_\delta=gu_\delta$. Now, (1) implies

$$\begin{aligned}\psi(d(\omega,\delta)) &= \psi(d(fu_\omega, fu_\delta))\\ &\le F(\psi(d(gu_\omega, gu_\delta)), \phi(d(gu_\omega, gu_\delta)))\\ &= F(\psi(d(\omega,\delta)), \phi(d(\omega,\delta)))\le \psi(d(\omega,\delta)),\end{aligned}$$

that is

$$F(\psi(d(\omega,\delta)), \phi(d(\omega,\delta))) = \psi(d(\omega,\delta)). \tag{2}$$

From (2) according to the property of the function F follows that either $\psi(d(\omega,\delta))=0$ or $\phi(d(\omega,\delta))=0$. In both cases, we get a contradiction.

Further, let x_0 be an arbitrary point in X. Let us choose a point $x_1\in X$ such that $y_0=fx_0=gx_1$. This can be done, since the range of g contains the range of f. Continuing this process, having chosen x_n in X, we obtain x_{n+1} in X such that $y_n=fx_n=gx_{n+1}$. Now consider the following two possible cases:

1^0 $y_k=y_{k+1}$ for some $k\in N$. Hence, $gx_{k+1}=fx_{k+1}$ is a (unique) point of coincidence and then the proof of Theorem 1 is finished.

2^0 Thus, suppose that $y_n \neq y_{n+1}$ for all $n \in N \cup \{0\}$. In this case, we have

$$\begin{aligned}\psi(d(y_{n+1}, y_{n+2})) &= \psi(d(fx_{n+1}, fx_{n+2})) \\ &\leq F(\psi(d(gx_{n+1}, gx_{n+2})), \phi(d(gx_{n+1}, gx_{n+2}))) \\ &= F(\psi(d(y_n, y_{n+1})), \phi(d(y_n, y_{n+1}))) \\ &\leq \psi(d(y_n, y_{n+1})).\end{aligned}$$

Since $\psi \in \Psi$ we get that $d(y_{n+1}, y_{n+2}) \leq d(y_n, y_{n+1})$, i.e., $d(y_n, y_{n+1}) \downarrow, r \geq 0$. We prove now that $r = 0$. Indeed, if $r > 0$, then passing to the limit in the previous relation when $n \to \infty$, we obtain that

$$\psi(r) \leq F(\psi(r), \phi(r)) \leq \psi(r),$$

that is $F(\psi(r), \phi(r)) = \psi(r)$. This implies that either $\psi(r) = 0$ or $\phi(r) = 0$. In both cases we get a contradiction. Hence, $\lim_{n\to\infty} d(y_n, y_{n+1}) = 0$.

We next prove that $\{y_n\}$ is a Cauchy sequence in a complete metric space (X, d). If that is not case, then by using Lemma 1 we get that there exist $\varepsilon > 0$ and two sequences $\{m_k\}$ and $\{n_k\}$ of positive integers and sequences

$$d(y_{m_k} y_{n_k}), d(y_{m_k} y_{n_k+1}), d(y_{m_k-1} y_{n_k}), d(y_{m_k-1} y_{n_k+1}),$$

all tend to ε^+ when $k \to \infty$. By applying condition (1) to the elements $x = x_{m_k}$ and $y = x_{n_k+1}$ and since $y_n = fx_n = gx_{n+1}$ for each $n \geq 0$, we get that

$$\psi(d(y_{m_k} y_{n_k+1})) \leq F(\psi(d(y_{m_k-1} y_{n_k})), \phi(d(y_{m_k-1} y_{n_k}))). \tag{3}$$

Letting $k \to \infty$ in (3), we obtain

$$\psi(\varepsilon) \leq F(\psi(\varepsilon), \phi(\varepsilon)),$$

which is a contradiction because $\varepsilon > 0$. This shows that $\{y_n\} = \{fx_n\} = \{gx_{n+1}\}$ is a Cauchy sequence in a complete metric space (X, d).

Since $g(X)$ is closed in a complete metric space (X, d), then it is a complete metric space. Therefore, there exists $u, v \in X$ such that $v = gu$

and $\lim_{n\to\infty} gx_n = gu = v$. We shall show that also $fu = v = gu$. Indeed, putting $x = x_n, y = u$ in (1) we get

$$\psi(d(fx_n, fu)) \le F(\psi(d(gx_n, gu)), \phi(d(gx_n, gu))). \tag{4}$$

Letting $n \to \infty$ in (4) and applying the properties of all three functions F, ψ and ϕ, we get

$$\psi(d(gu, fu)) \le F(\psi(d(gu, gu)), \phi(d(gu, gu))) \le \psi(d(gu, gu)) = \psi(0) = 0,$$

i.e., $fu = gu$ is a (unique) point of coincidence of the functions f and g.

By the Proposition 1 f and g have the unique common fixed point.

In the case when $f(X)$ is a closed subset in (X, d), the proof is similar.

Putting $\psi(t) = \phi(t) = t, F(s,t) = \dfrac{s^2 t}{1+st}, g = I_X$ the identity mapping of X in Theorem 1, we get the following result:

Corollary 1 *Let (X, d) be a complete metric space. Suppose mappings $f : X \to X$ satisfies*

$$d(fx, fy) \le \frac{d^3(x, y)}{1 + d^2(x, y)} \tag{5}$$

for all $x, y \in X$. Then f has a unique fixed point in X.

Putting $\psi(t) = \phi(t) = t, F(s,t) = \varphi(s)$, where $\varphi : [0,\infty) \to [0,\infty)$ is upper semicontinuous from the right, satisfying $\varphi(t) < t$ for $t > 0$ as well as $\varphi(0) = 0, g = I_X$ the identity mapping of X in Theorem 1 we get the following well-known Boyd and Wong result (Boyd & Wong, 1969, pp.458-464).

Corollary 2 *Let (X, d) be a complete metric space. Suppose that a mapping $f : X \to X$ satisfies the following condition*

$$d(fx, fy) \le \varphi(d(x, y)) \tag{6}$$

for all $x, y \in X$. Then f has a unique fixed point, say $u \in X$ and $f^n x \to u$ as $n \to \infty$ for each $x \in X$.

Putting $\psi(t)=\phi(t)=t, F(s,t)=s-\varphi(s),$ where $\varphi:[0,\infty)\to[0,\infty)$ is a continuous function such that $\varphi(t)=0$ if and only if $t=0,$ $g=I_X$ the identity mapping of X in Theorem 1 we get the following well-known B.E. Rhoades result (Rhoades, 2001, pp.2683-2693).

Corollary 3 *Let (X,d) be a complete metric space. Suppose that the mappings $f:X\to X$ satisfies the following condition*

$$d(fx,fy)\le d(x,y)-\varphi(d(x,y)) \tag{7}$$

for all $x,y\in X$. Then f has a unique fixed point, say $u\in X$ and $f^n x\to u$ as $n\to\infty$ for each $x\in X$.

In the sequel of this section we shall consider two results which provide the existence of a coincidence point and a common fixed point for three mappings satisfying the generalized $(F,\psi,\phi)-$contractive condition. These results are addressed in the following theorems.

Theorem 2 *Let (X,d) be a metric space, and let $f,g,S:X\to X$ be three mappings such that for all $x,y\in X$*

$$\psi(d(fx,gy))\le F(\psi(m(x,y)),\phi(m_1(x,y))), \tag{8}$$

for some $\psi\in\Psi,$ $\phi\in\Phi$ and $F\in$ C, where

$$m(x,y)=\max\left\{d(Sx,Sy),d(Sx,fx),d(Sy,gy),\frac{1}{2}(d(Sx,gy)+d(Sy,fx))\right\}$$

and

$$m_1(x,y)=\max\{d(Sx,Sy),d(fx,Sx),d(gy,Sy)\}.$$

If $fX\cup gX\subset SX$ and $S(X)$ is a complete subspace of (X,d), then f,g and S have a unique point of coincidence. Moreover, if (f,S) and (g,S) are weakly compatible, then f,g and S have a unique common fixed point.

The proof of the following theorem is similar to that of Theorem 1.

Theorem 3 *Let (X,d) be a complete metric space, and let $f,g,S:X\to X$ be three mappings such that for all $x,y\in X$*

$$\psi(d(fx,gy)) \le F(\psi(m(x,y)),\phi(m_1(x,y))), \tag{9}$$

for some $\psi \in \Psi$, $\phi \in \Phi$ *and* $F \in \mathrm{C}$, *where*

$$m(x,y) = \max\left\{d(Sx,Sy), \frac{1}{2}(d(Sx,fx)+d(Sy,gy)), \frac{1}{2}(d(Sx,gy)+d(Sy,fx))\right\}$$

and

$$m_1(x,y) = \max\{d(Sx,Sy), d(fx,Sx), d(gy,Sy)\}.$$

If $fX \cup gX \subset SX$ *and* $S(X)$ *is a complete subspace of* (X,d), *then* f, g *and* S *have a unique point of coincidence. Moreover, if* (f,S) *and* (g,S) *are weakly compatible, then* f, g *and* S *have a unique common fixed point.*

The following results represent one other version of Altun Theorem (Altun et al, 2010, pp.310-316) in the terms of $(F,\psi,\phi)-$contractive mappings.

Theorem 4 *Let* (X,d) *be a complete metric space, and let* $f, g : X \to X$ *be two mappings such that for some* $\psi \in \Psi$, $\phi \in \Phi$ *and* $F \in \mathrm{C}$ *and for all* $x, y \in X$ *there exists*

$$u(x,y) \in \left\{d(x,y), d(x,fx), d(y,gy), \frac{1}{2}(d(x,gy)+d(y,fx))\right\}$$

such that

$$\psi(d(fx,gy)) \le F(\psi(u(x,y)),\phi(u(x,y))), \tag{10}$$

then f *and* g *have a unique fixed point.*

Let (X ,$\preccurlyeq$) be a partially ordered set. A pair (f,g) of self-maps of X is said to be weakly increasing if $fx \preccurlyeq gfx$ and $gx \preccurlyeq fgx$ for all $x \in X$. There are examples (see Altun et al, 2010, pp.310-316) when neither of such mappings f, g is nondecreasing w.r.t $\preccurlyeq$ In particular the pair (f, i_X), (i_X is the identity mapping on X) is weakly increasing if and only if $x \preccurlyeq fx$ for each $x \in X$.

Theorem 5 *Let (X,* $\preccurlyeq$*) be a partially ordered set and let there exist a metric* d *on* X *such that* (X,d) *is a complete metric space. Let* (f,g)

be a weakly increasing pair of self-maps on X. *Suppose that there exists* $\psi \in \Psi, \varphi \in \Phi$ and $F \in \mathrm{C}$ such that for every two comparable elements $x, y \in X$,

$$\psi(d(fx, gy)) \leq F(\psi(M(x, y)), \phi(M(x, y))), \tag{11}$$

where

$$M(x, y) = \max\left\{d(x, y), d(x, fx), d(y, gy), \frac{1}{2}(d(x, gy) + d(y, fx))\right\}.$$

Then in each of the following two cases the mappings f and g have at least one common fixed point:

(i) f or g is continuous, or

(ii) if a nondecreasing sequence $\{x_n\}$ converges to $x \in X$, then $x_n \preccurlyeq x$ for all n.

Proof. Using that the pair of functions (f, g) is weakly increasing, we can construct inductively, starting with an arbitrary $x_0 \in X$, a sequence $\{x_n\}$ such that $x_n \preccurlyeq x_{n+1}$. Namely, denote:

$$x_1 = fx_0 \preccurlyeq gfx_0 = gx_1,$$
$$x_2 = gx_1 \preccurlyeq fgx_1 = fx_2,$$
$$x_3 = fx_2 \preccurlyeq gfx_2 = gx_3,$$

....

and in general, $x_{2n+1} = fx_{2n}$ and $x_{2n+2} = gx_{2n+1}$.

Suppose first that $x_k = x_{k+1}$ for some k. Then, the sequence $\{x_n\}$ is constant for $n \geq k$. Indeed, let $k = 2m$. Then $x_{2m} = x_{2m+1}$ and we obtain from (11) that

$$\begin{aligned}\psi(d(x_{2m+1}, x_{2m+2})) &= \psi(d(fx_{2m}, gx_{2m+1})) \leq \\ &\leq F(\psi(M(x_{2m}, x_{2m+1})), \phi(M(x_{2m}, x_{2m+1}))),\end{aligned} \tag{12}$$

where

$$M(x_{2m}, x_{2m+1}) = \max\{d(x_{2m}, x_{2m+1}), d(x_{2m}, fx_{2m}), d(x_{2m+1}, gx_{2m+1}),$$
$$\frac{1}{2}(d(x_{2m}, gx_{2m+1}) + d(x_{2m+1}, fx_{2m}))\}$$

$$= \max\left\{0,0, d\left(x_{2m+1}, x_{2m+2}\right), \frac{1}{2}\left(d\left(x_{2m}, x_{2m+2}\right)+0\right)\right\}$$

$$= \max\left\{d\left(x_{2m+1}, x_{2m+2}\right), \frac{1}{2}\left(d\left(x_{2m}, x_{2m+2}\right)+0\right)\right\}$$

$$= d\left(x_{2m+1}, x_{2m+2}\right).$$

Now further from (12) we get that

$\psi\left(d\left(x_{2m+1}, x_{2m+2}\right)\right) \le F\left(\psi\left(d\left(x_{2m+1}, x_{2m+2}\right)\right), \phi\left(d\left(x_{2m+1}, x_{2m+2}\right)\right)\right) \le \psi\left(d\left(x_{2m+1}, x_{2m+2}\right)\right)$, that is,

$$\psi\left(d\left(x_{2m+1}, x_{2m+2}\right)\right) = F\left(\psi\left(d\left(x_{2m+1}, x_{2m+2}\right)\right), \phi\left(d\left(x_{2m+1}, x_{2m+2}\right)\right)\right),$$

or equivalently either $\psi\left(d\left(x_{2m+1}, x_{2m+2}\right)\right) = 0$ or $\phi\left(d\left(x_{2m+1}, x_{2m+2}\right)\right) = 0$, i.e., $d\left(x_{2m+1}, x_{2m+2}\right) = 0$. Hence, if $x_k = x_{k+1}, k = 2m$ we obtain that $x_{k+1} = x_{k+2}$. Similarly, if $k = 2m+1$, one easily obtains that $x_{k+1} = x_{k+2}$, and so the sequence $\{x_n\}$ is constant (starting from some k) and x_k is a common fixed point of f and g.

Suppose now that $x_n \neq x_{n+1}$ for each n. We shall prove that $d\left(x_n, x_{n+1}\right) \to 0$ as $n \to \infty$. Using condition (11) (which is possible since x_n and x_{n+1} are comparable for all n), we obtain

$$\psi\left(d\left(x_{2n+2}, x_{2n+1}\right)\right) = \psi\left(d\left(gx_{2n+1}, fx_{2n}\right)\right)$$

$$= \psi\left(d\left(fx_{2n}, gx_{2n+1}\right)\right) \le F\left(\psi\left(M\left(x_{2n}, x_{2n+1}\right)\right), \phi\left(M\left(x_{2n}, x_{2n+1}\right)\right)\right),$$

where

$$M\left(x_{2n}, x_{2n+1}\right) = \max\left\{d\left(x_{2n}, x_{2n+1}\right), d\left(x_{2n}, fx_{2n}\right), d\left(x_{2n+1}, gx_{2n+1}\right),\right.$$

$$\left.\frac{1}{2}\left(d\left(x_{2n}, gx_{2n+1}\right)+d\left(x_{2n+1}, fx_{2n}\right)\right)\right\}$$

$$= \max\left\{d\left(x_{2n}, x_{2n+1}\right), d\left(x_{2n}, x_{2n+1}\right), d\left(x_{2n+1}, x_{2n+2}\right), \frac{1}{2}d\left(x_{2n}, x_{2n+2}\right)\right\}$$

$$\le \max\left\{d\left(x_{2n}, x_{2n+1}\right), d\left(x_{2n+1}, x_{2n+2}\right), \frac{1}{2}\left(d\left(x_{2n}, x_{2n+1}\right)+d\left(x_{2n+1}, x_{2n+2}\right)\right)\right\}$$

$$= \max\left\{d\left(x_{2n}, x_{2n+1}\right), d\left(x_{2n+1}, x_{2n+2}\right)\right\}.$$

If $d(x_{2n+1}, x_{2n+2}) \geq d(x_{2n}, x_{2n+1}) > 0$, then it follows

$\psi(d(x_{2n+2}, x_{2n+1})) \leq F(\psi(d(x_{2n+1}, x_{2n+2})), \phi(d(x_{2n+1}, x_{2n+2}))) \leq \psi(d(x_{2n+1}, x_{2n+2}))$,

or equivalently, either $\psi(d(x_{2m+1}, x_{2m+2})) = 0$ or $\phi(d(x_{2m+1}, x_{2m+2})) = 0$.

This is a contradiction, because $d(x_{2n+1}, x_{2n+2}) > 0$. Hence, $M(x_{2n}, x_{2n+1}) = d(x_{2n}, x_{2n+1})$. Now, we further easily get that $d(x_{n+1}, x_{n+2}) \leq d(x_n, x_{n+1})$ for all $n \in N \cup \{0\}$. This means that $d(x_n, x_{n+1}) \downarrow r \geq 0$ as $n \to \infty$. Let $r > 0$. Passing to the limit in the last inequality, when $n \to \infty$, we get

$$\psi(r) \leq F(\psi(r), \phi(r)) \leq \psi(r),$$

i.e., $F(\psi(r), \phi(r)) = \psi(r)$, or equivalently, either $\psi(r) = 0$ or $\phi(r) = 0$. A contradiction. Hence, $d(x_n, x_{n+1}) \to 0$ as $n \to \infty$.

In order to prove that $\{x_n\}$ is a Cauchy sequence in (X, d) we shall use the ideas from (Radenović et al, 2012, pp.625-645).

It is enough to prove that $\{x_{2n}\}$ is a Cauchy sequence. Suppose the contrary. Then, for some $\varepsilon > 0$ there exist subsequences $\{x_{2m(k)}\}$ and $\{x_{2n(k)}\}$ of $\{x_{2n}\}$ such that $n(k)$ is the smallest index satisfying $n(k) > m(k) > k$ and $d(x_{m(k)}, x_{n(k)}) \geq \varepsilon$. In particular, $d(x_{m(k)}, x_{n(k)-2}) < \varepsilon$. Now, using Lemma 1 and putting in (11) $x = x_{2n(k)}, y = x_{2m(k)-1}$ (x and y are obviously comparable) we have

$$\psi(d(x_{2n(k)+1,}, x_{2m(k)})) = \psi(d(fx_{2n(k)}, gx_{2m(k)-1})) \leq$$
$$\leq F(\psi(M(x_{2n(k)}, x_{2m(k)-1})), \phi(M(x_{2n(k)}, x_{2m(k)-1}))), \quad (13)$$

where

$$M(x_{2n(k)}, x_{2m(k)-1})$$
$$= \max\{d(x_{2n(k)}, x_{2m(k)-1}), d(x_{2n(k)}, fx_{2n(k)}), d(x_{2m(k)-1}, gx_{2m(k)-1}),$$
$$\frac{1}{2}(d(x_{2n(k)}, gx_{2m(k)-1}) + d(x_{2m(k)-1}, fx_{2n(k)}))\}$$
$$= \max\{d(x_{2n(k)}, x_{2m(k)-1}), d(x_{2n(k)}, x_{2n(k)+1}), d(x_{2m(k)-1}, x_{2m(k)}),$$

$$\frac{1}{2}\left(d\left(x_{2n(k)}, x_{2m(k)}\right)+ d\left(x_{2m(k)-1}, x_{2n(k)+1}\right)\right)\Big\}$$

$$\to \max\left\{\varepsilon,0,0,\frac{1}{2}\left(\varepsilon+\varepsilon\right)\right\} = \varepsilon.$$

Passing to the limit in (13) when $k \to \infty$, we obtain that

$$\psi(\varepsilon) \le F(\psi(\varepsilon),\phi(\varepsilon)) \le \psi(\varepsilon),$$

that is $\varepsilon = 0$, which is a contradiction. Hence, the sequence $\{x_n\}$ is a Cauchy sequence. Since (X,d) is a complete metric space it follows that $x_n \to u$ for some element $u \in X$.

(i) Suppose that the mapping g is continuous. Since $x_{2n+1} \to u$, we obtain that $x_{2n+2} = gx_{2n+1} \to gu$. On the other hand, $x_{2n+2} \to u$ (as a subsequence of $\{x_n\}$). It follows that $gu = u$. To prove that $fu = u$, using $u \preccurlyeq u$ we can put $x = y = u$ in (11) and obtain that

$$\psi(d(fu,gu)) \le F(\psi(M(u,u)),\phi(M(u,u))) = F(\psi(d(u,fu)),\phi(d(u,fu))),$$

because $M(u,u) = d(u,fu)$. We further have,

$$\psi(d(fu,u)) \le F(\psi(d(u,fu)),\phi(d(u,fu))),$$

from which follows (as in the previously cases) that $u = fu$.

The proof is similar if f is continuous.

(ii) Suppose now that the condition (ii) of the theorem holds. The sequence $\{x_n\}$ is nondecreasing w.r.t $\preccurlyeq$ and it follows that $x_n \preccurlyeq u$. Take $x = x_{2n}$, and $y = u$ (which are comparable) in (11) to obtain that

$$\psi(d(fx_{2n},gu)) \le F(\psi(M(x_{2n},u)),\phi(M(x_{2n},u))),$$

where

$$M(x_{2n},u) = \max\left\{d(x_{2n},u), d(x_{2n},fx_{2n}), d(u,gu), \frac{1}{2}\left(d(x_{2n},gu)+d(u,fx_{2n})\right)\right\}$$

$$\to \max\left\{0,0,d(u,gu),\frac{1}{2}d(u,gu)\right\} = d(u,gu).$$

Hence, we further obtain

$$\psi(d(fx_{2n},gu)) \le F(\psi(d(u,gu)),\phi(d(u,gu))),$$

or passing to the limit, we get

$$\psi(d(u,gu)) \le F(\psi(d(u,gu)),\phi(d(u,gu))).$$

From the last relation we get that $gu = u$.

The fact that $u = fu$ is now derived in the same way as in the case (i). The theorem is proved.

Finally, we address the following definitions as well as maybe a new result.

Consider the following classes of functions from $[0,\infty)$ into itself:

$$\Phi_\gamma = \{\gamma : \gamma \mid \text{is nondecreasing and lower semi - continuous}\},$$

$$\Phi_\alpha = \{\alpha : \alpha \mid \text{is upper semi - continuous}\},$$

$$\Phi_\beta = \{\beta : \beta \mid \text{is lower semi - continuous}\},$$

Also by using Ansari's method, one can prove that the following Theorem genuinely generalizes recent results from (Karapinar & Salimi, 2012) in several directions. Its proof is omitted.

Theorem 6 *Let (X, ≼) be a partially ordered set and let there exist a metric d on X such that (X,d) is a complete metric space and let $f: X \to X$ be a nondecreasing selfmap. Assume that there exist $\gamma \in \Phi_\gamma, \alpha \in \Phi_\alpha, \beta \in \Phi_\beta$ and $F \in \mathrm{C}$ such that for all $s,t \ge 0$,*

$$t > 0 \text{ and } (s = t \text{ or } s = 0) \text{ implies } \gamma(t) - F(\alpha(s),\beta(s)) > 0,$$

and

$$\gamma(d(fx,fy)) \le F(\alpha(M(x,y)),\beta(M(x,y)))$$

for all comparable $x, y \in X$, where

$$M(x,y) = \max\left\{d(x,y), d(x,fx), d(y,fy), \frac{1}{2}(d(x,fy)+d(y,fx))\right\}.$$

Suppose that, either

(i) f is continuous, or

(ii) if a nondecreasing sequence $\{x_n\}$ converges to $x \in X$, then $x_n \preccurlyeq x$ for all $n \in N \cup \{0\}$.

If there exists $x_0 \in X$ such that $x_0 \preccurlyeq fx_0$, then f has a fixed point.

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ПРИМЕНЕНИЕ МЕТОДА АНСАРИ В ОБОБЩЕНИИ РЯДА РЕЗУЛЬТАТОВ В РАМКАХ ТЕОРИИ НЕПОДВИЖНОЙ ТОЧКИ: ОБЗОР

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ОБЛАСТЬ: математика
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Цель данной статьи заключается в намерении показать, насколько функция С-класса, введенная А. Х. Ансари, является мощным средством для обобщения многих важных результатов в теории неподвижной точки.

Ключевые слова: «С» класс функций, метрическое пространство, последовательность Коши, общая неподвижная точка, неподвижная точка.

ПРИМЕНА АНСАРИЈЕВОГ МЕТОДА У ГЕНЕРАЛИЗАЦИЈИ НЕКИХ РЕЗУЛТАТА ИЗ ТЕОРИЈЕ НЕПОКРЕТНЕ ТАЧКЕ (ПРЕГЛЕД)

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ОБЛАСТ: математика
ВРСТА ЧЛАНКА: оригинални научни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Циљ овог рада јесте да се покаже да је С класа функција која је уведена у раду А. Х. Ансарија моћно средство у генерализацији многих важних резултата у теорији непокретне тачке.

Кључне речи: С класа функција, метрички простор, Кошијев низ, заједничка непокретна тачка, непокретна тачка.

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MATHEMATICAL MODELING AND COMPUTER SIMULATION OF A BASIC PROBLEM OF TUBE ARTILLERY EXTERNAL BALLISTICS BY MEANS OF THE MATHCAD SOFTWARE

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Summary:

The paper presents mathematical modeling and computer simulation (MM&CS) in the area of numerical solving of the basic problem of external ballistics for tubed artillery. Five-stage MM&CS scheme for conducting a ballistic simulation is developed. It is shown that a formal mathematical procedure allowing to solve the basic problem of external ballistics is a numerical solution of the Cauchy problem for a system of ballistic differential equations. The trajectory of a projectile flight for the 57-mm ZIS-2 anti-tank cannon is estimated. A solving algorithm and the Mathcad program code are given.The numerical solution for a system of four first order ballistic differential equations is a five-dimensional space.The possibility of visual presentation for a numerical solution was proposed in the form of a square matrix. The boundaries of each subspace are determined. A procedure based on spline functions is developed for checking the correctness of the numerical solution. As a result of such verification, the effects of a light increase in the error at the edges of the integration interval are observed. A comparison of the numerical solution of the basic ballistics problem is conducted by means of "soft" and "stiff" solver-functions.The trajectory parameters estimated by "soft" and "stiff" methods are the same up to the fifth decimal place.

Key words: external ballistics, projectile trajectory, mathematical modeling, computer simulation, Cauchy task, numerical solution, Mathcad.

Introduction

As a physical phenomenon, a tubed artillery shot belongs to the class of fast processes. One of the ways of studying them is based on

the method of mathematical modeling and computer simulation which replaces the real physical process by its formalized mathematical description. A problem is thus dealt with a significant amount of calculation, but it can be partially solved by using computer technology and automating calculations due to a program environment. As such, the Mathcad software was selected.

In view of the insignificant number of printed publications related to the technology of conducting external ballistic calculations in Mathcad[1], as well as their non-systemic nature, the author wanted to contribute to filling this gap. To this goal, basic program modules have been developed for making it possible to carry out the MM&CS process for an external-ballistic trajectories assessment and to realize the calculations of flight path parameters.

In this part, the paper is a continuation of (Khaikov, 2018), where a method for estimating a projectile initial velocity as a two-point boundary value problem was proposed.

The aim of this paper is to solve the following subtasks:

- the development of a program module for the Cauchy problem solution due to various numerical methods for “soft“ systems of ordinary differential equations (ODEs);
- the proposal of a method for the correctness verification of the obtained numerical solution;
- the application of numerical methods for the solution of the classical basic problem of external ballistics as probably “stiff“ ODEs.

All the subtasks must be determined in the Mathcad software.

MM&CS in the area of external ballistics

MM&CS (mathematical modeling and computational experiment[2]) in the ballistics of tubed weapons is regarded here as a research methodology and technology, based on applied mathematics, mechanics, programming and computer technologies for:

- a deeper understanding of a shot as a physical phenomenon;
- developing new and improving existing designs of small firearms and artillery tubed weapons;
- developing new and improving existing ammunition;
- developing measuring instruments for experimental ballistics goals.

[1] Publications from Eastern Europe were checked. The wide capabilities of the Mathcad software are used in many engineering activities. A preliminary study carried out by the author showed that there is no manual for a Mathcad application in analyzing internal and external ballistics of tubed weapons.

[2] Here the term “computational experiment” is used as a synonym for “computer simulation”.

With regard to ballistics problems, the process of MM&CS can be conditionally divided into five stages (Figure 1). Their names and essence are listed in Table 1.

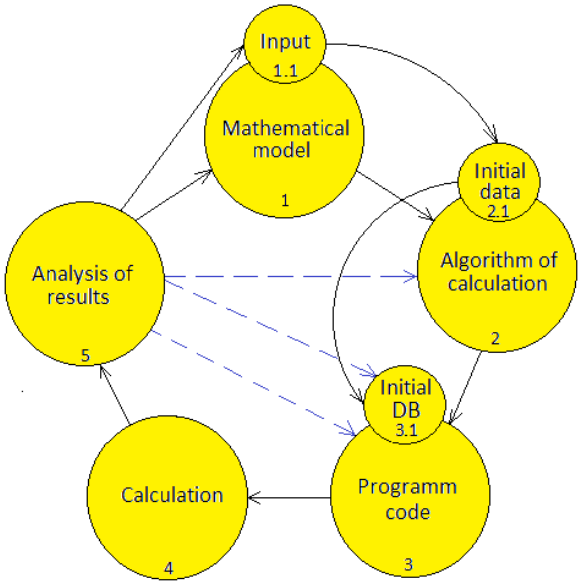

Figure 1 – A generalized presentation of the MM&CS process
Рис. 1 – Обобщенное представление процесса маттоделирования
Слика 1 – Уопштена представа процеса MM&KS

Table 1 – Name of the stage and the essence of the performed actions
Таблица 1 – Характеристика этапов математического моделирования
Табела 1 – Називи фаза и кратки описи предузетих активности

№	Name of the stage	The essence of the performed actions
1	2	3
1	Development of a mathematical ballistic model	The construction of a mathematical model as a formal mathematical description of a physical phenomenon or object.
2	Development of a calculation algorithm	Selection of numerical methods for the calculation and development of a computational algorithm.
3	Choice of the programming environment and the development of a program code	Implementation of the developed algorithm in the selected software for engineering calculation. An important element in the development of program code is a definition of the existence area for the initial database (DB) and the development of management tools.

№	Name of the stage	The essence of the performed actions
1	2	3
4	Calculation performance	Carrying out the calculations and the postprocessing of the resulting computing data.
5	Analysis of the results	Analysis of the calculation results, comparison (if possible) with the data of physical experiments or with conclusions of other computational simulations.

In the fifth stage, researchers can go back to the previous stages and make the necessary changes (for example, they can change the program-code or refine the initial data). The ways to perform feedback are shown by a dashed line in Figure 1.

Further on, the paper will describe a sequence of stages for assessing unguided projectile external-ballistic trajectories.

Ballistic trajectories and their elements as a result of numerical integrating of a system of ODEs throughthe Mathcad solver-functions

The following will be demonstrated: 1) how to calculate a trajectory and evaluate its parameters on the basis of a numerical solution, 2) how to verify the correctness of the obtained numerical solution, and 3) how to solve the basic ballistics (sometimes the word “main“ is used) problem of external ballistics by various numerical methods.

The realization of all five stages of the MM&CS process will be shown below by solving problem (1).

Numerical calculation of an external-ballistic flight path and its parameters

MM&CS Stage 1. Mathematical model of a projectile external-ballistic flight path.

The longitudinal motion of an artillery projectile in the Earth's atmosphere can be described by the system of ODEs with an independent argument time (t) (Burlov et al, 2006, p.249). This type of mathematical expressions belongs to the type of the Point-Mass Trajectory Model:

$$\left.\begin{aligned}\frac{dx}{dt} &= v\cos(\theta)\\ \frac{dy}{dt} &= v\sin(\theta)\\ \frac{d\theta}{dt} &= -\frac{g}{v}\cos(\theta)\\ \frac{dv}{dt} &= -(J + g\cdot\sin(\theta))\end{aligned}\right\} \quad (1)$$

here[3] x – the abscissa of the trajectory (m); y – the ordinate of the trajectory (m); θ – the angle of a velocity vector relative to the base of the trajectory (degrees or radians); v – the instantaneous projectile velocity (m/s); t – the time of flight (s); g – the acceleration of gravity (m/s^2); J – the acceleration of the air resistance force (m/s^2).

In order to assess an external-ballistic trajectory, we will perform an example for the flight of the 57-mm Armor Piercing Tracer Solid Projectile 53-BR-271SP (weight 3.14 kg) of the anti-tank gun, ZIS-2 1943 model[4]. The ZIS-2 gun is a so-called direct fire weapon and provides shooting with a flat trajectory.

MM&CS Stage 2. Projectile flight path calculation algorithm.

A calculation algorithm is a simple chain of performing computational operations. It is presented in Figure 2. The chain consists of eight elements. In boxes 1, 2, and 6, the values of the constants are determined. Boxes 3 and 4 define individual functions, and box 7 sets a functional matrix-column. The value of a ballistic coefficient is calculated in box 5.

The numerical solution of the Cauchy problem is done in box 8. The difference between box 8 and boxes 1-7 is that box 8 is called the built-in Mathcad solver-function. Data from boxes 1-8 is necessary for the solver-function for its correct functioning. In the block diagram, Figure 2, it is

[3] A more complete description of a system of ODEs and its elements is given in (Khaikov, 2018).

[4] Despite the almost identical initial data, the difference between (Khaikov, 2018) and this paper is in the following: the direct external-ballistical task is solved here, and the inverse task fullfiled in the previous work. The direct task (basic ballistic problem) requires the solution of the Cauchy task, and the inverse task deals with the solution of the boundary value problem.

implied that after box 8 the results (errors) are output in a tabular or graphical form.

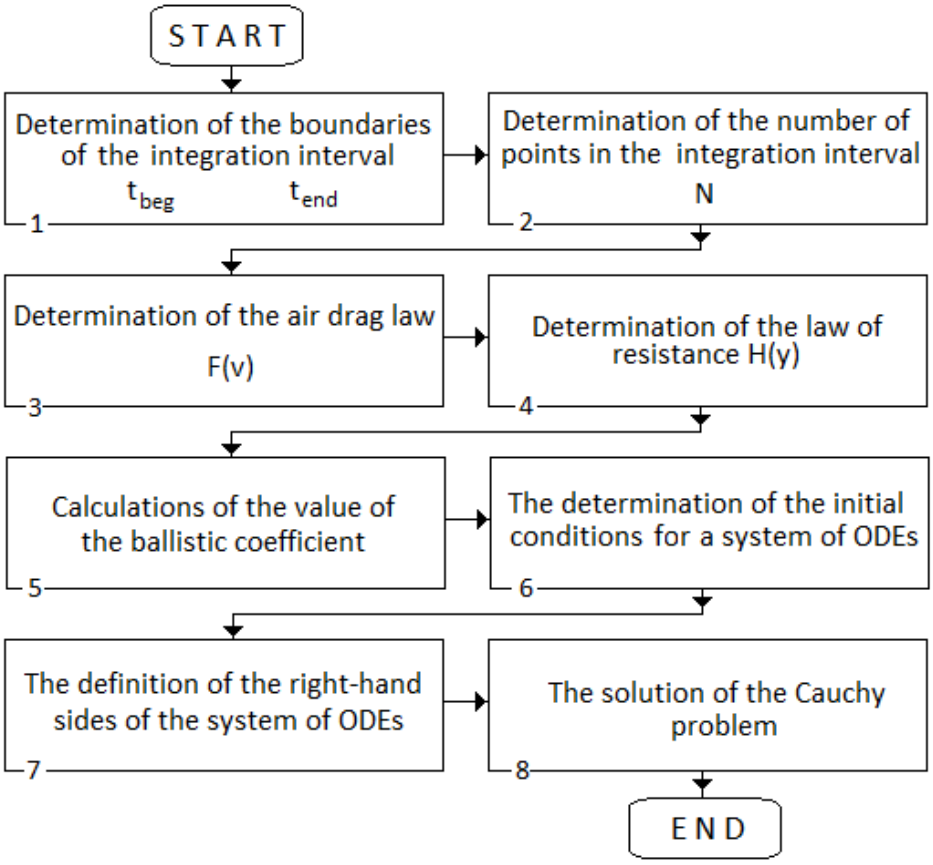

Figure 2 – An algorithm for calculating a projectile flight path
Рис. 2 – Алгоритм расчета траектории полета снаряда
Слика 2 – Алгоритам за израчунавање путање лета пројектила

MM&CS Stage 3. Program-code for a numerical solution.

In accordance with Figure 1, a process for program-code preparing is divided into two parts: the preparation of a database and the development of computational Mathcad procedures. The structure of the initial DB is given in Table 2.

Table 2 – Characteristics of the initial database
Таблица 2 – Характеристика исходных данных
Табела 2 – Карактеристике почетне базе података

I. Departure point conditions		
1	X coordinate of the departure point (X, m)	0
2	Y coordinate of the departure point (Y, m)	0
3	Angle of departure (θ_0, angle minute)	10
4	Projectile initial velocity (V_0, m/s)	990
II. Integration interval		
5	Time interval (t, s)	t_{beg}.. t_{end}
5.1	Beginning of the time-interval (t_{beg}, s)	0
5.2	End of the time-interval (t_{end}, s)	1.1
6	Number of points (dimensionless)	1000
7	Integration step (Δt, milliseconds)	1.1
III. Functions, variables (constants) of the right parts of a system of ODEs		
8	Air drag law (see (Khaikov, 2018))	quadratic
9	The law of density variation with altitude ($H(y)$)	Eberling[5]
10	Coefficient that depends on a shape of a projectile, i (dimensionless)	0.483
11	Caliber of a projectile (main diameter) (d, m)	0.057
12	Projectile weight (q,kg)	3.14
13	Air density at the departure point (ρ_N, kg/m^3)	1.206
14	Acceleration of gravity at the departure point (g, m/s^2)	9.81

When using system (1), 12 constants (variables) and 2 functions are necessary for a numerical solution of the Cauchy problem.

The Mathcad-code program is commented below. Using formula 1 and Table 1, one starts programming the elements of the Cauchy problem.

Let us determine the caliber for an artillery projectile (57 mm = 0.057 m), the weight (3.14 kg) and the value of the i coefficient (according to the quadratic drag law):

$$d:=0.057\ q:=3.14\ i:=4.83 \qquad (2)$$

[5] By Eberling law, H(y) is determined as: $H(y)=10^{-0.000046(y)}$

An angle of departure (in radians) is calculated as a set of angular degrees, minutes and seconds according to the formula:

$$\text{Gradus:}=0 \qquad \text{Min:}=10 \qquad \text{Sec:}=0$$

$$\theta_0 := \frac{\pi}{180}\left(Gradus + \frac{Min}{60} + \frac{Sec}{3600}\right) = 2.909 \cdot 10^{-3} \tag{3}$$

At a point of departure, the value of the acceleration coefficient of gravity is determined as 9.18 m/s^2. Further on, it is necessary to determine the time interval of integration, its boundaries and the total number of points:

$$t_{beg}:=0 \qquad t_{end}:=1.1 \qquad n_{points}:=1000 \tag{4}$$

As a law of air resistance, we will use the quadratic dependence of the type:

$$F_{si\,ap}(v) = B_{si}v^2, \tag{5}$$

where B_{si} = 0.00002694. This simplification is made in order to avoid the complicated mathematical formulas that describe the law of air resistance.

The value of the ballistic coefficient is estimated from formula (3) (Germershausen, 1982, p.159). It is equal to 0.5 m^2/kg. The acceleration of the air resistance force J will be characterized by form[6]

$$J = 0.5 \cdot \left(10^{-0.000046(y)}\right) \cdot \left(0.00002694v^2\right). \tag{6}$$

The initial conditions (for (1)) are determined as a matrix-column y, which will contain their known numerical values:

$$y := \begin{pmatrix} y_0 = x(0) \\ y_1 = y(0) \\ y_2 = \theta(0) \\ y_3 = v(0) \end{pmatrix}.$$

[6] Here it should be noted that the formula for calculating the ballistic coefficient and the method of its introduction into the *J*-equation for different countries (their national standards) may be not the same. In order to avoid ambiguous understanding, it must be agreed in advance.

In view of the fact that the initial velocity of the 57 mm armor-piercing solid tracer projectile 53-BR-271SP is 990 m/s (Burlov et al, 2006, p.425), the matrix-column y will look like:

$$y := \begin{pmatrix} 0 \\ 0 \\ 2.909 \cdot 10^{-3} \\ 990 \end{pmatrix}. \qquad (7)$$

The matrix-column D is the right-hand part of the system of ODEs (1). It includes variables with the following notation: the abscissa of the trajectory $x–y_0$; the ordinate of the trajectory $y–y_1$; the angle of the inclination of the tangent $\theta –y_2$, and the instantaneous projectile velocity $v –y_3$:

$$D(t, y) := \begin{bmatrix} y_3 \cdot \cos(y_2) \\ y_3 \cdot \sin(y_2) \\ -\frac{g}{y_3} \cdot \cos(y_2) \\ -\left(0.5 \cdot \left(10^{-\frac{46}{1000000}(y_1)}\right) \cdot \left(\frac{2694}{10000000} y_3^2\right) + g \sin(y_2)\right) \end{bmatrix}. \qquad (8)$$

Calling the solver-function *rkfixed* for numerical solution, (1) is performed by the command:

$$Result1 := rkfixed(y, t_{beg}, t_{end}, n_{point}, D).$$

For solving differential equations, the solver-function *rkfixed* implement the fourth order Runge-Kutta methods with a fixed step.

The variable *Result1* is the matrix containing the results of the numerical solution of the system of ODEs (1). In this case, the matrix has a size of 5 by 1001 elements and contains 5005 numbers. Five rows of the *Result1* matrix are the independent argument time (t) and the elements of the matrix y (or D). The first column (argument time) counts 1001 numbers. This number includes the initial conditions plus the numbers of the points in the integration interval.

A special feature of the basic problem of external ballistics is that the system of differential equations (1) contains the quantity J, which does not have an exact analytic expression. The fact is that J is a empirical function which can be described as

$$J = CH(y)F(v), \tag{9}$$

where C – a ballistic coefficient estimated by the Siacci mathematical expression (Germershausen, 1982, p.159), m^2/kg;

$H(y)$ – a function characterizing the dependence of air density vs altitude;

$F(v)$ – a function characterizing the dependence of the air resistance vs the instantaneous projectile velocity.

The functions $H(y)$ and $F(v)$ can be described by means of:

- an approximate analytical function;
- a piecewise function;
- a spline function.

For example, the 1943 air drag law[7] can be described by a piecewise function (Konovalov, 1979, p.84):

$$C_{x_{43}}(M) = \begin{pmatrix} 0.157 & 0.1 < M \le 0.73 \\ 0.033M + 0.133 & 0.73 < M < 0.82 \\ 3.9M^2 - 6.419M + 2.8025831 & 0.82 \le M < 0.91 \\ 1.5M - 1.176 & 0.91 \le M \le 1.00 \\ -1.6M^2 + 3.7632M - 1.828716 & 1.00 < M \le 1.18 \\ 0.384\sin(1.85M^{-1}) & 1.18 < M < 1.62 \\ 0.29M^{-1} + 0.172 & 1.62 \le M < 3.06 \\ -0.011M + 0.301 & 3.06 \le M \le 3.53 \end{pmatrix},$$

which will lead to the complication of the program-code. The drag coefficient C_{x43} is a function of the Mach number (M).

[7] It means the law of air resistance that was developed in the USSR during World War II. It has a short name: the 1943 law.

By using the drag functions $C_x(M)$ the quantity J will be calculated as

$$J = 4.732 \cdot 10^{-4} CH(y) a_0^2 M^2 C_x(M), \quad (10)$$

where a_0 - the speed of sound constant (about 340 m/s).

MM&CS Stage 4. Calculation.

An example of the numerical solution of ODEs (1) as a *Result1* matrix is shown in Figure 4. Note that the Mathcad software independently enumerates the columns and rows. The vertical column and the horizontal row with numbers and gray background should not be confused with numerical data.

The first row contains the initial conditions for (1). The leftmost column is the independent argument (in this case, the time of flight). The values of the first column are limited by the boundaries of the integration interval.

Result1 =

	0	1	2	3	4
0	0	0	0	$2.909 \cdot 10^{-3}$	990
1	$1.1 \cdot 10^{-3}$	1.089	$3.162 \cdot 10^{-3}$	$2.898 \cdot 10^{-3}$	989.855
2	$2.2 \cdot 10^{-3}$	2.178	$6.311 \cdot 10^{-3}$	$2.887 \cdot 10^{-3}$	989.709
3	$3.3 \cdot 10^{-3}$	3.266	$9.448 \cdot 10^{-3}$	$2.876 \cdot 10^{-3}$	989.564
4	$4.4 \cdot 10^{-3}$	4.355	0.013	$2.865 \cdot 10^{-3}$	989.418
5	$5.5 \cdot 10^{-3}$	5.443	0.016	$2.854 \cdot 10^{-3}$	989.272

Figure 3 – An example of data for a numerical solution of ODEs (1)
Рис. 3 – Пример матрицы численного решения системы ОДУ (1)
Слика 3 – Пример података за нумеричко решење ОДЈ

The time step of the Table is constant and it is determined as (in milliseconds)

$$Step = \frac{t_{end} - t_{begin}}{n_{points} + 1} = \frac{1.1 - 0}{1001} = 1.09 ms.$$

In order to use the found values independently from the matrix *Result1* will create 6 variables; their purpose are explained in Table 3. If necessary, the variables can be combined into a new matrix.

$$T := Result1^{(0)} \qquad X := Result1^{(1)} \qquad Y := Result1^{(2)}$$

$$\theta_{Ra} := Result1^{(3)} \qquad \theta_{Gr} := 180\pi^{-1}\theta_{Ra} \qquad V := Result1^{(4)}$$

Usually, the output of tabular data is accompanied by graphs. Their coordinates type and scale must be convenient for further analyses.

Table 3 – Characteristics of variables of a numerical solution of the system of ODEs (1)
Таблица 3 – Характеристика переменных численного решение системы ОДУ (1)
Табела 3 – Карактеристике променљивих нумеричког решења система ОДЈ(1)

№/№	Designation	Specification
1	T	A time of flight (t, s)
2	X	A horizontal range (X, m)
3	Y	A height of a trajectory (Y, m)
4	$\theta_{R\alpha}$	An angle of the velocity vector relative to the base of a trajectory in radians
5	θ_{Gr}	An angle of the velocity vector relative to the base of a trajectory in degrees
6	V	An instantaneous projectile velocity (m/s)

MM&CS Stage 5. Analysis of results.

It is known that the analysis of any two quantities can be expressed analytically, in a tabular form and graphically. The numerical solution of the system of ODEs (1) enables ananalysis of tabular and graphic data. The graphs of functions performed in the Cartesian coordinates for the system of ODEs (1) are shown in Figure 4.

Figure 4 shows the complete set of dependencies for the five quantities which characterize the system of ODEs (1). This image is constructed in the form of a square matrix. The quantities indicated in the upper horizontal line (X, Y,θ_{Gr}, V, T) of Figure 4 are plotted respectively on the ordinate axis of each graph. The quantities showed in the left vertical column of this figure are plotted respectively on the abscissa axis. The total number of dependencies is 25. Five graphs along the matrix diagonal are functions of the magnitude itself. Thus, there are 20 dependencies. From this number, 10 are direct dependencies and 10 are reverse ones. The functions Y-X, V-X, and V-T are the most widespread ones in practice.

Sometimes for the value of Y as a height of the trajectory and as an argument of function, there are 2 points (ordinates) on the graphs (for one Y-value). Such ambiguity characterizes the ascending and descending parts of the trajectory.

A starting point in the form of a square is added to each graph. This is done to explain the dynamics of the projectile flight and it displays the initial state from the point of view of the physical process.

The domain of the numerical solution for the system of ODEs (1) is the five-dimensional space (5D) of X, Y, θ_{Gr}, V and T quantities. The boundaries of each of the quantities are shown in Table 4.

If the quantities X, Y, θ_{Gr} and V are the parametric equations from the argument T, then, in the three-dimensional space, they can be expressed by two types of 3D-graphs: X, Y, θ_{Gr} X, Y and V. A parametric equation and the three-dimensional coordinate space give an opportunity to create a better graphic image.

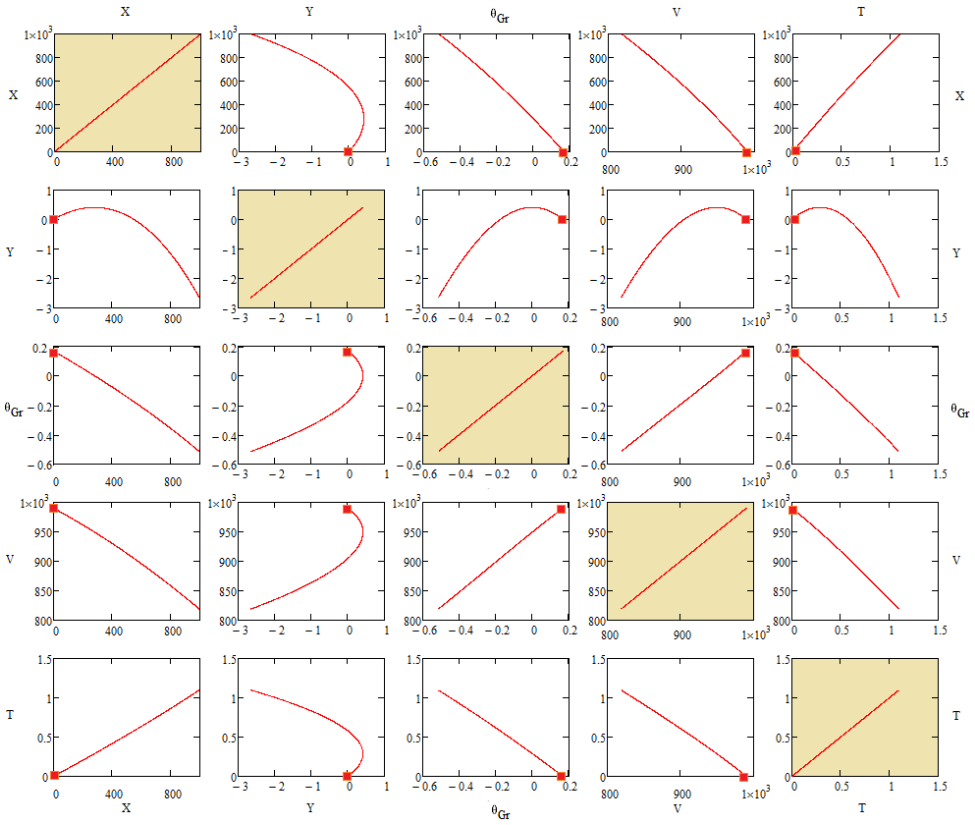

Figure 4 – Complete set of 2D dependencies between the values of the system of ODEs (1)

Рис. 4 – Полное множество 2D зависимостей между величинами системы ОДУ (1)

Слика 4 – Комплет 2D зависности између вредности система ОДЈ (1)

Table 4 – Characterization of the boundaries of the quantities (X, Y, θ_{Gr}, V, T)
Таблица 4 – Характеристика границ величин (X, Y, θ_{Gr}, V, T)
Табела 4 – Карактеризација граница величина X, Y, θ_{Gr}, V, T

№	Physical quantities	Min	Max
1	The horizontal range (X, m)	0	1000
2	The height of the trajectory (Y, m)	0	1.1
3	The angle of the velocity vector relative to the horizontal plane, in degrees	-0.5	$2.909 \cdot 10^{-3}$
4	The instantaneous projectile velocity (m/s)	820	990
5	The time of flight (t, s)	0	1.1

Verification of the correctness for external-ballistics trajectory parameters obtained as result of a numerical solution

In view of the fact that the existing solver-functions are nothing more than "black boxes", and the information about their implementation algorithm is characterized by incompleteness, it may be necessary to verify the correctness of the obtained solution by the substitution method.

At the first level of this process, we create a matrixline of discrete time values:

$$t_{in} := t_{beg}, t_{beg} + \frac{t_{end} - t_{beg}}{1001} .. t_{end}$$

At the second level, we perform the spline interpolation of the four obtained quantities (X, Y, θ_{Gr}, V) that are the result of the numerical solution of the system of ODEs, and express them as a spline function with the argument t_{in}. Thus, we define the four new functions: $X_{in}(t_{in})$, $Y_{in}(t_{in})$, $\theta_{in}(t_{in})$ and $V_{in}(t_{in})$.

$$X_{in}(t_{in}) := interp\left(lspline(T, X), T, X, t_{in}\right)$$
$$Y_{in}(t_{in}) := interp\left(lspline(T, Y), T, Y, t_{in}\right)$$
$$\theta_{in}(t_{in}) := interp\left(lspline(T, \theta), T, \theta, t_{in}\right)$$
$$V_{in}(t_{in}) := interp\left(lspline(T, V), T, V, t_{in}\right)$$

In this case, a linear spline function is used, but M allows the use of quadratic and cubic spline functions.

For the first differential equation (1), namely

$$\frac{dx(t)}{dt} = v(t)\cos(\theta(t))$$

express the left part and right one in the form of the spline functions. For the left-hand side, we perform numerical differentiation and obtain the function $L_X(t_{in})$

$$L_X(t_{in}) := \frac{d}{d(t_{in})}(X_{in}(t_{in}))$$

The right-hand side of $R_X(t_{in})$ is obtained by multiplying

$$R_X(t_{in}) := V_{in}(t_{in})\cdot\cos(\theta_{in}(t_{in})) .$$

One visualizes the results (both the right and the left part) in the form of a graph in the Cartesian coordinates

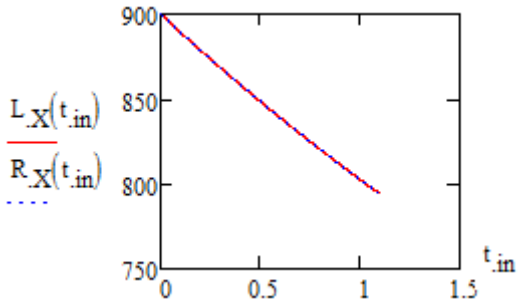

Figure 5 – Comparison of the right and left part of the first differential equation of (1)
Рис. 5 – Сравнение правой и левой частей первого уравнения системы ОДУ (1)
Слика 5 – Поређење левог и десног дела прве диференцијалне једначине (1)

The graph of the right and left part of the first differential equation of system (1) is presented as a decreasing function of time. Figure 5 shows its form for the integration interval 0-1.1 s. In order to find a magnitude of the relative error of their difference, one will look for (in percent):

$$Delta_X(t_{in}) := \frac{100\cdot\left|L_X(t_{in}) - R_X(t_{in})\right|}{L_X(t_{in})}.$$

To improve the image, the value of $Delta_X(t_{in})$ is summed with the constant $a = 1 \cdot 10^{-10}$.

The graph in Figure 6 shows that at the ends of the integration interval there are "edge" effects and the error of numerical solving increases.

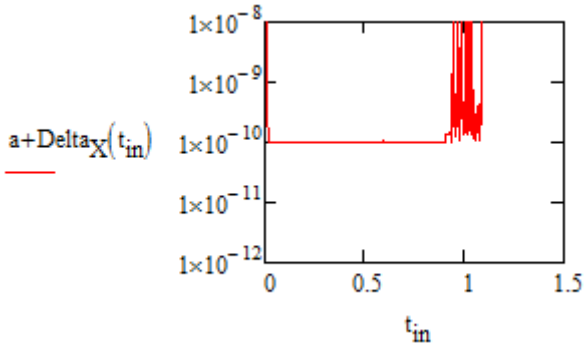

Figure 6 – Visual presentation of the relative error of the right and left parts of the first differential equation expressed in percent (integration interval 0-1.1 s.)
Рис. 6 – Визуальное изображение относительной погрешности правой и левой частей первого уравнения, выраженной в процентах (интервал интегрирования 0-1.1 с.)
Слика 6 – Визуелни приказ релативне грешке десног и левог дела прве диференцијалне једначине изражене у процентима (интеграциони интервал 0 – 1,1s)

In a similar way, the left and right parts for the second, third and fourth differential equations of system (1) are compared (Figure 7).

There is a coincidence of the function graphs. The right-hand sides of the second and third equations of the system of ODEs (1) are monotonically decreasing time functions. Their shape is close to linear dependence. In contrast, the right-hand side of the fourth equation is an increasing function. By the adopted initial conditions, their domain is negative.

A visual presentation of the errors of the right-hand and left-hand sides of equations 2-4 of the system of ODEs (1) is shown in Figure 7.

A visual presentation of the relative error of the right and left parts for the second, third and fourth differential equation expressed in percent (integration interval 0-1.1 s.) is shown in Figure 8.

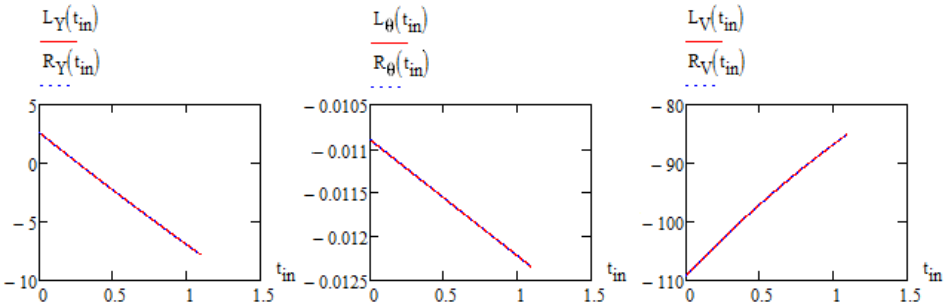

Figure 7 – A proof of the numerical solution for the second, third and fourth differential equation
Рис. 7 – Проверка численного решения второго, третьего и четвертого дифференциальных уравнений
Слика 7 – Доказ нумеричког решења друге, треће и четврте диференцијалне једначине

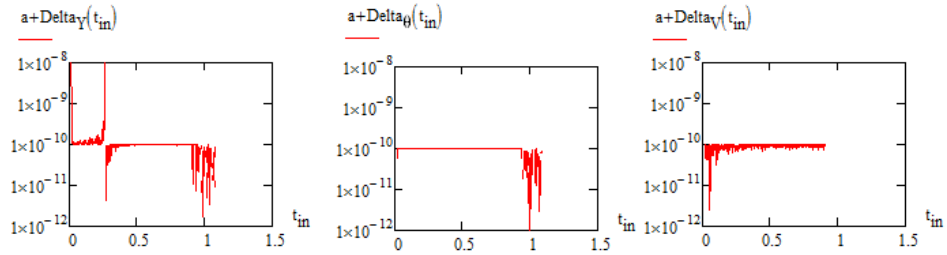

Figure 8 – A visual representation of the relative error of the right and left parts of differential equations
Рис. 8 – Визуальное представление относительной погрешности правой и левой частей дифференциальных уравнений
Слика 8 – Визуелни приказ релативне грешке десног и левог дела диференцијалних једначина

The conclusion for paragraph 2.2 is that the verification of the numerical solution can be carried out using spline functions with the help of which the approximation of the numerical solution is performed and the right parts of the systems of differential equations are calculated. The left-hand parts of the system of ODEs are calculated by numerical differentiation. At the final stage, we compared the right and left parts of the chosen interval of integration. For system (1), the error in the numerical solution does not exceed $1 \cdot 10^{-7}$%.

Numerical solving of the basic external-ballistics problem by numerical methods for "soft" and "stiff" systems of ODEs

From a practical point of view, it is interesting to consider the following problems:

I. Comparison of the calculation results obtained through various numerical methods.

II. Determination of the "stiff" properties of the system of ODEs characterizing the external ballistician problems.

Regarding the first problem: doing research for comparing the usefulness of various numerical methods by solving a system of ballistic differential equations will possibly allow an increase in a number of methods that can be conducted for numerical solving procedures. During the research, the level of errors, computational costs and the average solution time will be established.

The Mathcad solver-functions for solving the ODEs for "soft" and "stiff" systems are collected in Table 5. There are 7 solver-functions.

Table 5 – Functions-solvers of ODEs for "soft" and "stiff" systems
Таблица 5 – Функции-решатели ОДУ для «мягких» и «жестких» систем
Табела 5 – Функције за решавање ОДЈ за „меке" и „круте" системе

Functions-solvers of "soft" systems of ODEs	Functions-solvers of "stiff" systems of ODEs
Adams	
rkfixed	Radau
Rkadapt	Stiffr
Bulstoer	Stiffb

The commands for calling a solver-function and the required variables are shown below:

$$\text{Result1:= Adams}(y, t_{beg}, t_{end}, n_{point}, D, 10^{-9})$$
$$\text{Result2:= rkfixed}(y, t_{beg}, t_{end}, n_{point}, D)$$
$$\text{Result3:= Rkadapt}(y, t_{beg}, t_{end}, n_{point}, D)$$
$$\text{Result4:= Bulstoer}(y, t_{beg}, t_{end}, n_{point}, D)$$

The computational experiments conducted by the author showed that the calculations of system (1) performed by "soft" ODEs such as *rkfixed, Rkadapt* and *Bulstoer* give identical results up to the 5th digit after the decimal point (there were no experiments with the solver-function Adams).

Regarding the second problem: a parallel solution of the same ballistic problem by several numerical methods will make it possible to detect the appearance of probable "stiff" properties of the system of ODEs.

System (1) was solved with numerical methods for solving "stiff" ODEs: for instance, the *Stiffb* solver-function which implements the Bulirsch-Stoer method and the *Stiffr* solver-function – the Rosenbrock method.

To evaluate a trajectory using "stiff" methods, it is necessary to know the matrix J_k that has a size $n*(n+1)$: n rows and $n+1$ columns. The first column J_k contains the partial derivatives dF/dt, while the remaining columns and rows represent the Jacobi matrix dF/dy.

The structure of the matrix J_k applied to (1) has the following form

$$J_k(t,y)=\begin{bmatrix} \frac{\partial F_0}{\partial t} & \frac{\partial F_0}{\partial y_0} & \frac{\partial F_0}{\partial y_1} & \frac{\partial F_0}{\partial y_2} & \frac{\partial F_0}{\partial y_3} \\ \frac{\partial F_1}{\partial t} & \frac{\partial F_1}{\partial y_0} & \frac{\partial F_1}{\partial y_1} & \frac{\partial F_1}{\partial y_2} & \frac{\partial F_1}{\partial y_3} \\ \frac{\partial F_2}{\partial t} & \frac{\partial F_2}{\partial y_0} & \frac{\partial F_2}{\partial y_1} & \frac{\partial F_2}{\partial y_2} & \frac{\partial F_2}{\partial y_3} \\ \frac{\partial F_3}{\partial t} & \frac{\partial F_3}{\partial y_0} & \frac{\partial F_3}{\partial y_1} & \frac{\partial F_3}{\partial y_2} & \frac{\partial F_3}{\partial y_3} \end{bmatrix}$$

For $D(t,y)$ (8), the matrix $J_k(t,y)$ of size 4*5 (4 rows and 5 columns) has the kind

$$J_k(t,y)=\begin{bmatrix} 0 & 0 & 0 & -y_3\sin(y_2) & \cos(y_2) \\ 0 & 0 & 0 & -y_3\cos(y_2) & \sin(y_2) \\ 0 & 0 & 0 & \frac{g\sin(y_2)}{y_3} & \frac{g\cos(y_2)}{y_3^2} \\ 0 & 0 & 0 & g\cos(y_2) & \frac{0.0000538Cy_3}{10^{0.000046y_1}} \end{bmatrix} \quad (11)$$

The element of the matrix *a* has the form

$$a=\frac{\partial F_3}{\partial y_1}=\frac{1.237\cdot 10^{-9}\ln(10)Cy_3^2}{10^{0.000046y_1}}. \quad (12)$$

The result of testing solutions (1) by the methods of solving a “stiff“ system of ODEs *Stiffb*, *Stiffr* gives a similar result as “soft“ methods. For such solutions, there are 5 digits after the decimal point.

Conclusion

In this article, it is proposed to consider that a numerical solution of the basic problem of external ballistics can be considered as a five-stage process of MM&CS.

It is shown that a formal mathematical procedure allowing to solve the basic problem of external ballistics is a numerical solution of the Cauchy problem for a system of ballistic differential equations.

The flight trajectory of a projectile for the 57-mm ZIS-2 anti-tank cannon is estimated and visualized. A solving algorithm and the Matcad program-code are given.

The numerical solution for a system of four first order ballistic differential equations is a five-dimensional space. The possibility of a 2D visual representation for a numerical solution was proposed in a form of a square matrix. The boundaries of each subspace are determined.

A procedure based on spline functions is developed for checking the correctness of the numerical solution. For verification purposes, spline functions of three kinds can be used: a linear spline, a quadratic spline and a cubic spline. As a result of such verification, the effects of a light increase in the error at the edges of the integration interval are observed.

A comparison of the numerical solution of the basic ballistics problem is conducted by means of “soft“ and “stiff“ solver-functions. The article considers a possibility of solving a ballistic problem using five types of the Mathcad solver-functions. The trajectory parameters estimated by “soft“ and “stiff“ methods are the same up to the fifth decimal place.

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МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ И ВЫЧИСЛИТЕЛЬНЫЙ ЭКСПЕРИМЕНТ ПРИ ОЦЕНКЕ ВНЕШНЕЙ БАЛЛИСТИКИ СТВОЛЬНОЙ АРТИЛЛЕРИИ СРЕДСТВАМИ ПРОГРАММЫ MATHCAD

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ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В статье представлены примененный метод математического моделирования и компьютерный эксперимент при решении задач оценки внешней баллистики ствольных систем. Разработана общая схема проведения баллистического моделирования, состоящая из пяти уровней. Формальной математической процедурой, позволяющей решить основную задачу внешней баллистики является решение задачи Коши системы дифференциальных уравнений. Для 57-мм орудия ЗИС-2 оценена траектория полёта её снаряда. Разработан алгоритм решения задачи и программный Mathcad код.

Численное решение системы четырех баллистических дифференциальных уравнений первого порядка представляет собой пятимерное пространство. Показана возможность визуального представления решения в виде квадратной матрицы и определены границы подпространств. Разработан механизм проверки численного решения системы дифференциальных уравнений с использованием сплайн функций. В результате проверки обнаружены эффекты незначительного увеличения погрешности на краях интервала интегрирования. Проведено сравнение решения основной задачи баллистики при помощи «мягких» и «жестких» функций-решателей. По результатам оценок «мягкими» и «жесткими» методами параметры траектории одинаковы до пятого знака после запятой.

Ключевые слова: внешняя баллистика, внешнебаллистическая траектория, математическое моделирование, вычислительный эксперимент, задача Коши, численное решение, программа Mathcad.

ПРИМЕНА ПРОГРАМА MATHCAD У МАТЕМАТИЧКОМ МОДЕЛОВАЊУ И РАЧУНАРСКОЈ СИМУЛАЦИЈИ ОСНОВНОГ ПРОБЛЕМА СПОЉНЕ БАЛИСТИКЕ ЦЕВНЕ АРТИЉЕРИЈЕ

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ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У раду су представљени математичко моделовање и компјутерска симулација (MM&KS) у области нумеричког решавања основног проблема спољне балистике цевне артиљерије. Развијена је шема MM&KS у пет фаза за извођење балистичке симулације. Показано је да формални математички поступак који омогућава решење основног проблема спољне балистике представља нумеричко решавање Кошијевог проблема за систем балистичких диференцијалних једначина. Испитана је путања лета пројектила противтенковског топа ЗИС-2 калибра 57мм. Представљени су алгоритам и код програма Mathcad који су коришћени за решавање. Нумеричко решење система који се састоји од четири балистичке диференцијалне једначине првог реда јесте тродимензионални простор. Предложена је могућност да се нумеричко решење представи визуелно у облику квадратне матрице. Одређене су и границе сваког потпростора. Развијен је поступак заснован на „spline" функцијама ради провере исправности нумеричког решења. Приликом дате провере, примећени су ефекти лаког повећања грешке на крајевима интеграционог интервала. Нумеричко решење основног балистичког проблема упоређено је помоћу „меких" и „крутих" функција за решавање. Параметри путања испитани „меким" и „крутим" методама исти су до пете децимале.

Кључне речи: спољна балистика, путања пројектила, математичко моделирање, компјутерска симулација, Кошијев задатак, нумеричко решење.

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FORMATION OF *P-, N*-CONDUCTIVITY IN SEMICONDUCTORS

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Abstract:

The paper considers the energy position of negative ions of impurity atoms in the band gap of a semiconductor. Owing to the Boltzmann law, the energy levels of negative ions in the vicinity of the conduction band supply electrons to the conduction band, while resonance exchange of electrons occurs from the energy levels of negative ions in the vicinity of the allowed terms of the atoms of the main crystal. It is shown how energy band diagrams of n-conductivity and p-conductivity are formed. The applied external electric field acts oppositely on the impurities located in the vicinity of the conduction band and on those located in the vicinity of the allowed energy levels of the atoms of the main crystal. Impurity conductivity is determined by dielectric permittivity formed by the induced electric dipole moments of negative ions.

Key words: n-conductivity, p-conductivity, negative ions, electron affinity, thermionic emission, polarization.

Introduction

Nano-electronics is developing at a particularly rapid pace. This progress became possible after p- and n-conductivity[1] had been discovered in semiconductors featuring a wide enough band gap with the allowed energy levels. Semiconductor plates not exceeding 100 *μm* in width are cut from a crystal in plane (111). The conductivity of n-type is obtained using various techniques, by introducing atoms of boron, tellurium, gallium or indium into the body of a plate. The conductivity of p-type is created when atoms of arsenic, phosphorus or selenium are

[1] For clarity sake, commonly used terminology will be followed here. The terminology will be specified in due course.

introduced into the body of a semiconductor material. The action of the external electric field on n- and p-conductivity has been considered, for the most part, qualitatively. The quantitative substantiation of the phenomenon in terms of electronic theory was sufficiently performed in the 70s of the last century (Gretchikhin & Lenets, 1972).

The results could be put to practical use and, therefore, microelectronic engineering has been developed so far, for the major part, experimentally.

Advances in nanotechnologies resulted in a dramatic development of new techniques related to micro- and nano-electronics. In connection to this, there appeared an urgent need to understand what happens in the process of micro- and nanostructures formation. Former concepts based on the electronic theory of Drude-Lorentz-Sommerfeld do not reflect the true state of things. New approaches are necessary. In this regard, former physical concepts have already being rethought now. In his time, Nikola Tesla, as an alternative to the electronic theory, suggested electric and magnetic phenomena to be considered in terms of electromagnetic fields interaction. Nikola Tesla's ideas in electrodynamics were systematically developed in the following works: (Gretchikhin, 2008a), (Gretchikhin, 2016), (Gretchikhin, 2004) and (Gretchikhin, 2008b). However, so far, there has been no clear physical basis for the occurrence of p- and n-conductivity at atomic-molecular and cluster levels since the following fundamental directions remain unclear:

It is not clear why introducing various impurities into a semiconductor makes it possible to obtain p- or n-conductivity.

1. It is unclear what qualities, along with valence, introduced atoms should possess to ensure p- or n-conductivity.

2. What does chemical potential represent and why it should be located in the middle of the band gap.

All the above directions are clear in a quantitative sense under the assumption that the chemical potential in semiconductors is located in the middle of the band gap. Therefore, it is very difficult to hope for a clear understanding of nano-technologies or their wide and effective applications in daily practice until a rigorous theory of *p*-and *n*-conductivity which offers profound explanation of the phenomena at atomic-molecular level with further transfer onto nano-level has been developed. In this regard, it is vital to set the following *goal*: to develop a profound explanation of *p*- and *n*-conductivity taking into account the latest achievements of experimental and theoretical physics at the nano-level and with a firm rejection of the electronic theory. To reach the goal, it is essential to solve the following problems:

- to provide a rigorous explanation of the crystal structure of semiconductors;
- to provide an explanation of how *p*- and *n*-conductivity are formed;
- to provide an explanation of the temperature dependence of *p*- and *n*-conductivity;
- to ascertain how *p*- and *n*-conductivity behave under the action of external electric fields;
- to find out the essence of semiconductor conductivity based on new physical concepts;

Let us consider, one after another, these problems.

Structure of the Semiconductor Surface

In the case of silicon and germanium, the papers (Gretchikhin et al, 2015a) and (Gretchikhin, 2004) provide a theoretical explanation of their crystal structure and present the valence electron distribution in the first Brillouin zone. The paper (Gretchikhin et al, 2015a) presents the crystalline structure appearing on the surface taking into account the cluster structure of the condensed state; the following binding energies have been determined in the paper:

1. Binding energy when forming diatomic and triatomic molecules of silicon.
2. Binding energy among triatomic molecules of silicon within cluster structures.
3. Binding energy among silicon clusters in the intercluster lattice structure with a due explanation of the melting temperature.

In order to verify theoretical calculations, the silicon surface was carefully investigated my means of a tunneling microscope.

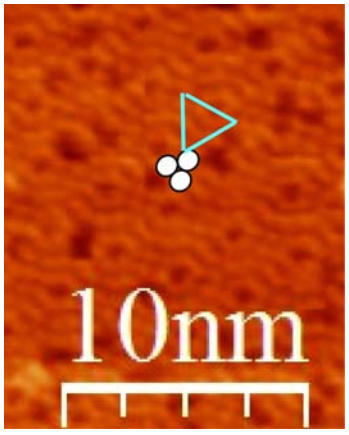

Figure 1 – Silicon Si (111) surface
Рис. 1 – Поверхность кремния Si (111)
Слика 1 – Површина силицијума Si (111)

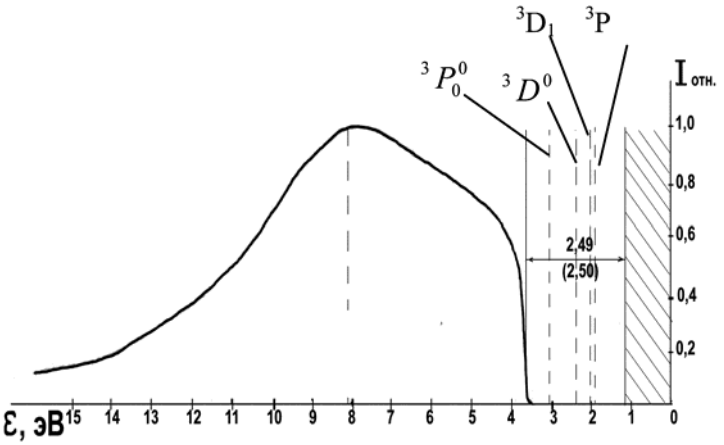

Figure 2 – General form of the first Brillouin zone for a silicon crystal
Рис. 2 – Общий вид первой зоны Бриллюэна для кристалла кремния
Слика 2 – Општи облик прве Брилуинове зоне код кристала силицијума

Figure 1 show a scanned silicon surface with an adhesion cell, filled with atoms and molecules of other elements, marked with a triangle. The theoretically calculated silicon surface shows agreement with the experimental data for all parameters of the design: in shape and in size of triatomic molecules on the silicon surface (Gretchikhin et al, 2015a).

Therefore, the Si(111) silicon surface is formed by triatomic molecules Si_3 with the radius of 2.122 Å (Gretchikhin et al, 2015a), accompanied by the formation of column-like gaps of 8.1 Å. Valence electrons in the crystalline state form a cloud which obeys the Fermi-Dirac distribution law. Figure 2 presents the results of the distribution calculated for silicon (Gretchikhin, 2004). The Fermi level of the silicon crystal possesses the energy of 2.49 *eV*. There are four allowed energy levels in the band gap; the levels feature the following values relative to the bottom of the conduction gap: 0.84; 1.03; 1.38 and 2.04 *eV*.

When neutral atoms are introduced as impurities onto the Si(111) surface of a silicon crystal they are located in places with the maximum binding energy. For instance, it has been proved experimentally that indium applied onto the silicon surface results in adhesion occurring on the surface between column-like gaps. The adhesion occurring between column-like gaps is formed by three triatomic molecules of silicon with close packing, marked with a triangle in Figure 1.

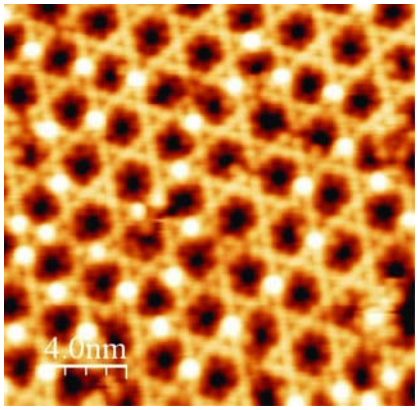

Figure 3 – Complete filling of the silicon surface when indium is sprayed onto the surface
Рис. 3 – Полное заполнение поверхности кремния при напылении индием
Слика 3 – Потпуно испуњавање површине силицијума при наношењу индијума прскањем на површину

Flat indium clusters consisting of three diatomic molecules are precipitated (Gretchikhin et al, 2015b). When such a cluster interacts with the silicon surface, the cluster and, at the same time, the molecules are deformed substantially. As this takes place, each atom independently interacts with the electron cloud of the valence electrons of the silicon crystal and with the ions of the crystal lattice. This situation with a complete filling of the silicon surface with indium atoms has been proved experimentally and is presented here in Figure 3. The emission properties are determined by individual atoms. A similar structure of atom arrangement on the silicon surface must be realized for other substances introduced into the silicon crystal.

Let us consider in detail the process of interaction of neutral atoms of different elements with the electron cloud of the first Brillouin zone of a silicon crystal, and find out what phenomena may occur in the process.

Formation of *p*- and *n*-Conductivity

The atoms embedded in the crystal structure must carry an excessive positive or negative electric charge to create an induced electric moment and, therefore, to participate in the conductivity of electric current. In this case, there may be positive ions created due to the ionization of neutral atoms, or negative ions in case of neutral atoms possessing a noticeable electron affinity. Table 1 presents the main parameters of the elements introduced into the silicon crystal to organize *p*- or *n*-conductivity.

Table 1 – Main parameters of the elements introduced into the silicon crystal
Таблица 1 – Основные параметры вводимых элементов в кристалл кремния
Табела 1 – Основни параметри елемената уведених у кристал силицијума

Para-meters	Introduced elements						
	Boron	Gallium	Tellurium	Indium	Arsenic	Phos-phorus	Selenium
Atomic radius (Å)	1.166	1.811	1.429	1.999	1.355	1.253	1.221
Ionization energy (eV)	8.30	6.00	9.01	6.79	9.82	10.49	9.75
Affinity energy (eV)	0.277	0.300	0.200	0.300	0.810	0.747	2.021
Share of emission centers	0.288	0.693	0.432	0.846	0.387	0.333	0.315

It follows from Table 1 that the process of ionization in the silicon crystal is practically impossible under normal conditions because of a high ionization energy. Therefore, the atoms of various elements cannot remain in the form of positive ions on the surface of the silicon crystal. A different situation arises when atoms possessing electron affinity other than zero are introduced into silicon. Such atoms are able to stay on the crystal surface in the form of negative ions which possess affinity energies within the band gap of the silicon crystal.

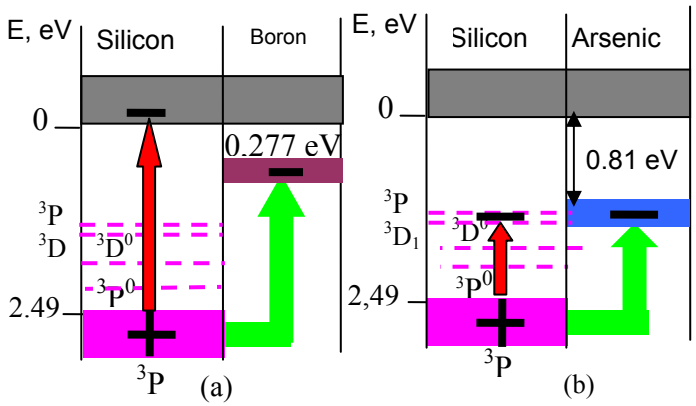

Figure 4 – Energy band diagrams of the formation of: (a) n- conductivity and (b) p-conductivity
Рис. 4 – Энергетическая схема формирования: а) n-проводимости и б) p-проводимости
Слика 4 – Енергетска шема формирања (а) н-проводљивости и (б) п-проводљивости

Figure 4 demonstrates, as an example, the principal energy band diagram in the case of boron and arsenic introduced into the silicon crystal. Boron and arsenic possess the ionization energies of 8.3 *eV* and 9.82 *eV* and, accordingly, are located in the vicinity of the electron density distribution maximum of the first Brillouin zone of the silicon crystal (Figure 2). Since these atoms possess electron affinity energy, they freely capture electrons from the first Brillouin zone of the silicon crystal and are turned into negative ions with further transition to the band gap where they permanently stay in the form of negative ions, regardless of various external influences. This process presents an obvious and fundamental fact.

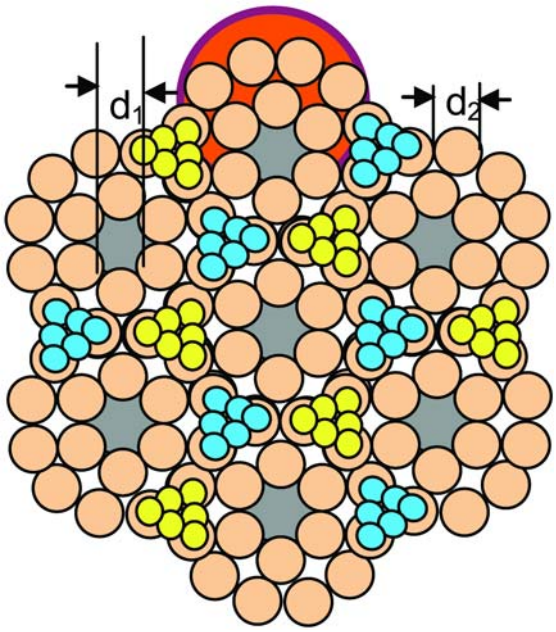

Figure 5 – Distribution of impurities on the silicon surface
Рис. 5 – Расположение примесей на поверхности кремния
Слика 5 – Дистрибуција примеса на површини силицијума

Figure 5 shows the arrangement of impurities on the silicon surface. Each adhesion cell is surrounded by three intermolecular gaps with the size of $d_p = (\sqrt{2} - 1) r_m$. The effective radius of triatomic molecules of silicon amounts to $r_m = 2.122$ Å (Gretchikhin et al, 2015a). In this case $d_p = 3$ Å. As the sizes of boron and arsenic atoms are known to be less

than 3 Å, then a part of the atoms will be captured by the gaps, and a certain share of the part may not participate in the thermal emission of electrons. The sizes of gallium and indium atoms exceed 3 Å. Therefore, these atoms will be located on the silicon surface and will fully participate in the thermionic process. Then, it follows from Figure 5 that the maximum concentration of introduced impurities (boron as well as arsenic) in the form of monolayer will amount to:

$$n_p \cong \frac{6 \cdot 4}{\pi (d_1 + 3d_2)^2 \cdot (d_2 + d_3)} \ m^{-3}, \qquad (1)$$

where d_1 is the diameter of the column-like gap, d_2 is the diameter of a triatomic silicon molecule, and d_3 is the diameter of impurity atoms. Based on formula (1), the maximum concentration of the atoms in the surface layer of boron impurity amounts to $2.68 \cdot 10^{27}\ m^{-3}$ while that one of the arsenic atoms is equal to $2.53 \cdot 10^{27}\ m^{-3}$.

In accordance with the Maxwell-Boltzmann distribution law, the negative ions of boron and, correspondingly, those of arsenic, will supply electrons to the conduction band due owing to thermionic emission. This process should last continuously until the electric field strength created by the electric dipole of silicon compensates the thermal emission of electrons from the negative ions of impurities. Thermionic emission is determined as follows (Gretchikhin, 2008a):

$$J_T = \frac{\gamma e}{4 r_a^3} \sqrt{\frac{8 k_b T}{\pi m_e}} \left(\frac{EA}{k_b T} + 1 \right) \exp\left(- \frac{EA}{k_b T} \right) \ (\mathrm{A \cdot m^{-2}}), \qquad (2)$$

where γ is the number of emission centers per unit of the surface area[2]; e is the electron charge; m_e is the electron mass; r_a is the radius of the emitted particle; k_b is the Boltzmann constant; and EA is the electron affinity energy.

In case of boron, the electron flow resulting from the thermionic emission is compensated by the reverse flow of electrons created by the electric field arising between the valence band and the conduction band, forming this way an electric dipole, while in case of arsenic an electric dipole moment occurs between the valence band and the level of its negative ion. Then, on the basis of the dimensional analysis, it follows that:

[2] It follows from Figure 4 that: $\gamma = 24 \pi r_a^2 / \pi (d_1 + 3d_2)^2$

$$J_{op} = en_p \sqrt{\frac{2e\Delta\varphi}{m_e}} \tag{3}$$

Here: $\Delta\varphi$ is the potential difference between the conduction band and the negative ion for *n*-conductivity, while for *p*-conductivity $\Delta\varphi$ means the potential difference between the valence band and the negative electron position in the band gap under the dynamic equilibrium $J_T = J_{op}$. The potential difference $\Delta\varphi$ is derived from this equation. Table 2 presents the results of the calculations for the elements featuring small affinity energies only.

Table 2 – Potential difference between the conduction band and the valence band
Таблица 2 – Разность потенциалов между валентной зоной и зоной проводимости
Табела 2 – Разлика потенцијала проводне зоне и валентне зоне

Impu-rity	Temperature (° K)									
	298	300	350	400	450	500	550	600	650	700
Boron	$2.7\cdot10^{-6}$	$5.5\cdot10^{-6}$	$1.2\cdot10^{-4}$	$1.2\cdot10^{-3}$	$7.6\cdot10^{-3}$	0.032	0.107	597 K - 0.277 eV		
Galli-um	$3.8\cdot10^{-7}$	$4.4\cdot10^{-7}$	$1.3\cdot10^{-5}$	$1.5\cdot10^{-4}$	$1.1\cdot10^{-3}$	$5.3\cdot10^{-3}$	0.019	0.057	0.141	698 K-0.3 eV
Tellu-rium	$7.1\cdot10^{-4}$	$7.8\cdot10^{-4}$	$7.4\cdot10^{-3}$	$2.7\cdot10^{-6}$	0.040	462 K – 0.2 eV				
Indi-um	$3.1\cdot10^{-7}$	$3.6\cdot10^{-7}$	$1.0\cdot10^{-5}$	$1.3\cdot10^{-4}$	$9.0\cdot10^{-4}$	$4.4\cdot10^{-3}$	0.016	0.046	0.116	0.257
	711 K – 0.3 eV									

Each line of Table 2 shows the limit values of the temperature polarization which ensures complete compensation of the affinity energy of the introduced impurity. At the temperature polarization limit value, the conductivity of a semiconductor transforms into the conductivity peculiar to metals.

In case of arsenic, phosphorus or selenium, the heating of the silicon substrate to the melting point can be ignored since these elements possess quite high affinity energy that is quite large (Table 1); these elements feature the temperature polarization limit values much higher than the melting point of silicon (1688 K).

Now let us consider the effects of external electric fields on *n*- и *p*-conductivity.

Action of Electric Fields on *n*- and *p*-Conductivity

An external electric field applied to a semiconductor with its surface containing impurities results in appropriate polarization of negative ions. Polarization energy will strengthen or weaken the impurity atom affinity energy depending on the direction of the applied field. If the electron affinity energy is known, then the energy under question can be represented as a model of a hydrogen atom with the effective charge and the radius of the negative ion, namely:

$$EA = \frac{Z^* e^2}{4\pi\varepsilon_0 r_i}. \quad (4)$$

The radius of the negative ion practically does not differ from the radius of the neutral atom (Gretchikhin & Kamarouskaya, 2016). Therefore, given the affinity energy, (4) determines the effective charge of the negative ion. For the negative ion of boron, the value equals to 0.0224 while for arsenic it equals to 0.0762. Let us apply this model to analyze the action of an external electric field on the negative ion. Under the action of an external electric field, the negative ion is polarized and then the interaction force between the external field and the valence electron of each particle of the substance must be compensated by a change in the internal binding forces of the valence electron with the effective charge of the particle. Therefore (Gretchikhin, 2008a),

$$eE_э = \frac{Z^* e^2}{4\pi\,\varepsilon_0 r_i^2} - \frac{Z^* e^2}{4\pi\,\varepsilon_0 (r_i \pm \Delta r_i)^2}. \quad (5)$$

where Δr_i is the displacement of the charge cloud of the negative ion relatively to its center.

Based on equations (4) and (5), the following expression for the displacement of the charge cloud is derived:

$$\Delta r_i = \pm \frac{4\pi\varepsilon_0 E_э r_i^3}{2Z^* e}. \quad (6)$$

The work done for the polarization:

$$A = eE_э \Delta r_i. \quad (7)$$

Based on (4) – (7), the following value of the effective electron affinity for the negative ion is derived:

$$EA_{eff} = EA\left(1 \pm \frac{e^2 E_э^2 r_i^2}{2EA^2}\right). \quad (8)$$

Finally, the thermionic current density (2), while taking into account (8), equals to:

$$J_T = \frac{\gamma e}{4r_a^3}\sqrt{\frac{8k_bT}{\pi m_e}}\left[\frac{EA}{k_bT}\left(1 \pm \frac{e^2 E_э^2 r_i^2}{2EA^2}\right)+1\right]\exp\left[-\frac{EA}{k_bT}\left(1 \pm \frac{e^2 E_э^2 r_i^2}{2EA^2}\right)\right] (A \cdot m^{-2}). \quad (9)$$

It follows from Figure 4 that the applied external electric field affects the negative ion affinity levels in different ways. When an external electric field is applied in the direction from the valence band to the conduction band, the energy affinity levels in the vicinity of the conduction band increase and the thermionic current decreases while the energy affinity levels in the vicinity of the valence band decrease and the thermionic current, in contrast, increases. The change in the direction of the applied external field results in a reverse direction of the thermionic current.

Impurities in semiconductors induce dipole electric moments while their concentration determines the change in the dielectric permittivity of semiconductors with impurities. This phenomenon, in turn, affects the conductivity of semiconductors.

Impurity Conductivity of Semiconductors

As an alternative to considering electric current as a movement of electric charges, Nikola Tesla proposed to consider it as a propagation of electromagnetic waves. In these terms, the energy transferred by electromagnetic waves is determined by the Poynting vector:

$$\vec{P} = [\vec{E} \cdot \vec{H}]. \quad (10)$$

where $\vec{E}$ is the electric field strength and $\vec{H}$ is the magnetic field strength.

In the absence of charges, according to the Lorentz equation, the electric field strength and the magnetic field strength in an electromagnetic wave are related by the following equation:

$$\vec{E} = [\vec{v} \cdot \vec{B}] = \mu_0 \mu_r [\vec{v} \cdot \vec{H}]. \quad (11)$$

Here $v = 1/\sqrt{\varepsilon \mu} = c/\sqrt{\varepsilon_r \mu_r}$ is the velocity of propagation of electromagnetic waves in a medium with given dielectric permittivity $\varepsilon = \varepsilon_r \varepsilon_0$ and magnetic permittivity $\mu = \mu_r \mu_0$. In their turn, ε_r и μ_r are

relative dielectric permittivity and relative magnetic permittivity, respectively, while $\varepsilon_0 = 8.854 \cdot 10^{-12}\, F/m$ and $\mu_0 = 4\pi \cdot 10^{-7}\, Gn/m$, according to Sommerfeld, present the absolute dielectric permittivity of classical vacuum, and $c = 1/\sqrt{\varepsilon_0 \mu_0}$ is light speed in vacuum.

When an electromagnetic wave propagates along a semiconductor, the electric field on the surface has tangential and normal components. Then Poynting vector becomes as follows:

$$\vec{P} = \left[\vec{E}_\tau \vec{H}\right] + \left[\vec{E}_n \vec{H}\right], \tag{12}$$

where E_τ and E_n are the components of the electric field strength along the conductor and normal to its surface.

The first term is due to the current conductivity determined by the Joule-Lenz law and Ohm's law while the second term is formed by the bias current which appears on the semiconductor surface and determines the transfer of electromagnetic field energy along the semiconductor (Gretchikhin, 2008b). Since the energy densities of the electric and magnetic fields are equal, it follows from (12) that $E_\tau = E_n$ on the semiconductor surface. Therefore, the resulting electric field strength of the electromagnetic wave is directed at an angle of 45^0 relative to the semiconductor surface (Gretchikhin, 2008b).

Let us consider an electric current I flowing through a semiconductor with a circular cross section of radius r and length l. When the electric current flows through the conductor, the intensity of the magnetic field is determined as $H = I/2\pi r$ and the tangential component of the electric field strength is determined as $E_\tau = (\varphi_1 - \varphi_2)/l$. Then equation (11) transforms as follows:

$$\varphi_1 - \varphi_2 = \sqrt{\frac{\mu_0 \mu_r}{\varepsilon_0 \varepsilon_r}} \frac{rl}{2\pi r^2} I\,. \tag{13}$$

For conductors, the linear relationship between current and voltage was established by Gustav Ohm and represents Ohm's law. Ohm's law is also valid for semiconductors. The difference lies in the different definition of relative permittivity and different manner of the interaction between the external electric field and the internal electric fields determined by the presence of induced and internal electric dipoles. Based on (13), the tangential component of the resistivity in case of propagation of electromagnetic waves through a semiconductor is derived as follows:

$$\rho = \sqrt{\frac{\mu_0 \mu_r}{\varepsilon_0 \varepsilon_r}} \frac{r}{2}. \tag{14}$$

For most materials including semiconductors $\mu_r \approx 1$ and so the resistivity is inversely proportional to the square root of the relative dielectric permittivity of the medium ($\sqrt{\varepsilon_r}$) and proportional to $\sqrt{\mu_0 / \varepsilon_0} = 120\pi$, i.e. so-called "characteristic impedance of vacuum", as well as to the radius of the semiconductor with a circular cross section.

It follows from the general definition of the electric displacement vector that:

$$\varepsilon_r = 1 + \frac{1}{\varepsilon_0 E_\tau} \frac{\sum_i p_{e,i}}{\Delta V} = 1 + \frac{\sum_i n_i p_{e,i}}{\varepsilon_0 E_\tau}, \tag{15}$$

where summation is performed over all electric dipole moments built-in and induced within the volume of ΔV while n_i is the concentration of the built-in and induced electric dipole moments, and $p_{э,i}$ is, correspondingly, their electric dipole moment. In most cases, the relative permittivity exceeds unit substantially. Then

$$\varepsilon_r = \frac{\sum_i n_{a,i} p_{e,i}}{\varepsilon_0 E_\tau}. \tag{16}$$

It is known that impurity conductivity far exceeds the intrinsic conductivity of semiconductors (Gretchikhin & Lenets, 1972). Therefore, impurity conductivity of semiconductors is determined only by the concentration of the introduced impurities while the value of resulting induced electric dipole moment is as follows:

$$\sum_i n_{a,i} p_{e,i} = e r_a n_{a,0} \exp\left[-\frac{EA}{k_b T} \left(1 \pm \frac{e^2 \Delta\varphi^2}{EA^2} \right) \right], \tag{17}$$

where $\Delta\varphi$ is the potential difference applied to the monolayer of impurity atoms, $n_{a,0}$ is the concentration of impurity atoms in the surface layer.

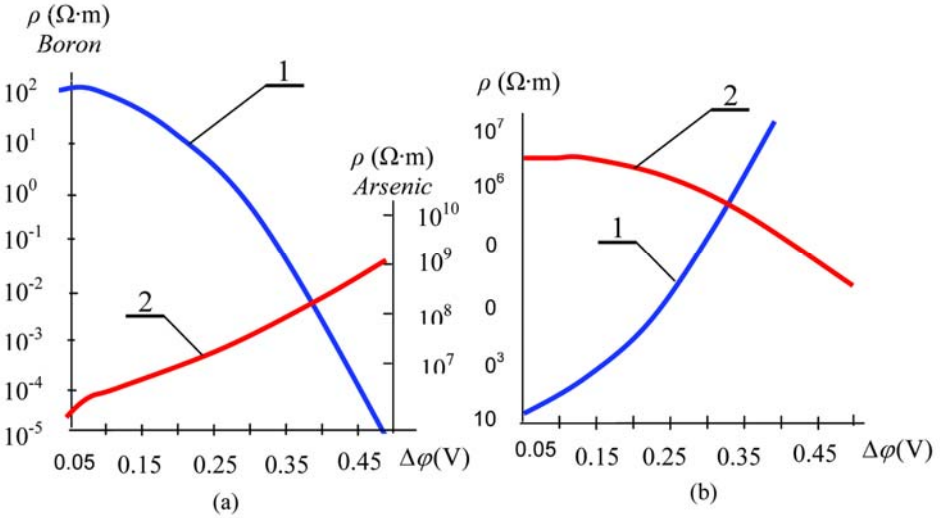

Figure 6 – Dependence of the resistivity of silicon: (1) with boron impurity, and (2) with arsenic impurity: (a) external electric field strength is directed from the valence band to the conduction band, and (b) external electric field strength is directed from the conduction band to the valence band.

Рис. 6 – Зависимость удельного сопротивления кремния 1 - с примесью бора и 2 – с примесью мышьяка: а) напряженность внешнего электрического поля направлена от валентной зоны к зоне проводимости и б) напряженность внешнего электрического поля направлена от зоны проводимости к валентной зоне.

Слика 6 – Зависност отпорности силицијума са (1) примесама бора и (2) примесама арсеника: (а) снага спољашњег електричног поља усмерена је од валентне зоне до проводне зоне, и (б) снага спољашњег електричног поља усмерена је од проводне зоне ка валентној зони

Based on (14) - (17), it is possible to completely determine the resistivity of a semiconductor with impurities. When determining the resistivity, normally the pills with a diameter of 1 cm and thickness of 3 mm are used. Figure 6 presents the results of the calculations, using such pills, for silicon with maximum concentrations of boron and arsenic impurities at the surface.

For metals, the resistivity amounts to 10^{-7}-10^{-8} $\Omega \cdot m$. Under an external electric field directed from the valence band to the conduction band, silicon with introduced boron acquires the conductivity inherent in metals when the potential difference at the contact boron-silicon reaches ~ 0.5 *V*. Silicon with introduced arsenic acquires the “metal” conductivity when the potential difference at the contact arsenic-silicon amounts to ~ 1.1-1.2 *V*.

It follows from Figure 6 that the lower the affinity energy of the introduced impurity is, the more the specific resistance varies depending on the value of the applied external electric field. As the applied electric field increases, the impurity conductivity tends to decrease linearly, or the resistivity tends to increase logarithmically along the ordinate axis, that is, the exponential dependence of the resistivity versus the applied external electric field becomes clearly recognized.

Conclusion

Summarizing the proposed alternative model for impurity conductivity occurring in semiconductors, we here formulate its main features:

1. In the band gap of a semiconductor, the energy position of the negative ions of impurity atoms is considered instead of considering the chemical potential relative to which the impurities are distributed.

2. The ionization of impurities distributed mainly on the crystal surface occurs not due to weakening the ionization energies because of high dielectric permittivity inside the crystal, but as a result of resonance electron capture from the Fermi-Dirac density distribution by neutral atoms possessing electron affinity.

3. Owing to the Boltzmann law, the energy levels of negative ions in the vicinity of the conduction band supply electrons to the conduction band. In this case, electric dipole moments are formed between the valence band and the conduction band, while the concentration of negative ions remains constant.

4. Resonance exchange of electrons occurs from the energy levels of negative ions in the vicinity of the allowed terms of the atoms of the main crystal accompanied with a formation of an electric dipole moment between the valence band and the allowed energy levels within the band gap of the main crystal. At the same time, the transition of electrons to the valence band from these energy levels is parity-forbidden.

5. Silicon crystal is formed by triatomic molecules. The structure of the silicon surface is considered and it is shown that the adsorption of impurities occurs in the region where the maximum surface density of silicon molecules is realized.

6. It is shown how the energy band diagram of *n*-conductivity and *p*-conductivity is formed and the potential differences due to the temperature polarization of impurity atoms are determined.

7. An applied external electric field acts oppositely on the impurities located in the vicinity of the conduction band and on those located in the vicinity of the allowed energy levels of the atoms of the main crystal.

8. Impurity conductivity is determined by dielectric permittivity formed by the induced electric dipole moments of negative ions but not by the electric dipole moments of the particles of the main crystal.

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ФОРМИРОВАНИЕ P-, N-ПРОВОДИМОСТИ В ПОЛУПРОВОДНИКАХ

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ОБЛАСТЬ: проводимость полупроводников
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В запрещенной зоне полупроводника рассматривается энергетическое положение отрицательных ионов примесных атомов. Уровни энергий отрицательных ионов вблизи зоны проводимости вследствие закона Больцмана поставляют электроны в зону проводимости, а с уровней энергий отрицательных ионов вблизи разрешенных термов атомов основного кристалла происходит резонансный обмен электронами. В работе представлено, как формируются энергетические схемы n-проводимости и p-проводимости. Приложенное внешнее электрическое поле действует взаимопротивоположно на примеси вблизи зоны проводимости и вблизи разрешенных уровней энергий атомов основного кристалла. Примесная электропроводность определяется диэлектрической проницаемостью, которая формируется наведенными дипольными электрическими моментами отрицательных ионов.

Ключевые слова: n-проводимость, p-проводимость, отрицательные ионы, сродство к электрону, термоэлектронная эмиссия, поляризация.

ФОРМИРАЊЕ ПРОВОДЉИВОСТИ КОД ПОЛУПРОВОДНИКА П-ТИПА И Н-ТИПА

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ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Рад се бави енергетском позицијом негативних јона атома примеса у енергетским процепима полупроводника. Захваљујући Болцмановом закону, енергетски нивои негативних јона у близини

проводне зоне снабдевају проводну зону електронима, док до резонантне размене електрона долази из правца енергетских нивоа негативних јона у близини дозвољених термина атома главног кристала. Показано је како долази до стварања дијаграма енергетских зона проводљивости Н-типа и П-типа. Примењено спољашње електрично поље делује супротно на примесе које се налазе у близини дозвољених енергетских нивоа атома главног кристала. Проводљивост примеса одређује се помоћу диелектричне пермитивности која се формира услед индукованог електричног диполног момента негативних јона.

Кључне речи: проводљивост Н-типа, проводљивост П-типа, афинитет према електрону, термојонска емисија, поларизација.

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PERFORMANCE ANALYSIS OF FULL-REFERENCE OBJECTIVE IMAGE AND VIDEO QUALITY ASSESSMENT METRICS

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Summary:

This paper presents the performance evaluation of image and video quality assessment metrics on two publicly available datasets with subjective quality ratings. In addition to the performance analysis at the global level – at the level of complete datasets, the paper presents the objective measures performance evaluation on subsets of signals inside them. The image dataset contains five subsets created by using different types of JPEG compression, while the video dataset contains six subsets of sequences – four created by compression of original sequences, and two subsets are with video signal transmission characteristic degradations. To determine the success of objective measures, i.e. comparison of subjective and objective quality scores, there were used measures accepted by the International Telecommunication Union – ITU (linear correlation coefficient, rank-order correlation coefficient, mean absolute error, root mean squared error and outlier ratio). It was shown that objective quality measures can reach a high level of agreement with the results of subjective tests on subsets of datasets. Objective measures performances depend on the type of degradation which significantly affects the performance at the complete dataset level. The difference in

performances is more pronounced on video sequences due to considerable visual differences in sequences created by using compression, packet losses and additive Gaussian noise. Therefore, we can say that a universal objective measure, i.e. measure that is useful for different types of signal degradation, for different degradation levels, and for different applications currently does not exist.

Key words: JPEG compression, H.264 and H.265 video compression, objective image and video quality assessment.

Introduction

Images, or videos, pass numerous processing and transmission phases before being viewed by the observer, and each of the phases may enter degradations that affect the quality of the final presentation. Image and video degradation in the recording process can occur due to the characteristics of the optics, sensor noise, color calibration, exposure time, motion of the camera, etc. After recording, an image or video adapts to the bandwidth of the transmission system through the compression process. The introduction of a high degree of compression is carried out at the expense of greater signal degradation. During transmission through a communication channel or during archiving, bit errors can also lead to degradation. Finally, end-user devices can affect the subjective quality impression (poor resolution, calibration, etc.) (Bovik, 2013).

As a human is an observer and user of the largest number of imaging systems, subjective assessment is the most reliable method for evaluating the quality of visual signals. In order to avoid subjective assessment, a procedure for automatic, computational image/video quality evaluation is required. An automated assessment procedure is called objective assessment and is useful in many applications where visual effects on images during recording, processing, compression, transmission and archiving need to be evaluated. Objective assessment measures do not require testing equipment, there is no complex organization of viewers, and with software implementation, time estimates are reduced to real-time (Bovik, 2010).

The basic goal of the research in the field of objective quality assessment is the development of a quantitative measure that (algorithmically, automatically) evaluates the quality of images/videos and is in good correlation with the mean opinion score (MOS). The ideal objective quality assessment measure should be applicable to different types of distortion, quantitatively covering different degrees of distortion and a wide range of content of the source signal. In practical applications, due to demands for real-time work, besides the conditions listed, computational complexity is also important (Wang et al, 2002).

Objective quality assessment measures have three types of application. The first is to monitor the image quality to control the transmission system. In this sense, quality assessment algorithms can be used to improve image quality through the perceptual optimization of the recording process, change of the transfer rate, resource reallocation with the goal of balancing quality through the network, through post-processing or by combining such approaches. Second, they can be used to select the system and image processing algorithms. Third, they can be embedded in an image processing system to optimize the algorithms and parameters used. For example, achieve a minimum degree of signal degradation for the given bit rate using compression, or achieve an acceptable level of signal degradation with the lowest bit rate (Wang et al, 2002).

According to the amount of information of the original (source, reference) image used in the quality assessment process on the receiving side (observer side), objective image quality evaluation can be divided into three categories: no-reference (NR), full-reference (FR) and reduced-reference (RR) (Bovik, 2013).

NR objective measures do not require knowledge of the original image and the assessment depends entirely on the human perception of the test image. Such measures can be used in all applications where quality measurement is required. Reliable NR quality assessment is currently possible if the type of distortion is known (JPEG compression, JPEG2000 compression, blurring), and in recent times general NR techniques for quality assessment appear (Wang & Bovik, 2011).

FR measures require full knowledge of the original image information. In this case, the quality assessment system can be considered as a communication system in which the original image is on the transmitting side and a test image (image with degradation) is on the receiving side. The basis of FR measures is comparison of the two images (source and test images) at the pixel level, region level and/or frequency characteristics level. However, in some real-world applications, it is not possible to know the original image on the receiving side. Also, objective FR image/video quality measures usually require precise spatial and temporal registration.

The original image/video usually comes from a high quality sensor and as such requires much more resources than image/video after compression. For this reason, FR quality assessment measures are used in laboratory tests to select image and video processing techniques.

RR techniques are between the previous two categories and are designed to provide practical solutions in quality assessment while

retaining the accuracy of the quality assessment. In these techniques, only the most important source information is sent from the transmitting to the receiving side. Since in this case the amount of additional information is not large, the requirements regarding the bandwidth of the channel are not significantly changed.

RR and NR quality assessment algorithms can be used as agents in the network data transfer, for installation in routers, set boxes, smart phones, tablets, or laptops. Through them, feedback information can be obtained for source adaptation and control mechanisms resource allocation, source coding and other network parameters (Wang & Bovik, 2011).

In this paper, we analyzed the performance of full-reference objective image quality and video quality measures on two publicly available datasets with subjective quality impressions – JPEG XR Image Dataset (De Simone et al, 2009) and CSIQ Video Dataset (Vu & Chandler, 2014). The JPEG XR Image Dataset is selected because it contains high spatial resolution images, while the CSIQ Video Dataset is selected because it contains sequences with recently introduced H.265 compression. The analysis was carried out at the level of complete datasets (global level), as well as at the level of subsets (types of degradation) of the test signals within the datasets (degradation level). In the image quality assessment, eight objective measures were analyzed: peak signal to noise ratio (PSNR), universal image quality index (UIQI) (Wang & Bovik, 2002), structural similarity index (SSIM) (Wang et al, 2004) and its multi-scale version (MS-SSIM) (Wang et al, 2003), visual information fidelity (VIF) (Sheikh & Bovik, 2006), visual signal to noise ratio (VSNR) (Chandler & Hemami, 2007), most apparent distortion (MAD) (Larson & Chandler, 2010) and gradient-based objective image quality assessment measure Q^{AB} (Bondzulic & Petrovic, 2011).

Video quality estimation can be obtained directly by applying an image quality assessment measure frame by frame. Thus, the quality of the video sequence was carried out by averaging the frame quality values obtained using PSNR (Frame PSNR) and SSIM (Frame SSIM) measures.

Additionally, the paper also analyzes the performance of the objective video quality assessment measure VQ^{AB} (Bondžulić, 2016), which was created by the extension of the objective image quality assessment measure Q^{AB} (Bondzulic & Petrovic, 2011). The VQ^{AB} measure in its original form was used to evaluate the quality of the sequences in low bit rate transmission systems.

Some of the objective measures were analyzed for the first time in the quality assessment of high-resolution images (JPEG XR Image Dataset), and in the quality evaluation of the sequences with H.265 compression (CSIQ Video Dataset).

The work is organized in six sections. After the introduction, in the second part of the paper, the methods of generalization of the results of subjective tests are described. The third part of the paper presents the criteria used to evaluate the performance of objective image and video quality measures, which have been adopted by the International Telecommunication Union (ITU). The fourth and fifth parts of the paper present the performance of objective quality assessment measures on the JPEG XR Image Dataset and the CSIQ Video Dataset. The last part of the paper is a conclusion.

Subjective quality assessment

Procedures and standards for subjective quality assessment of speech, audio and video signals are available throughout the years. Subjective tests for assessing the quality of visual signals have been formalized in the recommendations (International Telecommunication Union, 2008), (International Telecommunication Union, 2012) and (International Telecommunication Union, 2016), which suggest observation conditions, criteria for the choice of observers and test materials, and methods of data analysis.

The outputs of subjective experiments are the observations of the quality of the observers, which are consolidated after the test and represented through the mean opinion score (MOS). MOS is the most commonly used method of subjective scores generalization and is used as the basis for the development of objective quality assessment measures:

$$MOS_i = \frac{1}{N_S}\sum_{n=1}^{N_S} SQ(n,i) \tag{1}$$

where are:

i – index (label) of the video with degradation in a subjective test,

$SQ(n,i)$ – the subjective quality given by the observer n to the sequence i,

N_S – the number of observers in the subjective test.

It can be said that MOS is a "democratic" measure that treats each subjective score equally and really represents a mean (average) opinion.

MOS values can be used to compare to the values obtained by applying objective measures.

Since the MOS value is obtained from several individual quality scores, a quality evaluation can be associated with a certain level of statistical uncertainty. If there are significant fluctuations of subjective scores, this uncertainty is high. The uncertainty of subjective scores can be measured in many ways, but standard deviation, variance and standard error are commonly used.

Standard deviation is determined on the basis of individual subjective video quality scores, SQ_i (index n corresponding to the observer is ignored) and the mean opinion score of that video:

$$\sigma_i = \sqrt{\mathrm{E}[SQ_i^2]\text{-}(\mathrm{E}[SQ_i])^2} = \sqrt{\mathrm{E}[SQ_i^2]\text{-}MOS_i^2} \tag{2}$$

where E[X] is the expected value of the variable X.

The standard error of the MOS is determined from the standard deviation of the subjective scores and takes into account the number of measurements in determining the measured value. In this case, that is the number of observers who participated in subjective tests, N_S:

$$SE_i = \frac{\sigma_i}{\sqrt{N_S}} \tag{3}$$

The standard error is usually displayed along with the mean value as its positive and negative deviation ($MOS_i \pm 2 \cdot SE_i$) – confidence interval, but it does not speak about the reasons for the deviation.

Except through the MOS, the results of subjective tests can also be presented through the difference mean opinion scores (DMOS) obtained by subtracting the subjective evaluation of the signal with a distortion from the average subjective estimation of the corresponding original signal:

$$DMOS_i = MOS_i^{original} - MOS_i^{distorted} \tag{4}$$

Criteria for performance evaluation of objective image and video quality assessment metrics

The most common attributes reflecting the success of the objective measure in the image/video quality prediction are: (1) the accuracy of the prediction, (2) the prediction monotonicity and (3) the consistency of the prediction (International Telecommunication Union, 2004). Objective and subjective tests provide numerical (scalar) values for each original and

test signal that indicate the relationship between the quality of the original signal and the test signal. From the subjective tests results, mean values of the scores (MOS/DMOS) and confidence intervals are used.

The results of the objective quality assessment metrics – video quality ratings (VQR) are compared with the results of subjective tests that can be delivered through DMOS or MOS quality scores. The connection between VQR and DMOS/MOS scores does not have to be linear as the results of subjective tests can have non-linear compression (scaling) of scores around the extreme values of the used quality range. In order to eliminate the nonlinearities introduced by the subjective evaluation process (Figure 1), the relationship between predictions of objective measurements and subjective quality scores is observed using nonlinear regression between VQR and DMOS sets. By introducing non-linear mapping, the accuracy and consistency of the prediction change, and the prediction monotonicity remains the same.

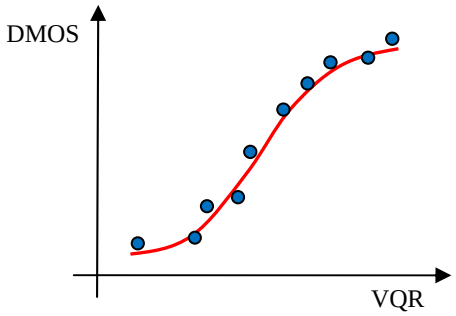


Figure 1 – An example of a connection between VQR and DMOS
Рис. 1 – Пример связи между VQR и DMOS
Слика 1 – Пример везе између VQR и DMOS

Nonlinear regression is performed over [VQR, DMOS] datasets, and must be monotone in the range of VQR scores. The shape of nonlinear regression is not critical, with the condition that it is a monotone, generally acceptable and has as few free parameters as possible to facilitate the interpolation of data. In regression, different forms are used for each of the objective measures and chooses the one that is the most appropriate (with minimal mean square error) for a given measure.

The most common functions used in regression are (International Telecommunication Union, 2004):

– third-order polynomial with four parameters

$$y = Quality(x) = A_0 + A_1 x + A_2 x^2 + A_3 x^3 \quad (5)$$

– logistic function with four parameters

$$y = Quality(x) = \frac{\beta_1 - \beta_2}{1 + \exp\left(\frac{x - \beta_3}{|\beta_4|}\right)} + \beta_2 \quad (6)$$

– logistic function with five parameters

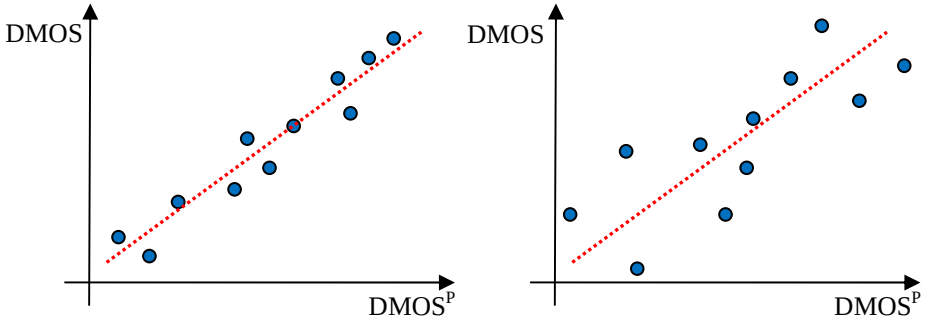
$$y = Quality(x) = \beta_1 \left(\frac{1}{2} - \frac{1}{1 + \exp\left(\beta_2 \left(x - \beta_3\right)\right)}\right) + \beta_4 x + \beta_5 \quad (7)$$

where x represents a set of VQR values ($x \equiv$VQR) while y represents a set of DMOS predictions, $DMOS^P$ ($y \equiv DMOS^P$), which are then compared with subjective DMOS scores.

For nonlinear mapping between objective estimates x and subjective scores y, the most commonly used function is accepted – the logistic function with four parameters (6).

Prediction accuracy

Accuracy is the ability of an objective quality estimation measure for the prediction of DMOS subjective scores with a minimal average error (International Telecommunication Union, 2004). Figure 2(a) shows the results of the measure with a smaller mean error between $DMOS^P$ and DMOS scores in relation to the measure of Figure 2(b). Therefore, the accuracy of the objective measure in Figure 2(a) is better.



(a) measure with greater accuracy *(b) measure with less accuracy*

Figure 2 – Objective quality assessment metrics comparison through prediction accuracy
Рис. 2 – Сравнение показателей объективности оценки качества методом точного прогнозирования
Слика 2 – Поређење мера објективне процене квалитета кроз тачност предикције

Numerous metrics can be used to determine the mean error, and the typically used ones are the mean absolute error (MAE) and the root-mean-squared error (RMSE) between objective estimates after non-linear mapping and subjective scores. If the difference between DMOS values and their predictions is determined as:

$$Perror_i = DMOS_i - DMOS_i^P \tag{8}$$

where the index *i* refers to the serial number of the analyzed test sequence, the mean absolute error and the root-mean-squared error for the set of *N* test sequences are obtained as:

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|Perror_i\right| \tag{9}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(Perror_i\right)^2} \tag{10}$$

The linear correlation coefficient (Pearson Linear Correlation Coefficient, LCC), although not a direct measure of the mean error, is also a common metric used to determine the accuracy of the prediction. The lower values of the MAE and RMSE (ideally equal to zero) correspond to the higher values of the correlation coefficient (ideally equal to the unit).

For a set of *N* pairs (x_i,y_i), the linear correlation coefficient is defined as:

$$LCC = \frac{\sum_{i=1}^{N}\left(x_i-\overline{x}\right)\left(y_i-\overline{y}\right)}{\sqrt{\sum_{i=1}^{N}\left(x_i-\overline{x}\right)^2\sum_{i=1}^{N}\left(y_i-\overline{y}\right)^2}} \tag{11}$$

where $\overline{x}$ and $\overline{y}$ are the mean values of the subsets *x* and *y*, which here represent DMOS and $DMOS^P$ sets.

Prediction monotonicity

Monotonicity is the degree to which objective predictions agree with the relative amplitudes of subjective assessments (International Telecommunication Union, 2004). $DMOS^P$ values derived from the results of an objective measure should ideally be completely monotone compared to the paired DMOS values, i.e. changing the $DMOS^P$ value should have the same sign as the change of the DMOS scores.

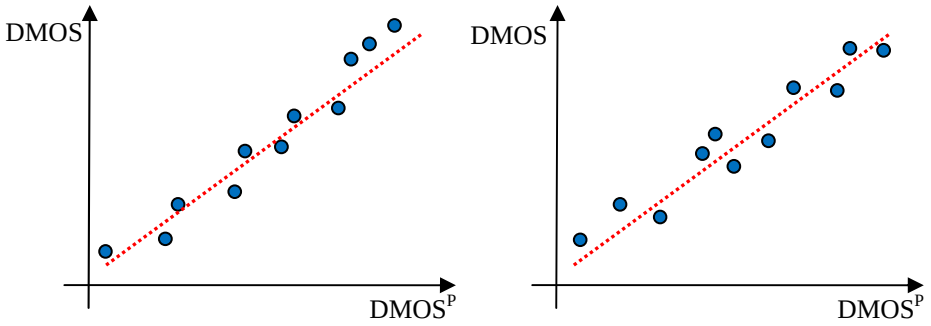
Figure 3 illustrates hypothetical connections between $DMOS^P$ and DMOS for two measures of different monotonicity. Both measures have approximately the same accuracy but the prediction monotonicity in Figure 3(a) is better. The monotonicity prediction in Figure 3(b) is worse. This is seen through the fall of the $DMOS^P$ values relative to what the observers actually see and what is being done through increasing the DMOS values.

Prediction monotonicity can be measured by the Spearman rank-order correlation coefficient (SROCC), which is defined as:

$$SROCC = \frac{\sum_{i=1}^{N}(\chi_i - \bar{\chi})(\gamma_i - \bar{\gamma})}{\sqrt{\sum_{i=1}^{N}(\chi_i - \bar{\chi})^2 \sum_{i=1}^{N}(\gamma_i - \bar{\gamma})^2}} = 1 - \frac{6 \cdot \sum_{i=1}^{N}(\chi_i - \gamma_i)^2}{N\left(N^2 - 1\right)} \qquad (12)$$

where χ_i and γ_i are x_i and y_i ranks, while $\bar{\chi}$ and $\bar{\gamma}$ are their mean values.

This parameter compares the change between adjacent pairs of DMOS values with a change between the corresponding $DMOS^P$ values. As the SROCC only works with the rankings (order) of the data and ignores the relative distances between them, it is taken as a measure of correlation with less sensitivity and is typically used if the number of points (samples) is small. With the increase in the SROCC value, the monotonicity of the objective quality assessment measure (ideally, SROCC=1) grows.



(a) measure with more monotonicity *(b) measure with less monotonicity*

Figure 3 – Objective quality assessment metrics comparison through prediction monotonicity

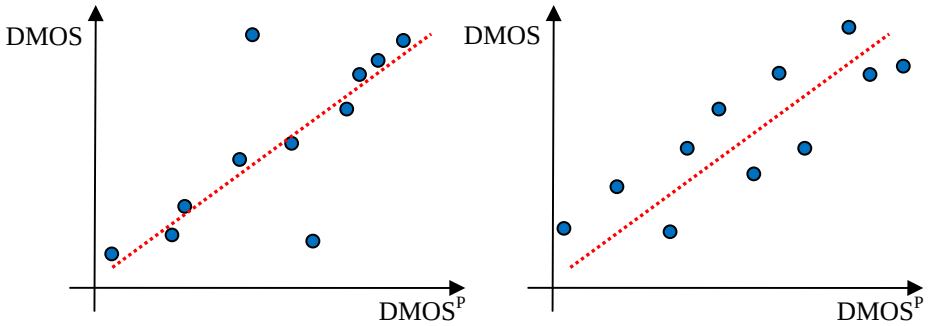
Рис. 3 – Сравнение показателей объективности оценки качества методом монотонного прогнозирования

Слика 3 – Поређење мера објективне процене квалитета кроз монотоност предикције

Prediction consistency

This attribute is related to the extent to which the objective quality assessment measure preserves the prediction accuracy through a whole set of analyzed video sequences (International Telecommunication Union, 2004). An objective measure should be consistent for all types of video sequences, that is, there is no significant deviation for subset of the analyzed sequences.

Figure 4 shows the results derived from two objective quality estimation measures with approximately the same values of the MAE/RMSE between DMOS and $DMOS^P$ datasets. Figure 4(a) is an example of a measure which has precise prediction for most of the sequences, but also has large prediction errors for two points in the middle part of the image. Figure 4(b) is an example of a measure that has balanced prediction errors – for most sequences it is not accurate as a measure in Figure 4(a), but its consistency is evident through acceptable predictions for all sequences.



(a) big prediction errors *(b) balanced prediction errors*

Figure 4 – Objective quality assessment metrics comparison through prediction consistency
Рис. 4 – Сравнение показателей объективности оценки качества методом согласованного прогнозирования
Слика 4 – Поређење мера објективне процене квалитета кроз конзистентност предикције

The consistency of an objective quality estimation measure can be determined by the number of points for which the prediction error is greater than the adopted threshold. The threshold is usually twice the DMOS scores standard error, i.e. the prediction error exists if:

$$\left|Perror_i\right| > 2 \cdot DMOS_i^{SE} \tag{13}$$

The number of prediction errors relative to the total number of points is called the outlier ratio, OR, and is used as a measure of the consistency of objective quality assessments. For an objective measure with a smaller OR ratio, it is said to be more consistent.

Analysis of results on the JPEG XR Image Dataset

The JPEG XR (eXtended Range) Image Dataset is designed to compare JPEG2000, JPEG and JPEG XR compression algorithms (De Simone et al, 2009). Compression of 24-bit high-resolution images (1280x1600 pixels) was considered through subjective tests carried out in four sessions. In subjective tests, 16 observers participated. The results of the subjective tests show a high degree of consistency, and can be used to compare the performance of the analyzed compression algorithms. The subjective quality evaluation was done in the laboratory of the Multimedia Signal Processing Group (MMSP) of the Ecole Politechnique Federale de Lausanne (Switzerland) academic institution (EPFL).

The dataset contain 10 original images of different content, the distribution of color and texture. Four original images were used in the observer training stage, while the remaining six original images were used in subjective tests.

In the JPEG2000 encoding, two configurations were used, which differ according to the sampling in the color channels (4:2:0 and 4:4:4). The JPEG XR compression was performed using two implementations obtained from Microsoft Corporation (MS) and Pegasus Corporation (PS). JPEG XR is a block-based compression developed to optimize image quality and compression efficiency with a small encoder/decoder complexity.

Test images were obtained using six degrees of compression – 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 bpp. In this way, 30 degraded images are obtained for each original image (5 compression algorithms x 6 degrees of compression), and the dataset contains 180 test images that are subjectively evaluated.

The observers gave subjective assessments by simultaneous observation of the original and test image, with the task of first detecting the test image, and then evaluating it. The impressions of quality were given using a continuous scale at an interval from 0 to 100. The results of subjective tests were presented through the mean subjective scores (MOS) and confidence intervals.

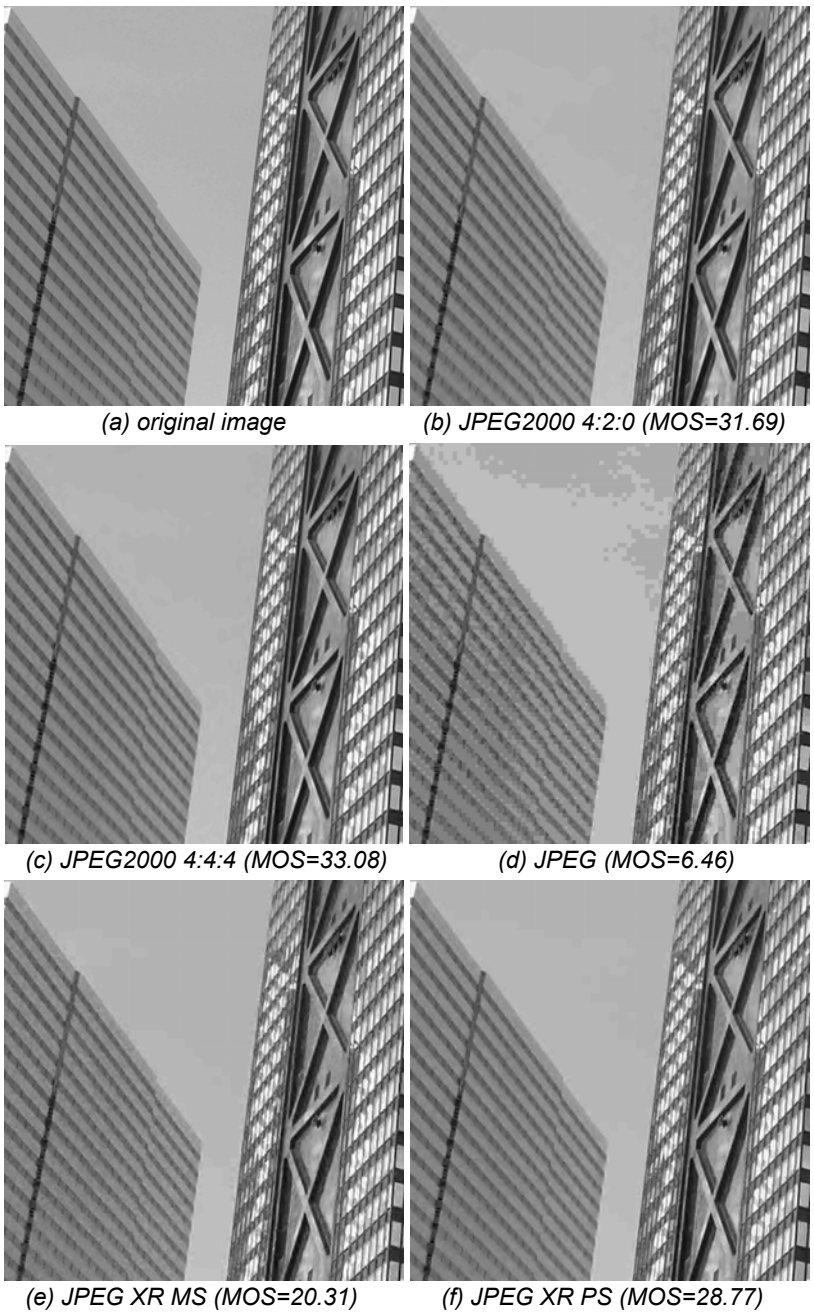
The results of the subjective tests have shown that for situations in which the pixel is represented with more than one bit (1 bpp) the quality of compressed images is approximately the same for all codecs. Also, JPEG2000 4:4:4, JPEG XR MS and JPEG XR PS compression algorithms have shown stable behavior for different content and different bit rates. On the other hand, the performance of JPEG2000 4:2:0 and JPEG compression algorithms significantly depend on the content of the image and the degree of compression (De Simone et al, 2009).

Figure 5 shows the image degradation examples of the JPEG XR Image Dataset (the original image "p10_orig.bmp" and the corresponding images with degradation at 0.25 bpp). In order to better understand the differences in quality, parts of images are shown (700x700 pixels). Subjective quality impressions are also given. The observers rated the JPEG compressed image with the smallest grade, in which the blocking effects are very noticeable. Blocking effects are less visible in the JPEG XR compression algorithms thanks to the adaptive quantization techniques used in them. The images with the JPEG2000 compression show typical artifacts created by wavelet compression – blurring and ringing. Blurring occurs due to the attenuation of high spatial frequencies of the image, while the ringing effect arises due to the quantization of high frequency coefficients in transformational coding. These effects are perceived through the spreading of edges, the loss of detail and waves around the boundaries of the regions.

The performance of objective quality assessment measures on the complete JPEG XR Image Dataset is given in Table 1. Eight objective quality assessment measures were analyzed. The performance of two measures with the best results are marked with bold font. The best matching of subjective and objective quality scores is obtained by using the MAD and VIF objective measures, while the PSNR is with the worst performance.

Table 1 – Performance of objective quality assessment metrics on the JPEG XR dataset
Таблица 1 – Эксплутационные характеристики показателей объективности оценки качества на основании JPEG XR базы
Табела 1 – Перформансе објективних мера процене квалитета на JPEG XR бази

Measure	LCC	SROCC	MAE	RMSE	OR (%)
PSNR	0.7819	0.7980	12.8737	16.5360	35.5556
UIQI	0.8621	0.8186	9.5605	13.4404	23.3333
SSIM	0.8744	0.8435	9.6144	12.8684	23.8889
MS-SSIM	0.9309	0.8930	7.0745	9.6863	14.4444
VIF	**0.9389**	**0.9130**	**6.8067**	**9.1278**	13.3333
VSNR	0.8765	0.7803	10.1065	12.7692	23.3333
MAD	**0.9466**	**0.9406**	**6.2598**	**8.5498**	**11.1111**
Q^{AB}	0.9269	0.8995	6.8809	9.9561	**11.6667**



(a) original image *(b) JPEG2000 4:2:0 (MOS=31.69)*

(c) JPEG2000 4:4:4 (MOS=33.08) *(d) JPEG (MOS=6.46)*

(e) JPEG XR MS (MOS=20.31) *(f) JPEG XR PS (MOS=28.77)*

Figure 5 – Degradation examples introduced in the JPEG XR original image
Рис. 5 – Примеры искажения исходного изображения из JPEG XR базы
Слика 5 – Примери деградација унетих у изворну слику JPEG XR базе

Figure 6 shows the scatter plots of subjective (MOS) versus MAD/VIF objective quality values on the JPEG XR Image Dataset, where each point represents a single test image (lower MAD, or higher VIF values correspond to better subjective quality). Vertical and horizontal axes represent MOS and the obtained objective estimates, respectively. There is an almost linear relationship between subjective and objective quality scores, with constant dissipation of quality scores around the interpolation curve in a complete range of quality.

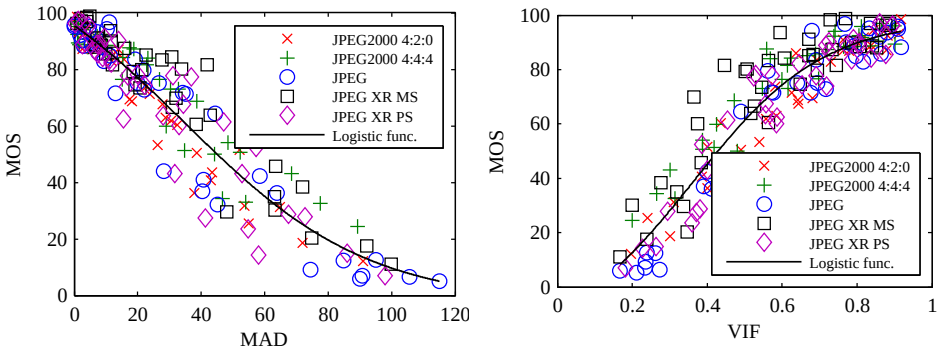


Figure 6 – Scatter plots of subjective (MOS) versus objective quality predictions on the JPEG XR Image Dataset
Рис. 6 – Диаграмма распространения субъективных (MOS) и объективных показателей на основании JPEG XR базы
Слика 6 – Дијаграми расипања субјективних (MOS) и објективних вредности квалитета на JPEG XR бази слика

Tables 2 and 3 show the performance of objective measures on image subsets within the JPEG XR Image Dataset, through the linear correlation coefficient (LCC) and the correlation of the ranks (SROCC). The performance of objective measures depends on the choice of a subset of the JPEG XR Image Dataset. Thus, the degree of agreement between subjective and VSNR objective quality scores (measured through SROCC) in subgroups ranges from 64% to 84%. The performance of other objective measures also varies from a subgroup to a subgroup, with the most stable performance of the MAD objective measure (the correlation coefficient over all subsets is greater than 93%).

Perhaps the most important aspect of the performance of an objective measure is its ability to reliably evaluate and rank various image compression systems, which can be achieved through costly and

time-long subjective tests. The subjective codec evaluation at different compression levels is available from subjective tests and can be directly compared to objective scores. Methodologically, this includes separating the image quality scores obtained by different compression types for the specific compression rate and adding them to one score that reflects this type of compression (e.g. JPEG at 0.25 bpp). This is done for subjective and objective quality scores for all types of compression, after which a correlation of the resulting (mean) quality scores is determined.

Table 2 – Linear correlation coefficient (LCC) between subjective and objective quality scores (after nonlinear regression) on the JPEG XR Image Dataset
Таблица 2 – Коэффициент линейной корреляции (LCC) субъективных и объективных показателей (после нелинейной регрессии) на основании JPEG XR базы
Табела 2 – Коефицијент линеарне корелације (LCC) субјективних и објективних скорова (након нелинеарне регресије) на JPEG XR бази слика

Measure	JPEG2000 4:2:0	JPEG2000 4:4:4	JPEG 4:2:0	JPEG XR MS 4:2:0	JPEG XR PS 4:2:0
PSNR	0.8990	0.8359	0.7876	0.7743	0.7628
UIQI	0.8564	0.8420	0.9009	0.8780	0.8770
SSIM	0.9460	0.8773	0.8956	0.8609	0.8504
MS-SSIM	**0.9706**	0.9500	0.9389	0.9167	**0.9430**
VIF	0.9683	**0.9544**	**0.9643**	**0.9247**	**0.9657**
VSNR	0.9020	0.8822	0.9247	0.9221	0.9167
MAD	**0.9748**	**0.9608**	**0.9647**	**0.9516**	0.9306
Q^{AB}	0.9483	0.9225	0.9432	0.9231	0.9266

Table 3 – Spearman rank-order correlation coefficient (SROCC) between subjective and objective quality scores on the JPEG XR Image Dataset
Таблица 3 – Ранговая корреляция (SROCC) субъективных и объективных показателей (после нелинейной регрессии) на основании JPEG XR базы
Табела 3 – Корелација рангова (SROCC) субјективних и објективних скорова на JPEG XR бази слика

Measure	JPEG2000 4:2:0	JPEG2000 4:4:4	JPEG 4:2:0	JPEG XR MS 4:2:0	JPEG XR PS 4:2:0
PSNR	0.8888	0.8719	0.7640	0.7732	0.7938
UIQI	0.8234	0.8318	0.8049	0.8505	0.8278
SSIM	0.9284	0.8578	0.8005	0.8293	0.8239
MS-SSIM	0.9539	0.8981	0.8674	0.8698	0.8963
VIF	**0.9601**	**0.9268**	**0.9107**	0.8824	**0.9305**
VSNR	0.8376	0.6435	0.8414	0.8376	0.8095
MAD	**0.9665**	**0.9624**	**0.9428**	**0.9390**	**0.9315**
Q^{AB}	0.9323	0.9225	0.8746	**0.9148**	0.9012

Figure 7 shows the mean values of the subjective and objective quality scores of different types of compression, at different degrees of compression. In this case, averaging is carried out by taking the appropriate values of the subjective, i.e. objective quality values for six visual contents (generated from six original images). The degree of agreement between subjective and objective quality scores is given in Table 4. Although Table 4 shows an extremely high degree of agreement between subjective and objective quality scores, none of the objective quality assessment measures has reached a full compliance with the rankings of subjective quality impressions. This is also evident from Figure 7, where there is an almost constant quality of all compression algorithms for bitstreams greater than 1 bpp. As the compression rate increases, subjective and objective differences become greater. Objective measures correctly detected the worst quality obtained by using JPEG compression for the degree of compression of 0.25 and 0.5 bpp. However, while the observers in these situations preferred the JPEG2000 4:4:4 compression type, according to objective quality assessment measures, priority is given to the JPEG2000 4:2:0 compression. This is due to the introduction of the quantization tables of visual significance in the JPEG2000 4:4:4 compression, which gave the viewers better visual quality but "confused" the objective quality assessment measures (made an objective difference between test images and original images). Also, from Figure 7 it can be observed that the observers between two implementations of JPEG XR compression (with different quantization techniques) favor the MS implementation for all degrees of compression. However, objective measures favor the PS implementation.

Although the results/conclusions are derived from averaging on six visual content, it can be concluded that there is still a need for the development of new and improvement of existing techniques of objective image quality assessment. Bearing in mind the results on the JPEG XR Image Dataset, the possible direction for improvement is through the implementation of different characteristics of the human visual system in objective measurements (VSNR, MAD, VIF and Q^{AB} objective measures include some of the human visual system characteristics). As the image datasets mainly contain color images (as well as the JPEG XR Image Dataset), and objective measures are mainly designed to work only in the intensity channel, another possible direction of improving the performance of objective measures is through their extension to analyze the preservation of information from the color channels.

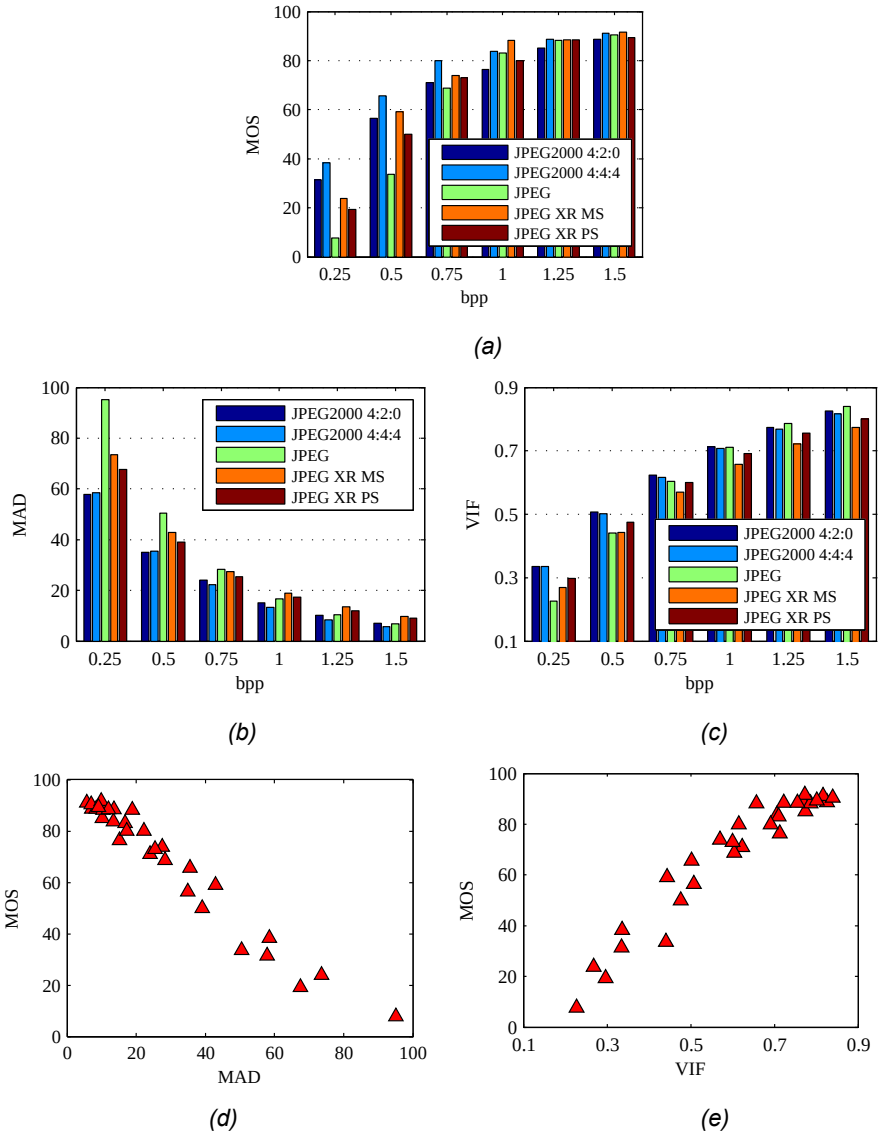


Figure 7 – (a) mean values of subjective quality scores (MOS), (b) (c) mean values of MAD and VIF objective quality scores and (d) (e) scatter plots of subjective versus objective quality predictions after averaging

Рис. 7 – (a) средние значения субъективных (MOS) показателей качества, (b) (c) средние значения MAD и VIF показателей качества и (d) (e) диаграммы распространения субъективных и объективных показателей качества после усреднения

Слика 7 – (a) средње вредности субјективних (MOS) скорова квалитета, (b) (c) средње вредности MAD и VIF скорова квалитета и (d) (e) дијаграми расипања субјективних и објективних скорова квалитета након усредњавања

Table 4 – Comparison of objective quality assessment metrics performances after averaging subjective/objective scores on the JPEG XR Image Dataset
Таблица 4 – Сравнение характеристик объективности оценки качества после усреднения субъективных/объективных показателей качества на основании JPEG XR базы
Табела 4 – Поређење перформанси објективних мера процене квалитета након усредњавања субјективних/објективних скорова квалитета на JPEG XR бази

Measure	LCC	SROCC
PSNR	0.9228	0.9138
UIQI	0.9756	0.9834
SSIM	**0.9769**	0.9670
MS-SSIM	0.9401	**0.9839**
VIF	0.9603	0.9552
VSNR	0.9462	0.8918
MAD	**0.9797**	0.9692
Q^{AB}	0.9676	**0.9879**

Analysis of the results on the CSIQ Video Dataset

The CSIQ Video Dataset (Vu & Chandler, 2014) was developed by the Oklahoma State University in order to obtain a set of data for the validation of objective video signal quality assessment measures. The dataset consists of 12 high quality reference videos and 216 degraded videos. Degradations were made by using six different types of distortion. In the subjective tests, 35 observers participated.

The video sequences in the dataset are in the raw YUV420 format, with 832x480 resolution, 10 seconds duration and a wide tempo range: 24, 25, 30, 50 and 60 fps. All types of distortion were applied to each reference video signal, in three different degrees. In this way, for each original video, there are 18 test video sequences. Four compression distortions and two distortions that occur during transmission were used:

– H.264 compression (H.264/AVC),
– HEVC/H.265 compression (HEVC),
– Motion JPEG compression (MJPEG),
– compression based on a wavelet transformation using the SNOW codec (Wavelet),
– packet losses caused by the wireless transmission of the H.264 compressed bitstreams (H.264/PLR) and
– additive white Gaussian noise (White noise).

The compression systems generally provide uniform distortion/quality in video, both spatial and temporal. The uniformity of the distortion is also characteristic for the sequences with the additive Gaussian noise. Packet losses, on the other hand, cause short-term distortions in the video in the form of flicker, both spatial and temporal.

Figure 8 shows the representative frames of the CSIQ Video Dataset test sequences, illustrating all six types of degradation used in this dataset. The figure shows that the visual effects of distortion are different. The video sequences with compression have typical compression artefacts, such as blocking effect, blurring, ringing effect and poor compensation of movement around the edges of the objects. It is also interesting to highlight the differences in the degradation of the resulting MJPEG and H.264/H.265 compressions, where the blocking effect is greatly reduced in the H.264/H.265 sequences. The errors in the packet networks are short-term and appear as sudden transitions in the video. Test sequences and frames were selected randomly, with the aim of illustrating the diversity of the contents of the original sequences and typical artefacts of their degradation. Through this set of selected sequences, the observers gave the highest quality to the H.264/AVC compressed sequence (DMOS=21.84) – Figure 8(a), and the lowest score was obtained for the H.265 (HEVC) compressed sequence (DMOS=75.79) – Figure 8(f).

Three objective quality assessment measures – Frame PSNR, Frame SSIM and VQ^{AB} were tested on the CSIQ Video Dataset, and their performance analysis is given in Table 5. Among the three measures, the best matching between subjective and objective quality scores is obtained with the VQ^{AB} objective measure. It is noted that the performance of objective measures is significantly worse than the performance of objective measures on the JPEG XR Image Dataset. A better understanding of these results can be obtained by analyzing the performance of objective measures on subsets of the CSIQ Video Dataset. The performance of objective measures in subgroups is given in Tables 6 and 7, through linear correlation (LCC) and rank-order correlation (SROCC) between subjective and objective quality scores. In addition to the three tested measures, the performance of four additional measures is also given – VQM (Pinson & Wolf, 2004), MOVIE (Seshadrinathan & Bovik, 2010), TQV (Narwaria et al, 2012) and VIS_3 (Vu & Chandler, 2014). The performance of additional measures was taken from (Vu & Chandler, 2014). Additionally, Figure 9 shows the scatter plots of subjective and objective quality scores on the CSIQ Video Dataset.

(a) H.264/AVC compression
BasketballDrive sequence (DMOS=21.84)

(b) H.264 with packet losses
Kimono sequence (DMOS=57.36)

(c) MJPEG compression
BQTerrace sequence (DMOS=66.48)

(d) wavelet compression (SNOW codec)
Timelapse sequence (DMOS=65.81)

(e) additive Gaussian noise
Keiba sequence (DMOS=42.06)

(f) HEVC compression
PartyScene sequence (DMOS=75.79)

Figure 8 – Example frames of the test sequences used in the CSIQ Video Dataset
Рис. 8 – Примеры кадров тестовых последовательностей на основании CSIQ видеобазы
Слика 8 – Репрезентативни кадрови тест секвенци CSIQ видео-базе

Table 5 – Performance comparison of various objective quality assessment metrics on the complete CSIQ Video Dataset
Таблица 5 – Сравнение характеристик объективности оценки качества на основании полной CSIQ видеобазы последовательностей
Табела 5 – Поређење перформанси објективних мера процене квалитета на комплетној CSIQ видео-бази секвенци

Measure	LCC	SROCC	MAE	RMSE	OR (%)
Frame PSNR	0.5820	0.5957	10.7469	13.5212	13.8889
Frame SSIM	0.6441	0.5769	10.1931	12.7189	12.0370
VQ^{AB}	**0.7160**	**0.6418**	**9.2039**	**11.6078**	**7.8704**

Table 6 – Linear correlation coefficient (LCC) between subjective and objective quality scores (after nonlinear regression) on the CSIQ Video subsets
Таблица 6 – Коэффициент линейной корреляции (LCC) субъективных и объективных показателей качества (после нелинейной регрессии) на основании подмножеств CSIQ видеобазы
Табела 6 – Коефицијент линеарне корелације (LCC) субјективних и објективних скорова квалитета (након нелинеарне регресије) на подскуповима CSIQ видео-базе

Measure	H.264/AVC	H.264/PLR	MJPEG	Wavelet	White noise	HEVC
Frame PSNR	0.8232	0.8236	0.6872	0.7713	**0.9494**	0.7851
Frame SSIM	0.8779	0.7666	0.8304	0.7878	**0.9446**	0.8258
VQ^{AB}	**0.9640**	0.6586	**0.9397**	**0.9000**	0.8815	**0.9589**
VQM	0.916	0.806	0.641	0.840	0.918	0.915
MOVIE	0.904	**0.882**	**0.882**	0.898	0.855	**0.937**
TQV	**0.965**	0.784	0.871	0.846	0.930	0.913
VIS_3	0.918	**0.850**	0.800	**0.908**	0.916	0.933

Table 7 – Spearman rank-order correlation coefficient (SROCC) between subjective and objective quality scores on the CSIQ Video subsets
Таблица 7 – Ранговая корреляция (SROCC) субъективных и объективных показателей качества на основании подмножеств последовательностей CSIQ видеобазы
Табела 7 – Корелација рангова (SROCC) субјективних и објективних скорова квалитета на подскуповима секвенци CSIQ видео-базе

Measure	H.264/AVC	H.264/PLR	MJPEG	Wavelet	White noise	HEVC
Frame PSNR	0.7949	0.8172	0.6530	0.7493	0.9053	0.7552
Frame SSIM	0.8582	0.7712	0.8196	0.7586	**0.9236**	0.8118
VQ^{AB}	**0.9627**	0.6792	**0.9393**	0.8937	0.8409	**0.9387**
VQM	0.919	0.801	0.647	0.874	0.884	0.906
MOVIE	0.897	**0.886**	**0.887**	**0.900**	0.843	**0.933**
TQV	**0.955**	0.842	0.870	0.831	0.908	0.902
VIS_3	0.920	**0.856**	0.789	**0.908**	**0.928**	0.917

Tables 6 and 7 show that the performance of objective quality assessment measures significantly depends on the type of degradation of the original sequences. Thus, the performance of the Frame PSNR is the worst for the MJPEG compression sequences, while the performance of the VQ^{AB} measure is the worst for a subset of sequences with packet losses (in this subset VQ^{AB} measure has the smallest agreement with subjective impressions among all other objective measures). The newly-proposed VQ^{AB} measure has very good performance for a subsets of sequences with compression, and slightly lower performance for the sequences with additive noise. This measure was tested on the H.265 compression sequences for the first time, where the best performance among the analyzed measures was achieved.

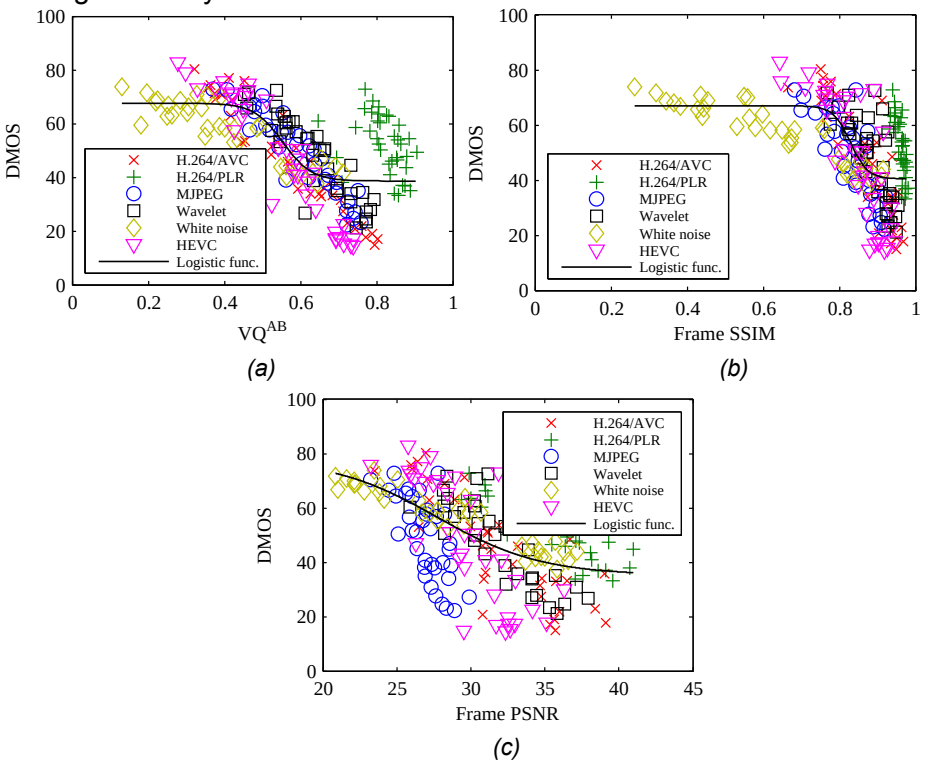


Figure 9 – Scatter plots of subjective (DMOS) versus objective quality predictions on the CSIQ Video Dataset: (a) VQ^{AB}, (b) Frame SSIM and (c) Frame PSNR

Рис. 9 – Диаграммы распространения субъективных (DMOS) и объективных показателей качества на основании CSIQ видеобазы последовательностей: (a) VQ^{AB}, (b) Frame SSIM и (c) Frame PSNR

Слика 9 – Дијаграми расипања субјективних (DMOS) и објективних вредности квалитета на CSIQ видео-бази секвенци: (a) VQ^{AB}, (b) Frame SSIM и (c) Frame PSNR

The scatter plot of the subjective and VQ^{AB} objective quality scores, shown in Figure 9(a), confirms that the bad VQ^{AB} measure results at the global level (on a dataset) originate from the worse results for a subset of sequences with packet losses, in which the objective values VQ^{AB} deviate from the trend of other scores. Also, with the frame SSIM objective measure, the deviation trend of the sequences with the packet losses compared to the sequences with compression is confirmed, and additionally there is the deviation trend of the sequences with additive Gaussian noise – Figure 9(b). With the Frame PSNR objective measure, it is possible to talk about an isotropic cloud in the space of subjective-objective quality scores – Figure 9(c).

Conclusion

This paper analyzed a possibility of using the full-reference objective quality assessment measures of visual signals – images and videos. The analysis was conducted on the two publicly available datasets with subjective quality impressions, with a representative number of visual signals (180 test images and 216 test sequences). These datasets contain the subsets of images/videos created by the characteristic degradations typical for processing and transmission of visual signals.

An analysis of the objective measures performance at the level of subsets of the signals inside the datasets has shown that the performance of objective measures depends on the choice of a subset, i.e. type of degradation. The difference between the performance is more pronounced on the video dataset due to significant visual differences inside the test sequences. Therefore, it can be said that there is no objective measure of quality assessment that will be useful in all situations – for different types of degradation, for different degrees of degradation, for various applications, etc. (universal measure).

It has been shown that the objective measures applied on the subsets can reach a high degree of agreement with the results of subjective tests. The maximum level of agreement between objective and subjective quality scores (measured through linear correlation) on the analyzed image subsets is 97.48% – MAD objective measure on the JPEG2000 4:2:0 subset. The same measure on complete image dataset also provided the maximum agreement with subjective quality scores – LCC=94.66%.

Within the video subsets with compression, the best results were achieved by the spatial and temporal gradient-based information

preservation measure, VQ^{AB}. At four subsets with compression, the degree of agreement between VQ^{AB} and the subjective quality scores ranges from LCC=90% to LCC=96.40%. The MOVIE objective measure provided the best results on the subset of sequences with the packet losses (LCC=88.20%), while the Frame PSNR measure is more suitable for quality evaluation of video sequences with the additive Gaussian noise (LCC=94.94%).

Objective quality evaluation is a very complex problem, but it is possible to solve it and reach high performance using approaches that have been proposed for image and video quality evaluation. Improvement of objective quality assessment at the global level is possible to be achieved by a fusion of objective quality assessment measures suitable for different types of degradation of the original signal.

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АНАЛИЗ ХАРАКТЕРИСТИК ОБЪЕКТИВНЫХ ПОКАЗАТЕЛЕЙ ОЦЕНКИ КАЧЕСТВА ФОТОГРАФИЙ И ВИДЕО НА ОСНОВАНИИ БАЗЫ ДАННЫХ

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Резюме:

В данной статье представлены рабочие характеристики объективных показателей оценки качества фотографий и видео, на основании двух соответствующих баз открытого доступа, с приведенными субъективными оценками качества. Наряду с анализом характеристик на глобальном уровне – полных баз, в данной работе представлен анализ и характеристики показателей подмножеств сигналов в их рамках. База фотографий состоит из пяти подмножеств, сформированных благодаря применению различных типов JPEG сжатия, в то время как видео последовательности содержат шесть подмножеств – четыре из которых образованы сжатием исходных последовательностей, а два подмножества представлены с искажениями, характерными для передачи видеосигналов. При определении успешности сравнения объективных и субъективных показателей качества применялись методы, утвержденные Международным телекоммуникационным содружеством (коэффициент корреляции, ранговая корреляция, средняя абсолютная ошибка и среднеквадратическое отклонение прогнозирования). В работе показано, что объективные показатели подмножеств сигналов из базы данных могут в большой степени совпадать с результатами субъективных тестов. Характеристики объективных показателей зависят от выбора подмножеств – типа искажения, и соответственно значительно влияют на характеристики на глобальном уровне, то есть, на уровне полной базы. Разница характеристик в большей мере выражена в видео последовательностях, вследствие значительных зрительных разниц в последовательностях, образовавшихся в процессе сжатия, потери пакетов и воздействия гауссовского шума. В заключение можно сказать, что на данный момент не существует единых универсальных объективных показателей, применяемых при различных типах искажений сигналов, и при различной степени искажений, и для различного назначения.

Ключевые слова: JPEG сжатие, H.264 и H.265 видеосжатие, объективная оценка качества фотографий и видео.

АНАЛИЗА ПЕРФОРМАНСИ ОБЈЕКТИВНИХ МЕРА ПРОЦЕНЕ КВАЛИТЕТА СЛИКА И ВИДЕА СА ПОТПУНИМ РЕФЕРЕНЦИРАЊЕМ

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Сажетак:

У раду су представљене перформансе објективних мера процене квалитета слика и видеа на две јавно доступне базе са субјективним импресијама квалитета. Поред анализе перформанси на глобалном плану – нивоу комплетних база, у раду су анализиране и перформансе мера на подскуповима сигнала унутар њих. База слика садржи пет подскупова насталих применом различитих типова JPEG компресије, док база видео- секвенци садржи шест подскупова – четири настала компресијом изворних секвенци и два подскупа са деградацијама карактеристичним за пренос видео-сигнала. За одређивање успешности објективних мера, тј. поређење субјективних и објективних скорова квалитета, коришћене су мере које је прихватио ITU (коефицијент корелације, корелација рангова, средња апсолутна грешка, средња квадратна грешка и стандардна девијација процена). Показано је да објективне мере на подскуповима сигнала из база могу достићи висок степен слагања са резултатима субјективних тестова. Перформансе објективних мера зависе од типа деградације, што знатно утиче на перформансе на нивоу комплетне базе. Разлика у перформансама је израженија на бази видео-секвенци због знатних визуелних разлика у секвенцама насталим компресијом, пакетским губицима и додавањем Гаусовог шума. Због тога се може рећи да универзална објективна мера, тј. мера која ће бити употребљива код различитих типова деградације сигнала, за различите степене деградације, за различите примене и сл., тренутно не постоји.

Кључне речи: JPEG компресија, H.264 и H.265 видео-компресије, објективна процена квалитета слике и видеа.

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ASPECTS OF REDUCING THE EFFECTS OF VEHICLE-BORNE IMPROVISED EXPLOSIVE DEVICES

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Abstract:

The paper deals with tactical and technical contexts of attacks by vehicle-borne improvised explosive devices (VBIEDs). This type of attack is usually conducted aiming at so-called "soft targets", i.e. people who are at a certain moment in the area of a planned attack. The objectives of these attacks can be diverse. The common denominator of attacks is usually to create damaging consequences, especially a large number of dead and injured people. This paper did not focus on the elimination of these attacks, but rather on the reduction of their consequences. Since their assumption is that a complete prevention of these attacks is impossible, the authors formulated some possible solutions, (regarding the technical parameters of the means in particular) to mitigate the consequences of attacks in different ways. Some measures and technical means to mitigate the effects on people are easier to implement while some are more complex and costly.

Key words: vehicle-borne improvised explosive device, barrier, terrorist, protection, explosion.

Introduction

After seizing Mosul, the Iraqi police confiscated cars which the militants of the so-called Islamic state had converted to armored vehicles used for suicide attacks (see Figure 1). These were modified, mostly armored cars, loaded with large amounts of explosives which could better overcome the defensive fire of Iraqi or Kurdish units - unless hit by

an anti-tank system. These cars would get to the immediate vicinity of the target where the driver would initiate an explosion. (Zahraničí et al, 2017)

Figure 1 – Seized cars ready for suicide attacks
Рис. 1 – Изъятые автомобили террористов-смертников
Слика 1 – Заплењени аутомобили намењени самоубилачким нападима

The explosion of a truck in the densely populated part of the Somali metropolis of Mogadishu near the Foreign Office had a huge impact. The explosion was so strong that several buildings collapsed, cars burned, and the victims' bodies were torn down on the streets (see Figure 2). The number of people died rose to 276, while approximately 300 people were injured. (ČTK, 2017)

Figure 2 – Consequences of the VBIED attack in Mogadishu
Рис. 2 – Последствия подрыва автомобиля в Могадишо
Слика 2 – Последице напада импровизованом експлозивном направом у возилу у Могадишу

The use of a vehicle-borne improvised explosive device (VBIED) is a very common way of terrorist attacks, not only in Muslim countries. Terrorists are using VBIEDs in many other cities, including European ones. It is necessary to continuously address the possibilities of protection and defense against VBIEDs and to increase the resistance of potential targets against such attacks. Experience shows that the current methods of fighting VBIEDs, particularly in asymmetric operations and terrorist attacks, can be considered obsolete, inadequate and ineffective. Especially for this reason, this means is increasingly used as a surprise and dangerous enemy weapon. The ordinary ways of conducting battle drills and tactical procedures, the use of small arms, barricades, and possibly anti-tank weapons cannot stop VBIEDs in time. It can be assumed that VBIEDs are and will be used in the future (as evidenced by current incidents in Afghanistan, Syria, terrorist attacks in France, Germany, etc.). Preparing and implementing measures against VBIEDs is essential, especially for the protection of stationary positions, checkpoints, important buildings, command posts, and all areas of deployment. It could be assumed that not only the Czech Army would face problems of missions focused on the protection of the above mentioned potential targets. Moreover, this is already happening not only within the operations but also in the Czech Republic and this situation would most probably be more frequent.

Tactical aspects of countering VBIEDs

The basic measure against any negative activity is to eliminate the causes of this activity. However, the cause for using a variety of attacks in an unstable environment is so diverse and for a civilized world illogical and atrocious. Fighting the causes of VBIED attacks is more or less impossible. Therefore, it is essential to continuously and intensively focus on measures to reduce the risk of VBIED attacks and to reduce the consequences of their use. (Headquarters, Department of the Army, 2013)

Enemies have a huge advantage when using VBIEDs. They can choose the place and time of use, and in most cases the method of use. In particular, the protection of so-called "soft targets", particularly civilians in populated areas, is very complex. VBIED attacks are far from being directed against "military targets" in the form of bases, military and police buildings and stations, or against embassies and other government institutions. Very frequent are attacks on marketplaces, church buildings, schools, squares, etc.

The ideal situation would be to prevent attacks completely by taking such measures which would lead to their elimination. But this is hardly ever possible. It is therefore necessary to monitor and evaluate the following in particular:

- the enemy has a reason to attack in the territory; the aim may be to demonstrate its presence, to induce instability and fear, to cause human losses and damage to property of the "opposing party";
- the enemy has the means to perform the attack - human, material and financial;
- territories which are "suitable objects" to attack.

For example, if the monitoring of suspects fails to detect and eventually thwart the attack, the response to a VBIED attack is almost always very difficult. There are objects in unstable zones around which various detectors and technical obstacles, including roadblocks, can be placed in advance. They are government buildings, barracks and police and other stations, i.e. institutions against which the enemy acts actively. These long lasting measures are almost impossible for countless other objects - churches, mosques, marketplaces, shopping centers, squares, etc. At least these measures could be applied on different occasions, such as during religious holidays where there is a significant concentration of people.

So what is the point of focusing on the efforts to fight VBIEDs? From the point of view of barriers, as a defensive measure against VBIEDs and their effects, a number of requirements can be traced in tactical terms:

- if vehicles loaded with explosives are driven by humans, it would be possible to stop or kill the vehicle driver, for example by dimensioning and shaping the barricade. However, this effect would have to occur at such a distance from the "soft targets" to ensure that, even after a controlled or uncontrolled detonation of the explosive, it would not endanger persons and objects in the impact area. Moreover, it is a fact that a number of VBIEDs are driven by suicide bombers who count on their own death.
- as in the previous case (VBIEDs driven by humans), it is a similar case when the vehicle is remote-controlled from its starting position with such a technical device which allows the operator to steer the vehicle, and in the final phase, to initiate explosion. Alternatively, the driver of a VBIED leaves the car at a safe distance.
- the basic requirement therefore appears to be a counter-attack on the vehicle, stopping the vehicle at a safe distance from the target.

It should be noticed that such a barrier would be necessary to comply with the provisions of the Ottawa Agreement called the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction. SROV: 5. (ICRC, 1997)

Devices diminishing the consequences of VBIED explosions

The most common threat to soft targets is represented by an explosion of charge plus a fragmentation charge, regardless of whether it is an improvised device filled only with nails or ball bearings or an industrially produced carbon steel insert. The size of the impact zone with the 100% threat of the death of an uncovered person due to fragmentation can be expressed by the formula:

$$R(f) = 109.62 \times Q0.164 \quad (1)$$

where

R(f) - Hazardous Fragmentation Distance Range (m),

Q - trinitrotoluene equivalent of a detonating explosive (kg).

Thus, if a tritol charge equivalent to 10 kg is considered (insurgents usually use explosives with less efficiency, but in a much larger amount), it forms a circular zone of 159m in radius from the explosion point of the charge. The surface threat is 79 382m^2 according to the calculation.

If such a charge did not contain a complement to the fragmentation (in the primary and secondary scale) of the material, the lethal effect would only be related to the pressure effect of the exploding ammunition, i.e. by the following formula:

$$r = K(m) \cdot \sqrt[3]{Q}\,; \quad (2)$$

where

r - the radius from the exploding charge determined by the critical factor *K(m)*,

K(m) - the critical factor for human survival being 10, for civilian buildings the critical factor of destruction is set at 70,

Q - trinitrotoluene equivalent to a detonating explosive in kg.

The uncovered person therefore has a theoretical chance of survival at a distance of 21 meters. The overhead impact of the pressurized charge is 1.384m^2.

From the above mentioned, it is clear that the threat zone caused by fragmentation material represents an area multiplied by almost 57 times.

This clearly indicates the requirement for a barrier to absorb or repel fragmentation material at least that directed towards a potential target. Unfortunately, most of the material used to make barriers is not only unable to absorb the high-kinetic energy of fragments, but, on the contrary, it itself becomes a secondary fragmentation material. Due to the size of a vulnerable area, it is absolutely necessary to fulfill this requirement so that the barrier has at least the basic ability to neutralize enemy VBIEDs.

Figure 3 – Zones of fragment effects after explosion
Рис. 3 – Зоны осколочного действия взрыва
Слика 3 – Зоне парчадног дејства експлозије

A very effective device of reducing the effects of VBIEDs may be a barrier that should (and could) perform the following functions (see Figure 3):

- discourage attackers from their intention only by its presence,
- slow down or stop a vehicle with an explosive at such a distance from a soft target that the loss of life is minimized or completely eliminated,
- direct the attacking vehicle into a zone where there are no major consequences after an explosion,
- at least partially absorb explosion fragments directed towards a potential target and thus prevent the death toll from increasing.

The subsequent passages of the article will focus on a technical means to reduce the consequences of VBIEDs - on barriers.

Basic requirements for devices diminishing consequences of VBIEDs

There are a number of technical requirements for such devices. It is not possible to compile a "ranking" of requirements for these means in terms of materiality - from the most significant to the least significant. This applies to all technical means, including roadblocks. However, possible requirements include:

- the goals which barriers have to achieve. These objectives may be:
  - deterring attackers from their intention to use VBIEDs,
  - slowing or stopping attacking vehicles,
  - directing attacks (including fragments after the explosion) into less dangerous directions and space;
  - mobility of the barrier. This is related in particular to the dimensions of the barricade, its weight, profile and shaping, the number of people to manipulate it, the need for other manipulation techniques, or a battle order. The outcomes from learning in this stage of training include also the issuing of battle order on the terrain.

Mechanization and automation of the barrier could reach such a degree that the barrier could be autonomously mobile, equipped with a "propeller" to move, even with environmental sensors (including the VBIED potential attack evaluation) and automatic shifting to the "vulnerable direction". However, this type of device would be very costly, and would significantly reduce its deployment.

- directing the effect of the attack into a less dangerous area;
- the strength of the location of the barrier at the specified location (adhesion conditions in relation to the lower part of the barrier and the ground on which the barrier is deployed);
- other aspects of the barrier, such as:
  - demonstration of force by a transparent barrier or hidden placement of the barrier,
  - minimizing the movement of persons and techniques unrelated to any attack in the area of the barrier location,
  - aesthetic aspect, and others.

Barrier manipulation

Mobility of the barrier is an important condition. The ease, simplicity, and speed of barrier installing on the required space need to be taken

into the consideration as well as picking it up after a VBIED attack and/or relocating it to another vulnerable site.

Only one person (for example, with portable road barrier spike systems) can handle a barrier or there can be up to several people with transport and handling equipment (e.g. heavy concrete segments and prefabricates; see Figure 4).

Figure 4 – Application of a portable road barrier spike system and the assembly of prefabricated roadblocks
Рис. 4 – Монтаж временного препятствия с шипами и сборка дорожного барьера
Слика 4 – Постављање привремене препреке са шиљцима и састављање блокова за запречавање пута

Angle of the VBIED direction towards a barrier

It is also advisable to influence the VBIED attack angle on the barrier. In the perpendicular direction, the result is that the vehicle force acts in the direction of the vehicle's impact. By altering the attack angle, the force is distributed and the resultant force is smaller than the force in the direction of the planned attack on the target.

The angle of attack on the barrier can be predetermined even when installing the barrier - by directing it to the desired direction of the vehicle (resultant forces). However, such a barrier direction is quite obvious to potential attackers, so terrorists can adapt the way and direction of the attack. The incospicuous redirection of the attacking vehicle can be achieved by varying the fixed parts of the barrier in relation to the support on which the barrier is installed (see Figure 5).

The non-clamped side of the barrier is released by the impact of the vehicle and rotates around the center represented by the fixed anchorage pin. The attacking vehicle is then directed where desired. The speed of rotation of the barrier in an unoccupied position can be influenced by the adhesion conditions in relation to the lower part of the barrier and the ground on which the barrier is installed (see the next passage). The desired heading of the resulting movement of the VBIED

can also be achieved by a subsequent "stopping point" that stops the rotation of the barrier.

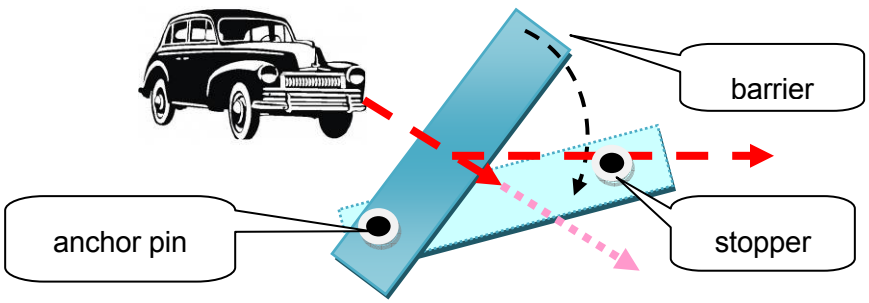

Figure 5 – Anchoring only one side of the roadblock to the base
Рис. 5 – Одностороннее крепление блока барьера к основанию
Слика 5 – Причвршћивање само једне стране блока баријере за основу

Figure 6 – Anchoring pins of different material
Рис. 6 – Крепежные детали из разных материалов
Слика 6 – Елементи за причвршћивање од различитих материјала

The desired heading of the VBIED in the case of the use of "unequal quality" anchoring of the barrier to the support (anchor pins / pins of different material) can be achieved by anchoring the "shear pin", its dimensions (diameter, cross-section) and material quality (see Figure 6).

Adhesion conditions

The term "adhesion conditions" can be used to describe the stability of the fixture of the barrier with the ground against VBIEDs. The stability with which the barrier is fixed will certainly influence the weight of the barrier and the area of the lower part of the barrier that is attached to the ground (road surface, etc.). In general, the following could be considered:

- unanchored barricades,
- anchored barriers,
- weight down roadblocks (modular vehicle barriers).

Unanchored barricades

If the above two significant barrier attributes (weight and contact area) are exceeded, the stability of the position of the barrier at a given

location will interfere with the interaction of the bottom area of the barrier and the nature of the "pad" on which the barrier will be installed. Both of these surfaces (barrier and pad) can have different structures, e.g.:

- flat, slightly roughened area (in the case of a roadblock such as metal or concrete, in the case of asphalt pavement, paved or other road),
- differently shaped surfaces (so as to fit the lower part of the barrier and the shape of the pad).

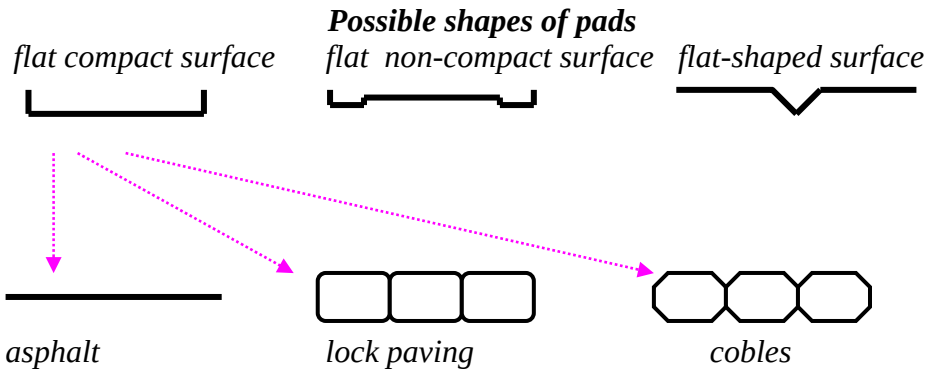

Figure 7 – Interaction of the interlocking surfaces of the barrier and pads
Рис. 7 – Взаимодействие нижней части барьера с основанием
Слика 7 – Интеракција доњих површина баријере и основе

In Figure 7, the arrows show the interaction of the lower part of the barrier with the surface of the pad. It is also possible to express the relationships of all surfaces (the lower parts of the barrier and the surface of the pads).

Anchored barriers

From the point of view of fulfilling the functions of the roadblock, especially in the sense of stopping VBIEDs, "somehow" anchored barriers appear to be more appropriate. The anchoring may relate to individual sections of the barrier field or to a series of individual barriers which are interconnected, for example, by chains, steel ropes, etc. In the case of anchoring a coupled barrier, it is necessary to bear in mind that after the vehicle has come to any part of the anchor of the barrier field, the whole field will somehow "behave", i.e. it will tend to shift fragments across the barrier field. This phase could shift some fragments into unwanted areas where casualties can be inflicted or objects damaged or destroyed.

Anchoring can be done to any fixed object in the placement of the barrier location, or as a separate function of the barrier itself. A rigid

anchorage of the barrier to the base can be achieved by pins which "immerse" into the prepared (drilled) holes in the base (for communication, see Figure 8).

Figure 8 – Anchored barrier
Рис. 8 – Анкерный барьер
Слика 8 – Фиксна баријера

Weight down roadblocks

As a possibility of combining both concepts, the barrier using the load of the attacking vehicle appears to be an effective solution. Before the vehicle starts pushing this barrier, it loads it by its own weight. Thus, the adhesion increases and the weight as well. Such a barrier is, contrary to the anchor, easy to handle and can provide an adequate degree of protection regardless of its low weight (see Figure 9).

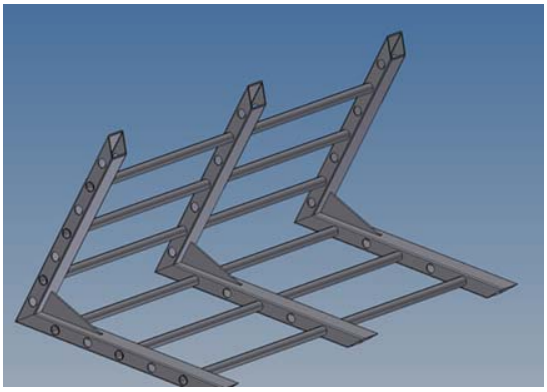

Figure 9 – Possible shaping of a barrier
Рис. 9 – Один из видов барьера
Слика 9 – Један од облика баријере

Other aspects of barriers

It is certainly possible to consider other aspects of barriers and requirements for them. Such aspects can include:

- acquisition costs for the whole process - minimal development, verification tests and production;
- costs of installing and reinstalling barriers;
- aesthetics. Particularly in historical or specific, architecturally built areas, "concrete monsters" may appear visually unpleasant. This requirement, of course, cannot have a major effect on the functionality of barriers.
- other requirements and aspects.

Different parts of built-up areas contain objects designed for purposes other than stopping VBIEDs. For example, there may be different decorative posts (sometimes connected by forged chains) around fountains, columns, etc., racks with waste containers, so-called "pins" (pillars connected to the water lines for refreshing passers-by), etc. Barriers could be constructed even as "imitations" of the above-mentioned objects and installed in case of danger to the area as an addition to the existing objects (see Figure 10). Of course, the stability requirements would be considerably higher than for common decorative posts, litter bins, etc. Instead of being anchored in the area, stands could be used on sports grounds, volleyball playgrounds, in gymnasiums, etc. In gym floors, there are holes in which the sports racks are inserted and fastened. If posts are not needed, they are removed from gym floors and the holes for them are covered by simple caps.

Such "strengthening" of the already existing objects in the area (creating a barrier field in width and depth) would cause a so-called tandem effect for VBIEDs. For example, the first row of barriers would slow the attacking vehicle while the other rows would lead to it being stopped or headed into safe spaces (including, for example, zones with walls to eliminate or reroute fragments after an explosion).

Figure 10 – Anchoring a wastebasket in a square – a discreet barrier
Рис. 10 – Крепеж урны для мусора в сквере – неброское препятствие
Слика 10 – Причвршћене корпе за отпатке на тргу – неупадљива препрека

Conclusion

VBIEDs are nowadays considered to be an effective weapon of asymmetric warfare. Preventing VBIED attacks is essential in order to diminish losses in human lives as well as material losses. The article shows some possibilities which could lead to this goal, especially the last mention barrier type called „weight down roadblock“. This type of barriers is easy to move and it uses the weight of a VBIED itself to stop the vehicle.

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АСПЕКТЫ СНИЖЕНИЯ ПОСЛЕДСТВИЙ ПОДРЫВОВ АВТОМОБИЛЕЙ, СОВЕРШЕННЫХ С ПОМОЩЬЮ САМОДЕЛЬНЫХ ВЗРЫВНЫХ УСТРОЙСТВ

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ОБЛАСТЬ: военные науки
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В данной статье представлены тактические и технические аспекты подрывов автомобилей, совершенных с помощью самодельных взрывных устройств. Характерной чертой подобных нападений является то, что они обычно применяются против „мягкой цели“, то есть людей, находящихся в зоне спланированного теракта в момент его осуществления. Цели нападения могут быть разными, но общим знаменателем является желание нанести как можно больший ущерб, особенно в виде большого количества жертв. В данной работе не затронуты вопросы искоренения терактов в целом, акцент делается на снижение негативных последствий после самого нападения. Исходя из предположения, что теракты подобного вида невозможно полностью извести, авторы данной статьи представляют решения по снижению негативных последствий для населения, посвящая особое внимание техническим параметрам различных стредств. Некоторые из предлагаемых мер отличаются простотой применения, в то время как более сложные из них требуют и значительных финансовых вложений.

Ключевые слова: подрыв автомобиля самодельным взрывным устройством, барьер, террористы, оборона, взрыв.

АСПЕКТИ УМАЊИВАЊА ЕФЕКАТА НАПАДА ИМПРОВИЗОВАНОМ ЕКСПЛОЗИВНОМ НАПРАВОМ У ВОЗИЛУ

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Сажетак:

У раду су разматрани тактички и технички аспекти напада помоћу импровизоване експлозивне направе у возилу (vehicle-borne improvised explosive device – VBIED). Овакви напади обично су усмерени против такозваних меких циљева, односно људи који се нађу у зони планираног терористичког акта у тренутку напада. Сврхе ових напада могу бити различите, а заједничко им је изазивање што већих последица, превасходно што већег броја људских жртава. Пошто се у раду полази од претпоставке да је немогуће у потпуности елиминисати нападе ове врсте, формулисана су могућа решења ради ублажавања њихових ефеката на људе, с посебним освртом на техничке параметре различитих средстава. Примена појединих мера и средстава је једноставнија, док нека сложенија средства захтевају знатније финансијске ресурсе.

Кључне речи: импровизована експлозивна направа у возилу, баријера, терористи, заштита, експлозија.

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PATENT OVERVIEW: DEVICE FOR FINGERPRINT IDENTITY GUARANTEE

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Abstract:

The patent device named "Device for biometric identification of maternity" is a dual fingerprint scanner that provides data of mother and baby fingerprints at the very moment of birth and further guarantees the maternity of a newborn baby by generating a unique ID reference and encrypting that data with the highest level of protection. For the first time, we enrolled qualitative research that proves a baby's identity at the very moment of birth based on the fingerprint minutiae. No one has done it until today! The realised technical solution scans, processes, stores, saves and encrypts personal data with one main purpose - to prove maternity of every newborn baby with 100% accuracy. By fingerprint scanning of both the mother and the baby's fingerprints simultaneously at the very moment of birth, ID is generated and stored. This allays potential fear of babies being replaced. Every identity is guaranteed. By encrypting this data, the whole process is raised to the highest security and confidentiality levels in maternity wards worldwide. In each case, the fear that almost every mother has in this period is allayed as well as the question: "Is this my baby?"

Keywords: biometrics, patent, fingerprint, identity, babies, maternity wards, algorithm.

Introduction

We can see various definitions of *Algorithm*[1] in different science fields and disciplines. As for a computer science algorithm, it is a step-by-

[1] *Algorithm* - stems from the name of a Latin translation of a book written by al-Khwarizmi, a Persian (Oaks, nd) mathematician, astronomer and geographer. Al-Khwarizmi wrote a

step set of commands, instructions and operations to be performed. The purpose of algorithms is to provide calculation, automatisation of actions and data processing.

An algorithm is a set of steps as explained. One has to learn how to make algorithms using pseudo-codes or real codes and that is why people who develop algorithms need to have programming knowledge. In order to optimize algorithms, the knowledge of mathematics is necessary, as well. Good news is that learning about algorithms can be as simple as you want it to be, and as easy as you are able to aquire (IEEE, 2018).

This Patent Device – Device for Biometric Identification of Maternity – the algorithm as a software part has been developed in an effort to solve a huge human problem and prevent possible undesirable events from happening, e. g. stealing or replacing the identity of newborn babies; it also allays the fear that all expecting mothers have, and makes that bright moment of bringing new life to this world easier and more relaxed to gynecologists, midwives and nurses.

This work presents all the functions that the device possesses. The figures show how the model is made, what the cross-section looks like, how it is constructed and implemented, what possible advantages and benefits are and the essence of a qualitative leap in health care systems, particularly in maternity wards worldwide. There is a possible wireless communication and different storage types. Fingerprints are scanned from a mother and a baby at the moment of birth, simultaneously, and the unique ID reference is generated, which will be encrypted and will guarantee maternity of every newborn baby with the probability of 100%.

This invention belongs to the field of applied information technology. The biometric system, i.e. the biometric device consists of a dual fingerprint scanner which scans two fingers of two different persons at the same time (one of a mother and one of a baby), and subsequently generates a unique Identification (ID^2) reference for each “mother-baby relationship” for every newborn baby in maternity wards (Lalovic et al, 2017).

According to the International classification of patents, this patent is classified with symbol G06F21/00 which belongs to biometry systems – devices for fingerprint scanners.

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book titled „*On the Calculation with Hindu Numerals*“ in about 825 AD, and was responsible for spreading the Indian system of numeration througout Europe.

[2] *ID – IDENTITY* (unique data for each fingerprint scanning process)

Material and methods

Technical issue

The technical issue which needs to be set, examined and solved with this algorithm of the Patent Device consists of three partial tasks as follows:

- Writing one optimal algorithm for emulating and executing every function that the device for biometric identification of maternity possesses. In future, the realization will give recommendations for transferring that pseudo-code into an accurate programming language, probably the C programming language, since it has to be structural and low level, not an object-oriented (OO) and high level programming language as JAVA or C++ are . It is very important that the algorithm realization is applicable for each existing platform of both hardware and software, and the C programming language is a proper choice for that (Lalovic et al, 2017).

- Modeling and building solution of the device - dual biometric fingerprint scanner for scanning fingers of the mother and the baby, right at the moment of birth, during the first baby's moments in this world. The device will be slightly different from today's existing classical fingerprint scanners, since it would have two fields for scanning fingers of two different persons (the mother and the baby). The two scanning fields can be physically divided during the process of device construction or they can be mapped by software definition on the scanning surface which existing scanners possess (NIST, 2014).

- It will be an effective device since it is highly practical and easy to work with, easy to control and manipulate. The device maintenance is easy, classical and similar to that of other fingerprint scanners. Besides its common purpose of scanning two fingers of different persons at the same time, it will provide a unique ID reference (similar to a Primary Key) which will be the basis for every scanned mother-baby pair (Lalović et al, 2016, pp.65-81), (Lalović et al, 2015, pp.293-302), (Oaks, nd).

Experiment

Modern well-known technical devices for scanning fingerprints use different algorithms and methods in their process of work to determine the identity of individuals.

The search through the National Base of Patents for similar devices, notably dual biometric scanners with their own power supply, did not give any results; namely, none of the Patents consider this idea and solution

in this way, with a dual biometric scanner (http://www.zis.gov.rs/pocetna.1.html, 2017), (http://www.epo.org/index.html, 2017).

The existing devices scan one or more fingers of **one** person only (we are emphasizing the fact that it is only one person) and there are no fingerprint scanners which scan fingers of two different persons at the same time using one device, especially not devices which generate a unique ID reference during scanning which will be connected with the record of fingerprint scanned and stored data (http://www.epo.org/index.html, 2017).

This scanner contains two fields for scanning one or more fingers of two different persons (the mother and the baby) and momentarily generates a unique ID reference which will be a guarantee for that record of fingerprints.

There is Patent confirmation П-2009/0253, International classification G 07 D7/12 (2008.04) for a device named “Hand mobile device for checking travel and personal documents, reading biometric data and face recognition of persons which carry those documents” which has only one function of scanning a fingerprint of one person at one moment (http://www.zis.gov.rs/pocetna.1.html, 2017).

Milestones of innovation

The main goals that we have accomplished are these:

The device can generate a unique ID reference and 100% guarantees the identity of each newborn baby and a bound record for the baby’s mother.

The device functions as a dual biometric scanner with two fields for scanning fingerprints of the mother and the baby or two babies (one after another) if they are twins, or three or more, simultaneously, at the very moment of birth. Precisely, one field is larger with the classic scan resolution of 500 dpi and the second filed is physically smaller but with a larger scan resolution – of minimum 1000 dpi so it can make a scan of a baby fingerprint that is very small (http://neurotechnology.com, 2017), (Chungkeun et al, 2012, 1253-1254).

It is a scientific fact in biometry that a fingerprint is formed during the prenatal period for every fetus and stays constant in the shape of minutiae during the whole life (Jain et al, 2008), (Keith et al, 2014), (NIST, 2014).

Many researches have done fingerprints minutia of a fetus; ultra waves and biometry scanning of the minutiae on each finger are formed by the end of the 7^{th} month of pregnancy. It is important to say that

babies born before the regular time of birth, during the 8th month and especially by the end of the 7th month of pregnancy have fingerprints on each finger as well as on each toe already formed, the fact which can be used to guarantee identity. (Jain et al, 2008), (Grzybowski & Pietrzak, 2015, pp.117-121), (Gutiérrez-Redomero et al, 2014, pp.199-207).

This scientific fact is essential for this device, this research and the realization or the Project that will provide a qualitative leap in gynecology, midwifery and nursing in every maternity ward all over the world.

In fingerprints, ridges and valleys are the only biometry that is formed prenatally and can be used for the purpose for determining baby's ID. The idea for the Patent Innovation is based on this scientific fact confirmed by both biometry systems and computer science and gynecology – midwifery as a branch of health care protection systems (Jain et al, 2008).

Here we cannot use other biometrics such as iris recognition because it is unstable. Why? Until the 4th year in humans, the pigmentation in children's eye is changing and becoming different. The shape and color both change which makes it impossible to be used for this purpose.

Other body features such as head, hand and body shape and size are rapidly changing since they normally grow up so it is obvious why they cannot be used. That is why this amazing scientific fact that a fetus's fingerprint is formed prenatally by the end of the 7th month in a uterus of a pregnant mother and stays constant with the same construction of minutiae is so important (Jain et al, 2008), (Dahlen& Caplice, 2014, pp.266-270).

If the procedure for the device is followed, the possibility of making any mistakes is excluded. Now the device and the system guarantee baby's identity 100% in each case of a newborn baby.

This is how we prevent any possible theft or replacement of the baby's identity, which has unfortunately probably happened at some places and parts of the World, especially in South-East Europe, in the Balkans, in the countries of former Yugoslavia. Now the device will guarantee, prove and serve as evidence of maternity for newborn babies.

Here, the authors took maternity with purpose because the maternal instinct is the strongest instinct in nature. To give respect to that natural instinct, the inventor decided to compare the mother's fingerprint with the baby's and make a unique ID reference that no one could change nor delete in the device.

The milestones gained from the patent will be:

- we got proof and evidence of maternity for every newborn baby

- we have no possibility of replacing or stealing identities of newborn babies
- all parents get safety
- device is of compact construction and practical for handling throughout the process
- device has its own energy supply with batteries
- device is of small size, low weight and it is portable
- device has a good price/quality ratio
- device is environmentally friendly
- device has a wide range of application and usage.

Research & Development

Description and figures showing the preview of the device

Finally, the visual representation of the software algorithm and the device preview are shown in eight figures. The first two figures represent the software algorithm where the logic, method and the sequence diagram can be seen.

For a better understanding of the functionality and usage of the device and its practical realization, there are three figures (1-3) that show the device in various views, use a case diagram and a cross-section of the Patent device.

Figure 1 shows Algorithm1 i.e. the algorithm for the determination of maternity identity and a new scan of the minutiae. It starts after powering the device and choosing option 1 on the device display.

Algorithm1 for the determination of the identity of maternity in the pseudo-code is defined as follows:

```
01  START
02  LOOP 1 TO 3
03  FIELD-1 F1 SCAN
04  IF F1 OK THEN GOTO GENERATE UNIQE ID
        ELSE IF LOOP < 3 GOTO END
05  LOOP 1 TO 3
06  FIELD-2 F2 SCAN
07  IF F2 OK THEN GOTO GENERATE UNIQE ID
        ELSE IF LOOP < 3 GOTO END
```

08 GENERATE UNIQE ID
09 GENERATE PIN
10 ENCRYPTING DATA
11 GENERATING HASH VALUE
12 STORE AND SAVE DATA
13 DISPLAY SUCCESS MESSAGE
14 END.

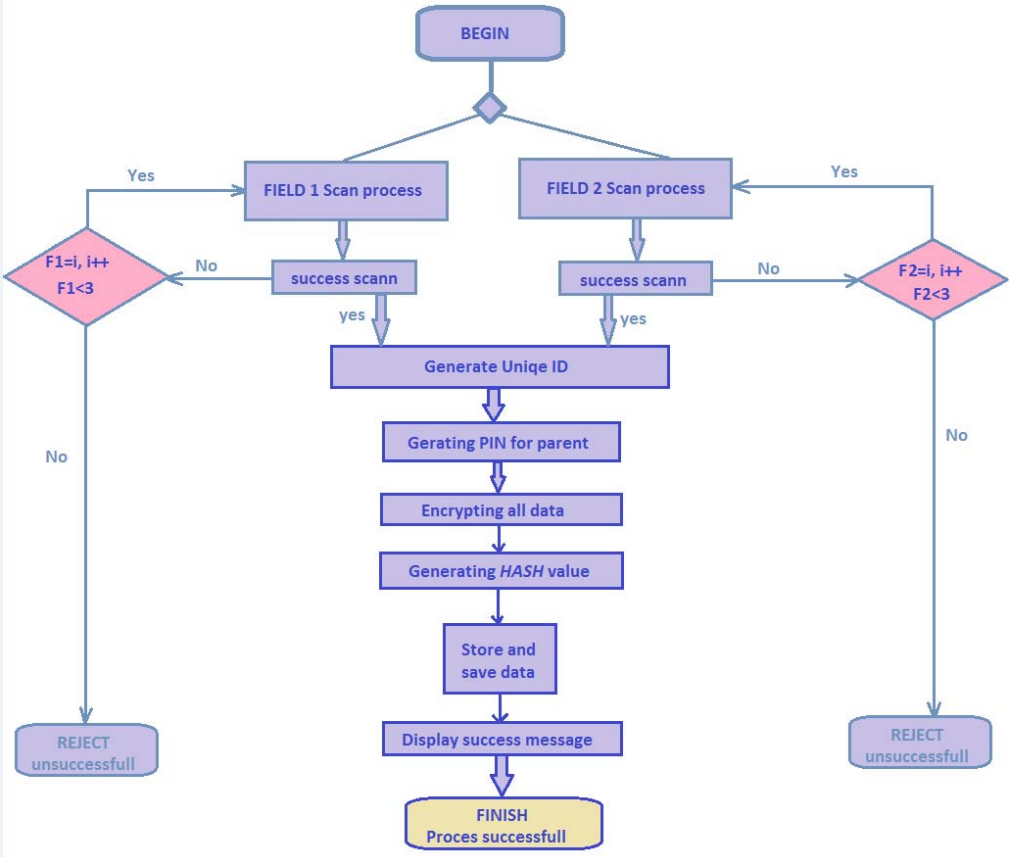

Figure 1 – Device algorithm for data acquisition
Рис. 1 – Алгоритм устройства для сбора данных
Слика 1 – Алгоритам уређаја за аквизицију података

After starting the device and choosing option 2, the software initializes Alrogithm 2 – algorithm for checking the identity of maternity. Figure 2 shows all functionality, logic and behavior of this algorithm. Based on the Figure preview, the conclusion can be derived about the possible usage of both cases and a sequence diagram of procedures and activities of the software.

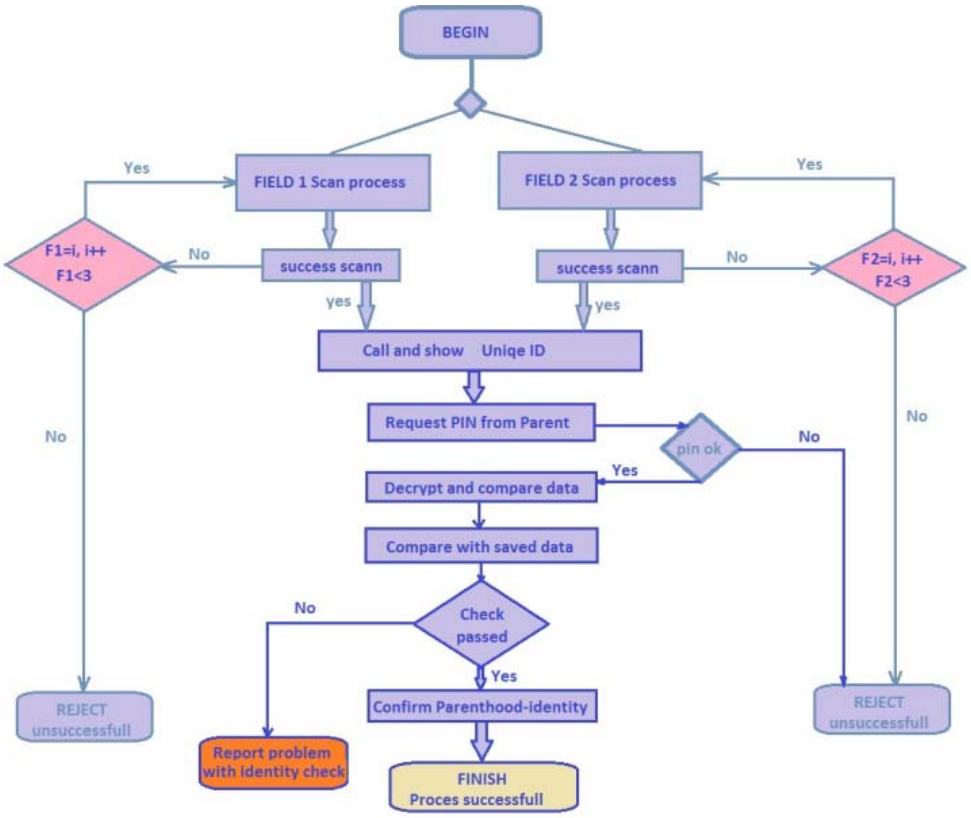

Figure 2 – Device algorithm for data verification
Рис. 2 – Алгоритм устройства для проверки данных
Слика 2 – Алгоритам уређаја за верификацију података

Algorithm 2 for the identity check of maternity in the pseudo-code is defined as follows:

```
01  START
02  LOOP 1 TO 3
03  FIELD-1 F1 SCAN
04  IF F1 OK THEN GOTO CALL AND SHOW UNIQE ID
        ELSE IF LOOP < 3 GOTO END
05  LOOP 1 TO 3
06  FIELD-2 F2 SCAN
07  IF F2 OK THEN GOTO CALL AND SHOW UNIQE ID
        ELSE IF LOOP < 3 GOTO END
8  CALL AND SHOW UNIQE ID
09  ENTER PIN
10  IF PIN VALID THEN GOTO DECRYPT AND COMPARE DATA
        ELSE GOTO END
11  COMPARE WITH SAVED DATA
12  CHECKING AND COMPARING DATA
13  IF CHECK OK THEN GOTO CONFIRM PARENTHOOD IDENTITY
        ELSE GOTO REPORT PROBLEM WITH IDENTITY
14  CONFIRM PARENTHOOD IDENTITY
15  END.
```

Figure 3 shows the device for biometric identification of maternity as a whole with the digital display, the switch and two fields for fingerprint scanning. The figure contain the following notification:

B – Body of the device.

I – Ignition switch which can be in two positions (on/off), and can be connected with timers for delayed on/off.

D – Display of the device for displaying all current device activities in real time, such as start of scanning, success of process, and results of a unique ID reference generated during the process of fingerprint scanning.

S – Set button for starting the scanning process and reading the acquired parameters by fingerprint scanning.

R – Reset button for resetting the acquired and processed data, after storing it.

R1 – Command button with a purpose of saving and storing data after the scanning process.

S1 – Field for fingerprint scanning of a baby's finger, much smaller than the field for mother's fingerprint scanning.

S2 – Field for fingerprint scanning of a mother's finger, larger that the S1 field.

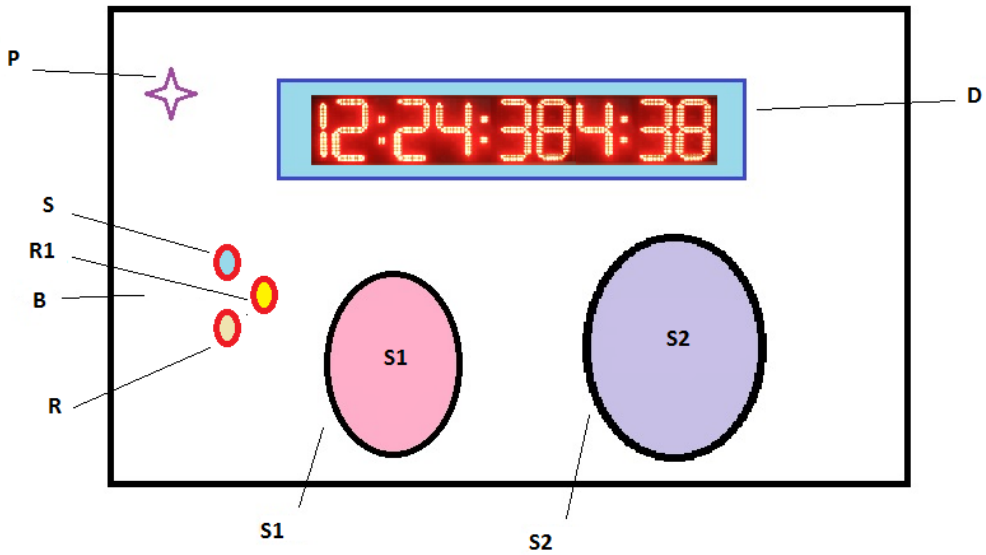

Figure 3 – Front view of the device
Рис. 3 – Изображение устройства (вид спереди)
Слика 3 – Фронтална слика уређаја

Description how the device functions

The device works as follows: putting P in the position on the device gives the information on the display that device is in function regularly and that there are no errors. Pressing the S button makes fingerprint scanning on both fields of the device start (S1 and S2) simultaneously, requiring that the fingers of the mother and the baby be placed in appropriate fields.

After scanning and pressing the R1 button, the data will be stored and a unique ID reference is shown on the display D. The ID reference can be both numeric and alphanumeric, considering that the numeral systems can be octal, decimal, binary or hexadecimal. The main fact is that the ID is unique.

Discussion - possibilities of further development

The software algorithm of the device for the biometric identification of maternity is realized in the pseudo-code in this work. It is also shown in details in Figures 1 and 2 which show the essence of the idea and programming. In future development, it can be written in a concrete programming language such as C.

This device with its essential idea about biometric identification of maternity can find place in further developments of similar biometry systems in day-care centers and in preschool institutions where there are various problems regarding the security of small children and keeping an eye on them in every moment.

Also, it can be a part of a much larger health care system regarding small children in pediatric institutions, where the device can provide basic data about possible allergies of each child and can improve that part of health care system globally.

Conclusion

This breakthrough proves that it is possible to guarantee babies' identities based on their fingerprints. Babies have their own IDs!

It can now be shared and used in different ways in different areas of social and health care systems. The system is highly modular, it can be updated and, what is most important, it can be a basis for some future development in the area of biometric systems.

This patent device can be applied in many countries in a fight against organized crime and it can help prevent thefts or replacements of newborn babies, especially in territories with low IT infrastructure and technological development.

Every type of biometrics tries to minimize both FAR[3] and FRR[4] in attempt to be much more accurate and secure. This device has accomplished that part since it combines two scanned data and its accuracy grows exponentially.

In developed countries, it can provide a new quality of health care services, help the staff in maternity wards, make the process of birth much easier and relaxed for future mothers as well as for gynecologists, midwives, and nurses: to put it shortly - for everybody!

[3] FAR – False Accept Rate
[4] FRR – False Reject Rate

Conflict of interest

None, since the Article's author is also the Patent owner.

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ОБЗОР ПАТЕНТА: УСТРОЙСТВО ИДЕНТИФИКАЦИИ ЛИЧНОСТИ ПО БИОМЕТРИЧЕСКОМУ ОТПЕЧАТКУ ПАЛЬЦА

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ВИД СТАТЬИ: обзорная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Патент под названием «Устройство биометрического установления родительства» это двойной сканер для снятия отпечатка пальца, который содержит данные о отпечатках пальцев матери и младенца с момента рождения ребенка и в течение дальнейшего процесса безошибочно идентифицирует мать новорожденного ребенка с помощью генерирования однозначных ИД сведений и их кодирования с наивысшей степенью защиты. Данное исследование посвящено первому качественному устройству, которое с уверенностью может установить идентитет новорожденного ребенка на основании минуций (признаков) отпечатка пальца. Этого до сих пор никто не делал! Осуществленное техническое решение сканера, который сканирует, сохраняет и кодирует данные изображено на рисунках, приведенных в статье. Целью изобретения данного устройства является полноценная защита и надежное безошибочное средство идентификации матерей каждого новорожденного ребенка. При одновременном сканировании отпечатков пальцев матери и новорожденного ребенка, непосредственно после его рождения, ИД генерируется и архивируется. Таким образом, потенциальная опасность от подмены новорожденного ребенка полностью ликвидирована, так как теперь идентитет каждой личности с точностью можно установить. Шифровование сведений также, как и весь процесс доведены до наивысшего уровня безопасности и конфиденциальности между всеми участниками родильных домов во всех точках мира. Страх, который испытывает каждая роженица: «Мой ли это ребенок?» навсегда останется в прошлом.

Ключевые слова: биометрия, патент, отпечаток пальца, идентитет, новорожденные дети, родильный дом, алгоритм.

ПРЕГЛЕД ПАТЕНТА: УРЕЂАЈ ЗА ГАРАНЦИЈУ ИДЕНТИТЕТА НА ОСНОВУ БИОМЕТРИЈЕ ОТИСКА ПРСТА

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ОБЛАСТ: информатика, патент
ВРСТА ЧЛАНКА: прегледни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Патент под називом „Уређај за биометријску идентификацију родитељства" је дуални биометријски скенер отиска прста који садржи податке о отисцима прстију мајке и бебе на самом рођењу. Генерисањем једнозначне ИД референце и шифровањем тих података постиже се највиши ниво заштите. По први пут је спроведено квалитативно истраживање које доказује идентитет тек рођене бебе на основу минуција отиска прста Тиме је онемогућена замена беба и гарантован сваки идентитет. Шифровањем тих података цео процес је подигнут на виши ниво безбедности и поверљивости између свих учесника у породилиштима широм света.

Кључне речи: биометрија, патент, отисак прста, идентитет, бебе, породилишта, алгоритам.

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ENTERPRISE ARCHITECTURE AS AN APPROACH TO THE DEVELOPMENT OF INFORMATION SYSTEMS

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FIELD: Computer Sciences, Informatics, Information Systems
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ARTICLE LANGUAGE: English

Abstract:

The link between business and information technology (IT) has been a constant topic in both academic and industrial circles for more than 30 years. Alignment (compliance) between business and IT is generally seen as an important component and a basis for optimizing the performance of any organization. Due to constant changes in the IT world as well as in modern business, the work on the alignment of business and IT is gaining in importance. The cause of the alignment problem lies primarily in different levels of business abstraction and IT concepts. In order to solve this problem, for a long time, the current approach to the development of information systems (IS) is based on the so-called enterprise architecture (EA). In this paper, a review of literature dealing with EA is given. The focus of the literature review was the identification of works dealing with motivational aspects for the use of EA as well as those that deal more closely with the process of development of EA using general and domain specific frameworks. The aim was also to give an insight into the current picture of academic research in this field and the use of EA in order to solve the problems of business and IT alignment. This overview can be a starting point for participants in EA development using existing frameworks as well as for developing specific frameworks that would be applied in specific domains.

Key words: business and IT alignment, information systems, enterprise architecture, enterprise architecture frameworks, TOGAF.

Introduction

For more than two decades, the need for aligning IT possibilities with business needs has been considered as one of the key issues in IT

management (Majstorović, 2016). In order to solve this problem, an approach to IS development based on EA has been used for a long time (Gregor et al, 2007). In (Krstajić et al, 2014), the EA-based approach is used as a direction for business and IT alignment in the domain of insurance industry.

Architecture is needed to manage the complexity of any large organization or system (Lankhorst, 2013). However, the notion of 'architecture' in many areas is not unambiguous. Most often, the architecture of a system implies its structure and functions. In (IEEE Computer Society, 2000, p.14), the following definition is provided: "*Architecture is a fundamental organization of the system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution.*" In this paper, the organization means a collection of organizational units that have a common set of goals and represent a specific organizational system. EA is defined in the literature differently. Thus, in (Lankhorst, 2013, p.3) EA is defined as: "a coherent whole of principles, methods and models used in designing organizational structure, business processes and infrastructure."

In (Kappelman & Zachman, 2013), EA is defined as a set of concepts and practices based on a holistic view of the system, principles and common languages, and long-standing disciplines of engineering and architecture. The work places EA as an architecture of the entire organization, including its IT. It also describes the ontology required for the holistic definition and presentation of architecture, and highlights the significant challenges facing IT professionals and researchers. Finally, EA is said to be one of the critical tools for organizational success, and will play an increasingly important role in increasing demands for speed, agility, synergy, efficiency, quality and complexity.

So, EA describes and model elements of the organization, and shows how they are organized and connected, and how they function as a whole. EA itself is not an artifact, but produces artifacts (eg. models) that illustrate the existing and future (desired) state of the organization (Seppänen, 2008). Although EA has been a very important field of research for a long time (Zachman, 1987), (Lankhorst, 2013), (ObjectWatch, 2007), (Kappelman & Zachman, 2013), there is still no full consensus on EA terminology, concepts, approaches and outcomes, ie. results of development of EA. In any case, although EA was primarily related to the architecture and development of information systems (IS), today it is an approach for a comprehensive modeling of enterprise architecture, in which standard IS components are provided, as well as

organizational and software models architectures through which an IS is implemented.

Below, attention is first paid to the development of EA. Since EA development is more efficient with the use of the framework, the paper gives a concise overview of literature that deals with frameworks that provide wider functionality as well as with those developed for specific fields, i.e. specific application domains. A special chapter is dedicated to the TOGAF Framework, the most widely used, industrial framework for EA and its key element - Architecture Development Method (ADM), which specifies the process for the development of EA (The Open Group, 2011). At the end of the paper, a conclusion is made indicating the basic contributions of this paper and the possible directions for further research.

Development of EA

Development of EA is a continuous process that involves the development, implementation, application and propagation of results. This process should be aligned with the internal development of the organization, as well as with its environment. This includes both the strategic and operational activities of the organization. Although architecture involves relatively stable parts of business and technology, it must be adapted to change; therefore, architecture products (artifacts) have a temporary status. Namely, architecture changes due to changes in the environment and new technical possibilities that affect the essential goals of the business system and the way in which these goals are achieved. Good architecture must clearly show the relation between the architectural decisions and business goals of the organization (Lankhorst, 2013). In the EA development, it is necessary to make a more or less abstract representation of the organization's positional and future state, as well as a road map that will enable the transformation from the current situation to a future one. The development and transformation process of EA is illustrated in Figure 1 (Majstorović et al, 2016a).

The EA of a future situation is based on the mission, vision, strategy and business goals of the organization. So, business is the driver and gives guidance for the development of EA. Creating a road map for translating an existing state into a future (desired) state involves a multitude of projects thet alter the existing EA, i.e. make its transformation. In this way, projects represent the implementation of changes in the organization, i.e. destination EA.

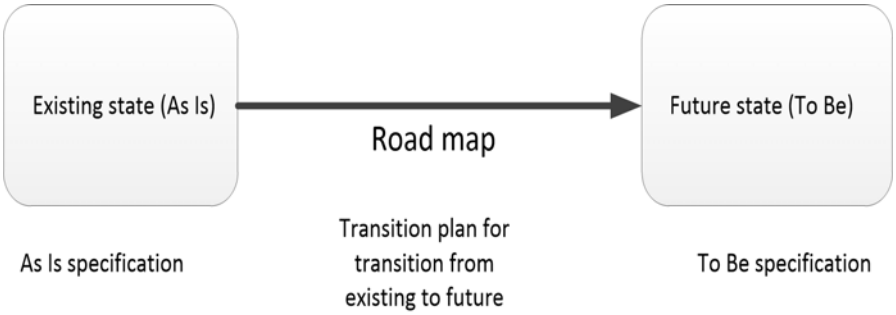

Figure 1 – EA development and transformation process
Рис. 1 – Процесс развития и трансформации EA
Слика 1 – Развој и процес трансформације EA

The most important feature of EA is that it represents a comprehensive view of the organization. Thus, it includes different domains in the organization, and should represent the optimal solution in the context of the entire organization, i.e. both its parts and the whole. In order to achieve the desired quality of EA, an approach is needed which will enable the necessary understanding and communication of all involved participants from different domains. Unlike, for example, architecture in construction, which has a thousand years of history, and in which common language and culture has been developed and established, such a general framework in business and IT is still missing (Lankhorst, 2013). In current practice, there are various descriptions, specification languages, i.e. various models, techniques and tools for EA development. The next part of the paper will focus more on EA frameworks which provide a mechanism, i.e. give guidelines, models, methods, techniques for the most successful development of EA.

EA Frameworks

Creating an enterprise architecture is more effective with the use of a framework that helps define areas to be covered by architecture and categorize artifacts for delivery, thus providing an organized and logical approach for EA creators. The EA frameworks contain a set of models, principles, and methods used to implement EA. They establish a link between EA artifacts and provide a common vocabulary for all stakeholders in the context of EA.

The established role and importance of the EA development framework have contributed to the development of multiple frameworks in the context of general and specific approaches. Below is a review of

some papers dealing with EA approaches, a brief overview of the most important frameworks and methods for developing EA.

Most of today's frameworks were created as the upgrading of the Zahman framework (Zachman, 1987). This framework represents a simple logical structure for the classification and organization of descriptive views of the organization, which are significant for the management and development of the system within the organization. This framework is focused on the structure of the view of the organization rather than on providing a process or methodology for creating an architecture. The organization is represented with a matrix of six columns and rows. The columns have the following attributes (different aspects of understanding the organization): what, how, where, who, when and why. The matrix rows represent the roles in the design process, and in a broader sense provide the taxonomy of the company and represent different observation views: the planner, the owner, the designer, the contractor, the programmer and the user. In this way, the Zahman framework enables: a good classification of the views of all interested participants in the organization, filling the cells of the array with artifacts, horizontally (between different perspectives) and vertically (from concepts to technical implementation) linking matrix cells, checking the completeness of descriptive views of complex business systems. The benefits of the Zahman framework are (Lankhorst, 2013): easy understandability; a comprehensive view of the organization; it is defined independently of tools or methodologies; any concept, or problem, can be mapped to a suitable place in the matrix. The most commonly encountered problems of applying the Zahman framework are (Lankhorst, 2013), (Fatolahi & Shams, 2006): a lack of methodologies that cover all aspects of the framework; the lack of robust rules for linking cell frames; the lack of popular notations for modeling all column frames; a large number of cells, which is an obstacle for practical application. Despite these shortcomings, the Zahman framework is still very much used, and Zahman's work has brought challenges and vision of the organization's architecture for the next twenty years. The challenges involved, above all, management of complexity in distributed systems.

The Zahman framework for EA had a major impact on the first attempt of the US Defense Department to create an EA. This effort is known as the Technical Framework for Information Management (TAFIM, 1994). The TAFIM EA promised that technical projects would be better offset (adjusted) to business needs.

The TAFIM was then submitted to The Open Group and thus converted into a standard known as The Open Group Architecture

Framework (TOGAF) (The Open Group, 2011). Although originally conceived as a general framework and methodology for the development of technical architecture, TOGAF evaluated the framework and method for the development of the organization's architecture, and the most widely used framework for EA in industry (Cameron & McMillan, 2013). TOGAF standard models for EA contain four main domains: business, applications, data and technology. The TOGAF framework is based on certain key concepts and methodologies for the development of architecture (ADM). ADM can be viewed as a process or tool for creating an EA. TOGAF ADM is cyclic and it contains 8 phases, which include defining, planning, implementing, managing the current basic architecture, and developing a migration plan in a future destination architecture. Along with ADM, the TOGAF standard contains a general dictionary, appropriate products and recommended standards for assistance in implementing EA.

In April 1999, the CIO (Chief Information Officers), a council formed by the chief executives responsible for IT in state institutions, launched a project called The Federal Enterprise Architecture Framework (FEAF) (Urbaczewski, Mrdalj, 2006). New ideas in this project were related to segmentation of architectures in large enterprises, and one of the main reasons for the implementation of FEAF was to achieve seamless integration of different architectures that existed in several federal agencies. This should have given citizens and clients a better, faster and cheaper access to information (Cameron & McMillan, 2013). In 2002, FEAF was renamed to FEA - Federal Enterprise Architecture. In 2005, FEA was the dominant EA approach in the public sector.

The GARTNER organization, with its dominant approach to the private sector, looked at EA as a continuous process involving the assessment of the current state of architecture, defining goals for building the future situation, and managing the entire portfolio throughout the process (Gartner, 2005). According to GARTNER, EA is more a strategy than an engineering discipline used to build a consolidated view of the organization, which aligns the business needs of the organization.

The previously presented EA approaches are very different. The answer to the question "Which approach is best for a specific company?" is not unambiguous. In (ObjectWatch, 2007), a comparison of these approaches was made using 12 criteria, giving a score of 1 to 4 (4 is the best estimate). According to this comparison, none of the compared EA approaches is complete; each of them has its advantages and disadvantages and they are complementary to one another.

However, it has been shown that the previously presented EA approaches are not sufficient to cover the domain companies providing Information and Communications Technology services. Thus, the New Generation Operation System and Software (NGOSS) program appeared in the field of telecommunications. The NGOSS program is developed by Telemanagement Forum (TMF), an international telecommunications association, and it represents EA for the telecommunications domain (http://www.tmforum.org/browse.aspx).

NGOSS represents a reference architecture for the telecommunications industry. It contains a set of frames that represent a generic classification scheme for design, as well as a display of a complex domain such as a telecom domain. The Business Process Framework - Enhanced Telecom Operations Map (eTOM) defines all major business processes inside and outside the company (TM Forum. *The Business Process Framework*). The company's information framework - known as SID (Shared Information and Data Model) - provides a comprehensive general information model for completing telecom activities in the company (TM Forum. *The Information Framework*). The application framework, known as the TAM (Telecom Application Map), is designed to be used by all participants in the software chain of Telekom. The eTOM provides a framework for telecom processes and the TAM framework for telecom applications (TM Forum. *The Application Framework*).

Telemanagement Forum has changed the NGOSS name for the industry standard to the name of Frameworx. All developments regarding the further development of this industry standard for telecommunications, can be monitored by the members of the TMF Association via the website (http://www.tmforum.org/browse.aspx).

In 2006, ACORD (Association for Cooperative Operations Research and Development), formed by insurance organizations from around the world, defined the strategy of developing the business architecture of insurance companies. The main result of this activity is the ACORD Framework - a framework that provides the architectural basis for insurance companies, to quickly and easily prepare and implement the changes necessary for successful business in a dynamic market (Gregory, 2005).

The ACORD framework provides insurance companies with a robust, detailed, consolidated and complete set of models that support business process innovation, transformation and efficiency improvements. Five basic components - models are (Jones et al, 2010): (1) A common vocabulary of all terms that exist and are used in the

ecosystem of insurance - Business Dictionary. The main purpose of this vocabulary is to improve communication by standardizing the name of the term in the business and unambiguous mutual communication of working teams; (2) Model of basic functionalities in the business of insurance companies - Business Capability Model. This model provides multi-level decomposition of business areas up to the level of business processes. Functions are located at higher levels of hierarchical decomposition and include all the standard functions that exist in insurance companies; (3) Information model which is the reference model for realization of business applications of the insurance company - Information Model. It is a detailed model that represents a conceptual overview of the insurance industry. It is based on UML (Unified Modeling Language) and covers all functional areas of the company and provides communication of other XML (e**X**tensible **M**arkup **L**anguage), EDI (**E**lectronic **D**ata **I**nterchange) and XBRL (e**X**tensible **B**usiness **R**eporting **L**anguage) standards with ACORD standards; (4) A data model specifically designed to meet the needs of the business data architecture of the insurance company - Data Model, represents the logical level of the entity-realatioship model. It serves primarily as a basis for the physical model of the relational database and data warehouse model (Data Warehouse); (5) A comprehensive model of components that form business processes with a detailed definition of interfaces and services across the value chain in insurance companies - Component Model.

(Cvetković et al, 2013) offered an approach to solving the problems of business and IT alignment in complex companies, with a special emphasis on the application in the domain of insurance industry, based on EA using TOGAF, TMF and ACORD frameworks. The specification of the future state of the insurance company (IC) is provided through TOGAF architectural layers. The IC business process map is used by using the structure of the TMF framework for business processes - eTOM and the basic functionality framework for the ACORD framework for the insurance domain. (Cvetković et al, 2016) presented a methodological framework for the construction of an EA insurance company, which is obtained by combining TOGAF, ACORD, and TMF accesses. The application of this methodological framework enabled a comprehensive business specification IC, which was the basis for specifying IT concepts in the domain concerned. Below is a more detailed TOGAF framework, as one of the most widely used general frameworks for the development of EA (ITpreneurs, 2013).

TOGAF - The Open Group Architectural Framework

TOGAF is an open, industrial framework for the architecture of an organization (The Open Group, 2011). It was originally conceived as a general framework and methodology for the development of technical architecture, but it was evaluated in the framework and method for the development of an enterprise architecture. The framework is described through a set of documents on the Open Group public web server (The Open Group, nd), and can be freely used in organizations that want the development of EA.

The TOGAF framework supports four architectural domains that represent EA components:

– **Business architecture** defines business strategy, management and key business processes.

– **Data architecture** describes the structure of logical and physical data sets and data management resources.

– **Application architecture** provides a sketch of individual applications, their layout, interaction, and their relationship with the organization's central business processes.

– **The technology architecture** describes the software and hardware functionalities that are necessary to support the development and deployment of business, data and application services. It includes: ICT (information communication technology) infrastructure, computer networks, communications, technological standards, etc.

Figure 2 shows the architectural domains of EA.

TOGAF is based on the next mission and strategy (State of Utah, 2007):

– **Mission**: Creating a system that will allow the free flow of information (Holmes, 2002), (Solomon & Blevins, 2003).

– **Strategy**: Firstly, working with users in order to capture, understand and deal with current and emerging requirements, establish policy, and exchange best practices. Second, work with suppliers, consortia and standardization bodies in order to develop consensus and facilitate interoperability.

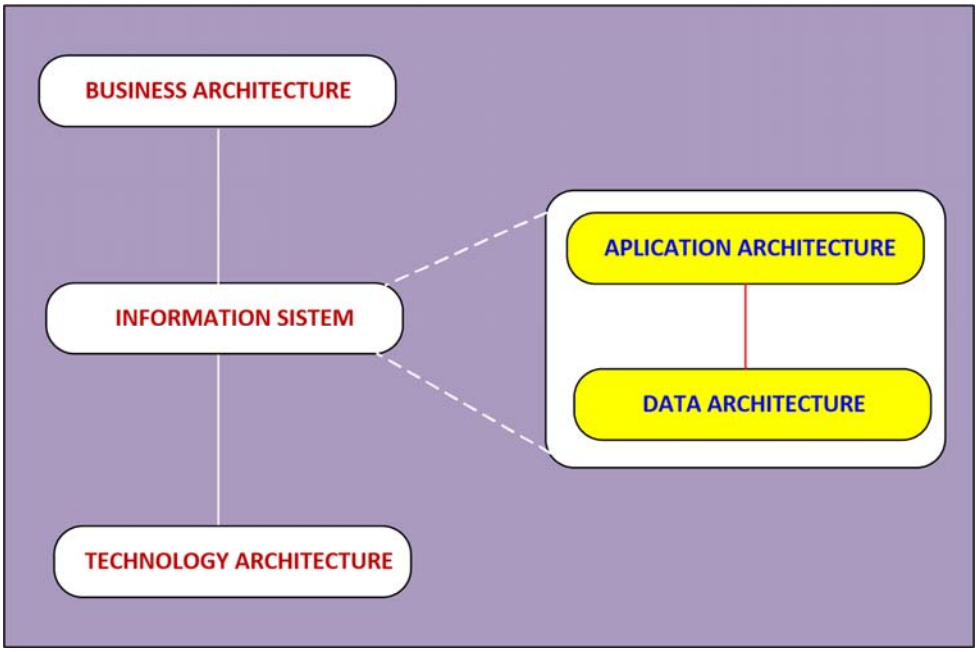

Figure 2 – Architectural domain of EA
Рис. 2 - Архитектурный домен EA
Слика 2 – Архитектурални домени EA

TOGAF contains three main sections (Minoli, 2008):

– **TOGAF method for the development of EA** (TOGAF Architecture Development Method - ADM), which defines how to implement EA for a specific organization, which will reflect specific business needs.

– **Enterprise Continuum**, a repository of all architectural artifacts (models, templates, architectural descriptions, etc.) that exist both in a specific organization and in wider IT industry, and at the disposal of the development of architectures. At the appropriate places around TOGAF ADM, there are reminders of which architectural resources should be used.

– **TOGAF Resource Base**, which is a set of resources (guidelines, templates, additional information, etc.) that helps architects in the use of ADM.

Below is a more detailed overview of the TOGAF method for the development of EA.

TOGAF method for the development of EA

The TOGAF Architecture Development Method (ADM) is a cyclical process for the development of architecture. ADM involves the establishment of a framework of architecture, the development of content architecture, the transition and management of the implementation of architectures. All these activities are carried out within the iterative cycle of the continuous definition of architecture and its realization, which enables organizations to transform their enterprises in a controlled manner in order to fulfill business goals and new possibilities (The Open Group, 2011).

Figure 3 shows the architecture development cycle according to the TOGAF ADM method. Below are brief description of ADM phases.

The Preliminary Phase describes the preparation and initiation of architectural creation activities, including the adaptation of TOGAF and the definition of architectural principles.

Phase A: The Architecture Vision describes the initial phase of the architecture development cycle. It includes:

– information on defining the scope of the architecture development initiative,
– identification of stakeholders,
– creating the architecture vision,
– obtaining consent to continue the work on developing EA.

Phase B: Business Architecture describes the development of a business architecture that supports a harmonized vision of architecture. The phase shows how an organization meets its business objectives. The phase includes the following:

– business goals and tasks,
– business functions, services, processes and roles,
– correlation of the organization and functions,
– confirm business context,
– defining current and future architecture,
– execution of gap analysis,
– creating a report on business architecture.

Phase C: Information System Architecture describes the development of an information system architecture that supports a harmonized vision of architecture. The phase shows how IT systems

fulfill the business goals of the organization and display application systems and data architecture.

Phase D: Technology Architecture describes the development of a technology architecture that supports a harmonized vision of architecture. This is the systemic basis of the IT system. It includes:

- hardware, software and communication technology,
- links between technologies,
- principles of design, management and evolution of technology.

Phase E: Opportunities and Solutions analyze different implementation capabilities, identify initial implementation projects and supplies for architecture defined in previous phases. The phase includes:

- access decisions (purchase or development, outsource, commercially available software, and open source solutions),
- priority assessment,
- dependence identification.

Phase F: Migration Planning defines a transition from an existing to a destination architecture, through the finalization of a detailed implementation and migration plan. It produces an implementation road map, and other relevant analyzes, such as costs and benefits, and risk assessment for major projects.

Phase G: Implementation Governance provides architectural control over implementation. It defines architectural limitations of implementation projects, and establishes contracts, or agreements. In co-operation with the project management department, it oversees work on the implementation in order to achieve general consent.

Phase H: Architecture Change Management establishes procedures for managing changes in the process of developing a new architecture. The phase ensures that architectural changes are managed in a cohesive and architecturally consistent manner. It establishes and supports EA in order to provide flexibility, which will enable rapid development, in response to technological changes and the business environment of the organization concerned.

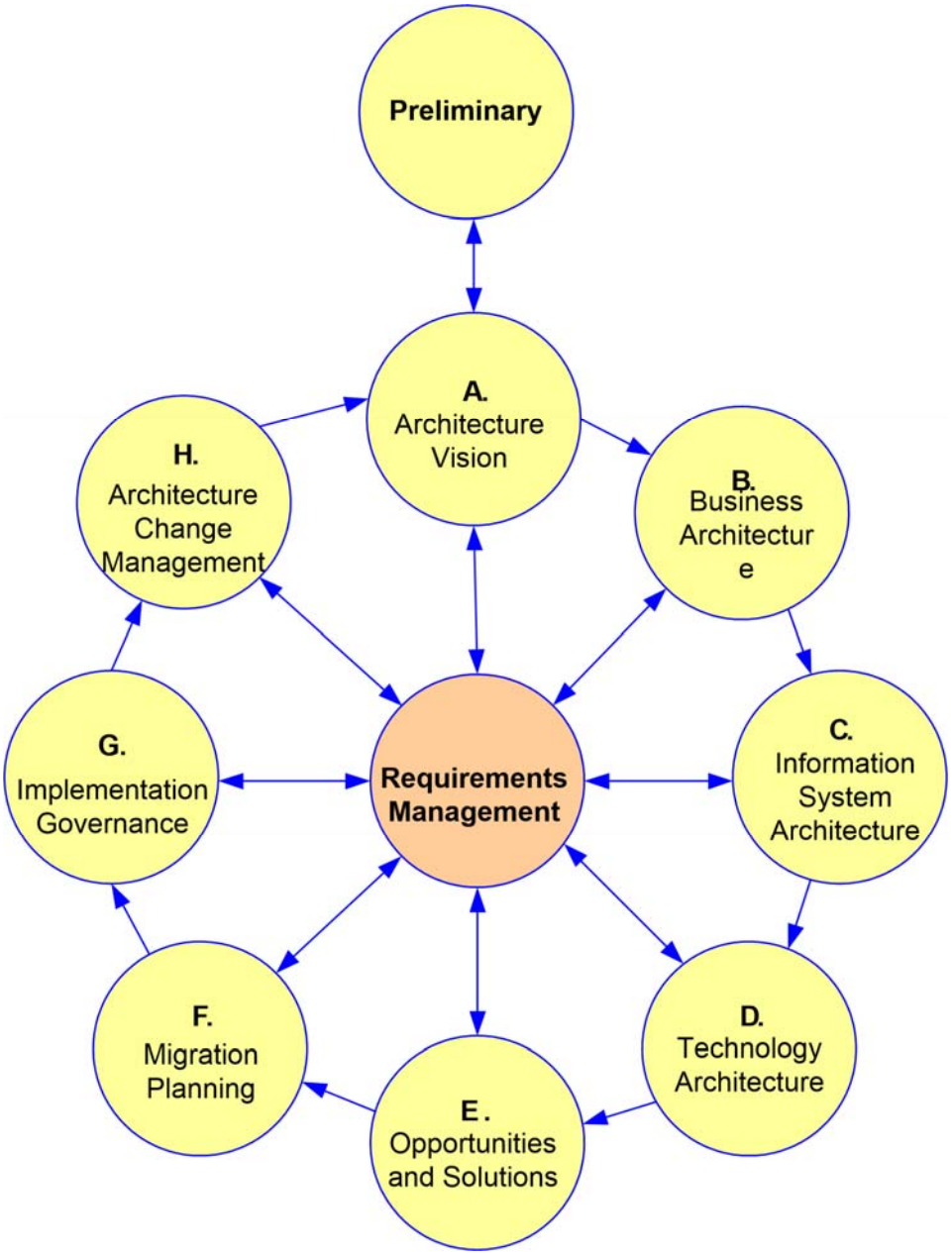

Figure 3 – Cycle of architecture development
Рис. 3 - Цикл развития архитектуры
Слика 3 - Циклус развоја архитектуре

Requirements Management determines the process of managing the architecture requirements through ADM. As Figure 3 shows, this phase is at the center of the ADM method, which means that ADM is continually driven by the demand management process. The objectives of this phase are:

Ensure that the process of managing the requirements is sustainable and pervasive through all relevant ADM phases.

Management of architectural requirements identified through the execution of any ADM cycle, or phase.

Ensuring that relevant architectural requirements are available for each stage during its execution.

The TOGAF ADM process can be adapted for different usage scenarios. In (The Open Group, 2011) are given guidelines for ADM process adaptation, as well as techniques for architecture development.

Conclusion

In order to solve the problem of business and IT alignment, for a long time the current approach to development of the IS has been based on EA (Gregor et al 2007). In the review papers related to EA (ObjectWatch, 2007), (Urbaczewski, Mrdalj, 2006), (Cameron & McMillan, 2013) the analysis of methodologies and frameworks was not performed in the context of business and IT alignment. Also, frameworks for specific business domains are not specifically considered.

The aim of this paper is to provide an overview of the current picture of academic research in this field and the use of EA in order to solve the problems of business settlement and IT. In accordance with this, the paper discusses the general framework for the development of EA, as well as the frameworks developed for specific business domains, such as the ICT (TMF framework) and the insurance industry (ACORD framework). The TOGAF framework is particularly presented as one of the most widely used general frameworks for the development of EA (ITpreneurs, 2013). As shown in (Cvetković et al, 2016), a combination of TOGAF frameworks with specific domain frameworks can build a methodological framework for the development of EA specific business areas. The review given in this paper can be a starting point for the participants in the development of EA using existing frameworks, as well as for the development of specific frameworks that would be applied in specific domains.

In the specific application domain, such as service-oriented business, the problem may be the operationalization of a general framework such as TOGAF itself. Also, a large number of domain

frameworks and standards bring the problem of organizing the development of ISs that are based on them. Bearing this in mind, further work is planned to explore the relationship between business models and EAs in order to alleviate these problems. During this work, it is desirable to formalize business models so that the elements of various EA development frameworks are adequately used. To this end, (Majstorović et al, 2016b) has developed a service-oriented business (SOB) metamodel that represents a unique conceptualization and contributes to a more precise definition of the SOB concepts.

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АРХИТЕКТУРА ОРГАНИЗАЦИИ КАК ДОСТУП К РАЗВИТИЮ ИНФОРМАЦИОННЫХ СИСТЕМ

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ОБЛАСТЬ: компьютерные науки, информатика, информационные системы
ВИД СТАТЬИ: обзорная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Связь между бизнесом и информационными технологиями (ИТ) на протяжении последних тридцати лет является самой актуальной темой как в академических, так и в промышленных кругах. Выравнивание (согласованность) бизнеса и ИТ является важным компонентом и фундаментом для оптимизации деловых процессов каждой организации. В связи с постоянным развитием как в области ИТ, так и в области организации бизнеса, выравнивание бизнеса и ИТ становится все более востребованной деятельностью. Основная причина проблем выравнивания прежде всего заключается в различных уровнях абстракции бизнеса и ИТ концептов. В целях решения данной проблемы, на протяжении долгого времени разрабатывается новый метод развития информационных систем (ИС), основанный на так называемой архитектуре организации (АО).

В данной статье представлен обзор научной литературы, посвященной вопросам АО. В данном обзоре литературы большое внимание посвящено работам, представляющим мотивационные аспекты применения АО, а также работам, представляющим процессы развития АО при применении обобщенных и специальных рамок доменов, а также использования АО в целях решения проблемы выравнивания бизнеса и ИТ. Данный обзор может служить отправной точкой в развитии АО при применении существующих рамок, а также в развитии специальных рамок, которые можно было бы применять в специальных доменах.

Ключевые слова: выравнивание бизнеса и ИТ, информационные системы, архитектура организации, рамки развития АО, TOGAF.

АРХИТЕКТУРА ОРГАНИЗАЦИЈЕ КАО ПРИСТУП ЗА РАЗВОЈ ИНФОРМАЦИОНИХ СИСТЕМА

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Сажетак:

Веза између пословања и информационе технологије (ИТ) више од 30 година стална је тема, како у академским, тако и у индустријским круговима. Поравнање (усаглашеност) пословања и ИТ-а генерално се види као важна компонента и основа за оптимизацију пословних перформанси било које организације. С обзиром на сталне промене, како у ИТ свету, тако и у савременом пословању, рад на поравнању пословања и ИТ све више добија на значају. Узрок проблема поравнања је, пре свега, у различитим нивоима апстракција пословања и ИТ концепата. Ради решавања овог проблема већ дуже време је актуелан приступ развоју информационих система (ИС), заснован на тзв. архитектури организације (АО). У раду је презентован преглед литературе која се бави АО, а фокус је на идентификацији радова који се баве мотивационим аспектима за коришћење АО, као и онима који детаљније обрађују процес развоја АО уз коришћење општих и доменски специфичних оквира. При томе, циљ је да се прикажу тренутна академска истраживања из ове области и коришћења АО ради решавања проблема поравнања пословања и ИТ. Овај преглед може бити стартна тачка учесницима у развоју АО, уз

Majstorović, M., Enterprise architecture as an approach to the development of information systems, pp.380-398

коришћење постојећих оквира, као и за развој посебних оквира који би се примењивали у специфичним доменима.

Кључне речи: поравнање пословања и ИТ, информациони системи, архитектура организације, оквири за развој АО, TOGAF.

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СТРУЧНИ ЧЛАНЦИ
ПРОФЕССИОНАЛЬНЫЕ СТАТЬИ
PROFESSIONAL PAPERS

THE METHOD OF "EXTERNAL SPIRAL" FOR SOLVING A LARGE SYSTEM OF LINEAR EQUATIONS

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Abstract:

Solving a linear system of n × n equations can be very difficult for the computer, especially if one needs the exact solution, even when the number n - of equations and of unknown variables is relatively small (a few thousands). All existing methods have to overcome at least one of the following problems: 1. Computational complexity, which is expressed with the number of arithmetic operations required in order to determine a

solution; 2. The possibility of overflow and underflow problems; 3. Causing variations in the values of some coefficients in the initial system, which may be leading to instability of the solution; 4. Requiring additional conditions for convergence; 5. In cases of a large number of equations and unknown variables it is often required that the systems matrix be: either sparse, or symmetrical, or diagonal, etc. This paper presents a method for solving a system of linear equations of arbitrary order (any number of equations and unknown variables) to which the problems listed above do not reflect.

Key words: system of linear equations, method of "external spiral", hyperplane.

Introduction

If we perceive mathematics as a science oriented primarily towards a man as a subject of its application, the problem of solving large systems of linear equations is not a mathematical one. It is essentially the problem steming from computer science since the very forming of such a system is impossible without the help of computers. Just to write down thousands of equations with thousands of unknowns, a man would have to spend a lifetime. Let us suppose you need to solve the full system of linear equations having a very large number of equations and unknowns, e.g. *n ~ 100,000 or more*. In order to solve such a system, it is necessary to devise a method which: 1) requires execution of the least possible number of operations; 2) does not require exhaustive memory usage; 3) does not produce unexpected overflow and underflow effects; 4) does not change the coefficients of the initial system; 5) can be applied for an arbitrary system scale – any number of equations; 6) does not insist that the systems matrix has any particular additional feature, and 7) unconditionally and quickly converges starting from an arbitrary initial point. The existing methods do not meet at least one of the issues listed above. The difficulties stated in abstract from 1. to 5., as well as the requirements listed above from 1) to 5) are well-known and described, e. g. in (Boht, 1978), (Higham, 2002), (Stoer & Bulirsch, 2002), and some in connection to solving large systems of linear differential equations in modelling complex systems, such as (Randall, 2015) or in other real-world applications (Gajić et al, 2008).

An exact solution to the system of $n \times n$ has n components. Each of these components functionally depends on every individual coefficient of the system. The number of coefficients is of order n^2. This implies that a minimum number of operations required to obtain the exact solution of the system of $n \times n$ is proportional to the number n^3, in general. If we

want to reach a solution using fewer operations, it is necessary to seek the approximate methods or approximate solution.

Formulation of the problem

Assume that the computer memory contains a system of linear equations $n \times n$ (where n is much higher than 1000). Let this system has the following form:

$$\begin{aligned} a_{1,1}x_1 + a_{1,2}x_1 + \ldots + a_{1,n}x_1 &= b_1 \\ a_{2,1}x_1 + a_{2,2}x_1 + \ldots + a_{2,n}x_1 &= b_2 \\ a_{n,1}x_1 + a_{n,2}x_1 + \ldots + a_{n,n}x_1 &= b_n \end{aligned} \quad (1)$$

For n greater than a thousand, the system (1) can only be formed inside a computer memory. For a system like this, it is possible to define the procedure for finding the solution, which has a minimal, almost trivial computation, and then, if the solution exists, to assure convergence to it.

For this work the only assumption made is that system (1) has a solution, as well as that when checking whether obtained result is a solution, there is no overflow in the intermediate results in any of equations in (1). If overflow of this kind happened, then it would be impossible to solve the system (1) in such an environment. Although the initial assumption is that system (1) has a solution, the procedure defined here could be utilized to determine whether system (1) is insolvable (impossible) or if it has some degree of freedom. It is important to assume that the solution of (1) exists in order to assure the convergence of the method.

Description of the procedure

In order to reach a solution of system (1), it is not necessary to solve it. To find the solution of system (1), it is suitable to apply a cybernetic approach (method of invariants), similar to the procedure defined in (Srdanov & Stefanović, 2017). Each equation in a system given in (1) carries a considerable amount of information. For example, each equation from system (1) can be interpreted geometrically as one hyperplane within a space whose dimension is at least equal to the number of unknown variables e. g. n. Then, each equation from (1) can reveal the coordinates of the line perpendicular to its respective hyperplane, and so forth. Parts of this information can be utilized in the process of finding solution of system (1). The essence of this idea is as

following: If the solution of system (1) exists, then it is a point of intersection of all hyperplanes defined by the equations of system (1). Starting the calculation of the solution approximation from an arbitrary point and advancing further using orientations and the positions of all hyperplanes makes it possible to reach a common intersection eventually.

At this point, it is necessary to precisely define the term angle between two hyperplanes – to generalize the term angle between two intersecting planes.

The angle between two intersecting three-dimensional spaces, both contained within the common four-dimensional space, is defined analogously to the definition of a dihedral angle between two intersecting planes within the same three-dimensional space. The angle between two three-dimensional spaces can be defined as a dihedral angle contained within a third three-dimensional space which is perpendicular to both of these. This dihedral angle consists of two intersecting planes of the third three-dimensional space with the previous two three-dimensional spaces. All three three-dimensional spaces are contained within the same four-dimensional space. Therefore, the generalized dihedral angle between the two three-dimensional spaces is the dihedral angle located within the third three-dimensional space that is perpendicular to both of the previous spaces (dihedron that makes up the cross-section area of the third space with the previous two spaces). All of these three three-dimensional spaces are within the same four-dimensional space.

Generalizing previous, more same-dimensional dihedral angles having a common point can be called justifiably the clew.

In a completely analogous manner, the angles between two four-dimensional spaces contained within the same five-dimensional space could be defined, etc.

For the first approximation of the unknown solution, an arbitrary point could be taken from the space the solution belongs to. Statistically speaking, the most optimal way to choose the starting point is pseudo-random. The problem connected to this is that the existing algorithms for generating pseudo-random numbers, as arule, provide pseudo-random choices within some range. Therefore, a pseudo-random initial choice should not take precedence over the chance to choose the starting point as always the same. If we choose the initial point in advance, it is preferable that it is the point $O = \underbrace{(0,0,\ldots,0)}_{n}$. A better method for the selection of the starting point is to determine the "centroid of the system (1)". To achieve this, it would be perfect to add up all the columns in

system (1) and all the results. Then, for the initial values of all unknown variables it would be perfect to take the value given by: $x_i^0 = \frac{1}{n} \cdot \frac{\sum_{i=1}^{n} b_i}{\sum_{j=1}^{n} a_{i,j}}$ if the nominator is not zero, and $x_i^0 = \frac{1}{n} \sum_{i=1}^{n} b_i$ otherwise, for all $i = 1, 2, ..., n$.

To determine the subsequent approximation of the solution of system (1) it is required to extract from (1) the two equations simultaneously. From now on, the first equation of these two will be referred to as the first plane, and the second equation - the second plane. Each equation is a hyperplane. The two hyperplanes within the space of the same dimension can have one of the following relationships - that these two hyperplanes: intersect, do not intersect or are overlaping each other. If hyperplanes do not belong to the same dimensional space, very different mutual relations are possible, which is not relevant from the point of view of this article.

Let us suppose that the two hyperplanes intersect. Then we can examine in detail the following cases. Dihedral angle that these two are forming is: acute, right or obtuse. Besides this, a position that the approximation of the solution has reached, namely the point O, is important as well (the position of O compared to these hyperplanes). The point O may: belong only to one hyperplane, to both hyperplanes or to neither one of these two hyperplanes. The idea of the method is that we should reach some of the points within the intersection of the first and the second hyperplane ariving from the initial point O. This would complete one semi-iteration. Then we eliminate the first hyperplane, the second hyperplane is declared to be the first, and for the second hyperplane - the following equation from system (1) is proclaimed. From the previously attained point O, we are descending into one of the points belonging to the intersection of the newly examined two hyperplanes. When the last of all equations in system (1) has been examined, a full iteration is completed.

The procedure of selecting one of the points from the intersection differs for each of the three above mentioned cases. It can be described as follows. Through the point O, we place two straight lines whose directions are determined by the perpendicular vectors of the first and the second hyperplane. We distinguish between the three cases: a) to c).

a) The point O already belongs to the intersection of the hyperplanes in concern. In this case, we should proceed with calculation retaining the previous point O.

b) The point O belongs to only one of the two hyperplanes. Then we should determine the point of penetration the intersection of the two hyperplanes with the line positioned perpendicular to the other hyperplane. Through this point of penetration, we set the hyperline and determine its intersection with the other hyperplane. The resulting penetration point represents the next choice for the point O.

c) The point O does not belong to any of the noted hyperplanes. Then we determine penetrations through both hyperplanes using the perpendicular hyperlines drawn from O. Thus, in each hyperplane we get two points that define the new pair of hyperlines. The intersection point of these two hyperlines should be the next position for O.

The method defined here differs from the one given in (Srdanov & Stefanović, 2017) as follows. The points we are taking to get closer to a solution, according to the method in (Srdanov & Stefanović, 2017), belong to a spiral located within some of the 2^n clews which are forming up all of the hyperplanes corresponding to all of the equations of system (1). Wherein, if a point is within the dihedron that is larger than a right angle, the next point should be taken in the new clew. This is carried out until the point is taken the clew which has all dihedral angles acute. Then further convergence towards a solution follows a unique internal spiral whose points of intersection with the clew are the bases of the perpendicular lines placed from one point of the dihedron side on the neighboring side (internal spiral). The method described in this paper follows the external spiral - the spiral located on one side of the clew face which passes through the points obtained as the bases of the perpendiculars from a point of the edge of the dihedron to the adjacent edge of the same face. The term the edge of the dihedron is basically the same: the edge is formed from the intersection points of the dihedron sides - dihedral planes.

For the system described with (1), the coordinates of the orthonormal vectors of all hyperplanes are given as the coefficients of the system: $\vec{n}_l = \left(a_{i,1}, a_{i,2}, \ldots, a_{i,n}\right) \;\; i = 1,2,\ldots,n.$ A procedure of finding an intersection of the line going through the given point O and being perpendicular to the second hyperplane requires a minimum of computation and is given as follows. Let the point O has the coordinates $\left(y_1^{'}, y_2^{'}, ..., y_n^{'}\right)$. Let the orthogonal vector of the first plane be

$\vec{n}_l = \left(a_{i,1}, a_{i,2}, \ldots, a_{i,n}\right)$, and of the second $\overrightarrow{n_{i+1}} = \left(a_{i+1,1}, a_{i+1,2}, ..., a_{i+1,n}\right)$, where $1 \le i \le n-1$. In order to determine the penetration point for the first perpendicular line through the second plane, i. e. the point $X_1 = \left(x_1^{'}, x_2^{'}, ..., x_n^{'}\right)$, we determine firstly $t = \dfrac{b_{i+1} - \left(a_{i+1,1} \cdot y_1^{'} + a_{i+1,2} \cdot y_2^{'} ... + a_{i+1,n} \cdot y_n^{'}\right)}{\overrightarrow{n_i} \cdot \overrightarrow{n_{i+1}}}$, and then $x_j^{'} = a_{i,j} \cdot t + y_j^{'}$, where $j = 1,2,..., n$. To determine the penetration point of another perpendicular line, i. e. the point $X_2 = \left(x_1^{"}, x_2^{"}, ..., x_n^{"}\right)$, we determine at first $t = \dfrac{b_{i+1} - \left(a_{i+1,1} \cdot y_1^{'} + a_{i+1,2} \cdot y_2^{'} ... + a_{i+1,n} \cdot y_n^{'}\right)}{\left\|\overrightarrow{n_{i+1}}\right\|^2}$, and then $x_j^{"} = a_{i+1,j} \cdot t + y_j^{'}$, where $j = 1,2,..., n$. Now the line is placed through the points X_1 and X_2 and its intersection with the first plane is determined. For this, it is necessary to calculate $t = \dfrac{b_i - \left(a_{i,1} \cdot x_1^{'} + a_{i,2} \cdot x_2^{'} ... + a_{i,n} \cdot x_n^{'}\right)}{\overrightarrow{n_i} \cdot \overrightarrow{\left(x_i^{'} - x_i^{"}\right)}}$ prior to calculating the coordinates of the new O point using the formulas $y_j^{'} = \left(x_j^{'} - x_j^{"}\right) \cdot t + x_j^{'}$, $j = 1,2,..., n$. When a full circle is taken, from $i = 1$ to $i = n-1$, the next iteration can begin.

Only in the first intermediate step, the point O can be placed outside both of the two planes observed. Each subsequent choice of the point O would belong to at least the first plane. During computation of intermediate steps within the same iteration, the following cases should be considered for in the program. a) The two planes that have been reached are mutually perpendicular. Then the line perpendicular to the second plane should be placed through the point O, and through its intersection with the second plane, a line should be placed that is perpendicular to the first plane. Then the intersection of this line with the first plane should be determined. b) The two planes reached are two parallel hyperplanes. Then, there are two passing lines through the point O that are the same (identical) and these lines penetrate both hyperplanes in the same points. The system is then impossible and the process should be stopped. c) Similarly to the above, only the

Srdanov, A. et al, The method of "external spiral" for solving large system of linear equations, pp.399-414

penetration points in the hyperplanes observed are coinciding with the point O. If this is the case, the process should be stopped because system (1) is indetermined.

When one pass through all of the equations is made this way, one full iterative cycle is completed. The next iterative cycle will begin with placing the line perpendicular to the first hyperplane through the O point reached in the last hyperplane.

The Problem of Accuracy and Completion of Iterating Process

After a full circle and one iteration completed, checks should be performed whether the required accuracy is reached. The problem of accuracy and completion of repeating the iterative method is possible to display in ranked levels. The user should choose the one level offering balance between the number of iterations required and acceptable accuracy. The method to be applied to a large number of equations and unknown variables should require the least possible necessary additional computation in every step, since in total there is a considerable amount of computation already. Another goal is that the solution obtained has the least possible relative deviation from the exact one, when each unknown variable is considered. The highest level of accuracy for the "internal spiral" is achieved by checking out whether the sum of the distances from the last point obtained to all of the planes is small enough. For the method according to the "external spiral", this criterion may be the sum of all distances between two consecutive points obtained over a full iterative cycle (the length of an arc of the spiral). In the first case, the number of operations is proportional to the number $2n^2+n$, and in the latter case - to the number n^2. These criteria for checking the accuracy both require relatively large number of operations. The next level of accuracy in both methods may be based on the length of the distance between the points of two consecutive iterations. In both methods, this criterion requires $2n$ operations. The number of operations is considerably lower; however, the resulting conclusion is in accordance with that. Using such a criterion in cases where the clew has all dihedral angles very small, it is possible to be still relatively far from the solution and to erroneously assume that the very high accuracy is already reached. The third level of accuracy may include checking out the distance of two consecutive semi-iterations or something of a kind. The number of necessary operations will not be decreased significantly; however, the end result may be improved considerably.

Apart from selecting any of the criteria above, regardless of the criterion rank, it is possible to reduce significantly the number of operations in the following manner. It is not necessary to check out the accuracy attained after each iterative cycle, but after ten or one hundred of full iterations.

Insolvable (Impossible) system and indetermined system

If the given system has no solution (impossible or insolvable system), the procedure described here can detect that. In terms of Geometry (geometrically speaking), there is no solution if any two of the hyperplanes are parallel. The method presented here can detect this if it happens at any position that the two adjacent hyperplanes have perpendicular lines of the same direction. Having in mind the process of solving equations, as soon as something like that is established, the procedure should be stopped. If paralel hyperplanes are not adjacent, then this can also be determined in advance, prior to solving - that the system is impossible or insolvable, by checking out whether any two vectors are of the same direction. The number of required operations is proportional to the number n^2.

The method proposed here provides a much simpler way to determine whether the system is impossible (insolvable) when compared to the method given in (Srdanov & Stefanović, 2017).

If the system is indetermined, then its uncertainty can be numerically evaluated with respect to the degrees of freedom. In the case observed, the system may have from 1 to 99999 degrees of freedom. If there is one degree of freedom, then all of the hyperplanes have a common line; If there are two degrees of freedom, then all hyperplanes have a common plane; If there are three degrees of freedom, then all hyperplanes have common three-dimensional space within the space of one hundred thousands dimensions, etc; If there are 99999 degrees of freedom, then all equations of the system represent one and the same hyperplane within the space of one hundred thousands dimensions.

In the algorithm proposed, the simplest way is just to establish that the system is indetermined because to find out more than that would require many more checks, which is not of great importance for this paper.

The method proposed here does not always detect that the system is indetermined and in cases when it is and not detected, the program will report the solution. If the program is run again only this time from a

different starting point, the method will again provide a solution, however different from the previous one. This way, it is possible to always accurately distinguish whether the obtained solution is unique or the system is indetermined.

Convergence and speed

We will present an outline of proof, while the rigorous proof differs only in detail. Let there be a system of *n* x *n* linear equations, where $n \in N$, which has a solution $X\left(y_1^*, y_2^*, ..., y_n^*\right)$. Let us assume that we have started solving that system using the method proposed here and starting from an arbitrary point of the first hyperplane, $O_1\left(y_1^0, y_2^0, ..., y_n^0\right)$. Then the next point in the first iteration is denoted by $O_2\left(y_1^1, y_2^1, ..., y_n^1\right)$. In (Srdanov & Stefanović, 2017), the subsequent iteration next point was the orthonormal projection of the point O_1 to the first hyperplane, denoted *M*. In this paper, the next iteration is obtained as the cross-section of the plane perpendicular to both of the hyperplanes with the "dihedral edge" and this is the point O_2. Now the angles $\angle O_1MX$ and $\angle MO_2X$ are both right angles. It is obvious that $O_1X > MX > O_2X$ (as the hypotenuse is of greater length than both catheti). It should be noted here that the reason why this method is faster than the method suggested in (Srdanov & Stefanović, 2017) is because here one point is approaching along two different catheti of the two right-angled triangles. In practice this means twice faster than the method in (Srdanov & Stefanović, 2017).

If we denote with $d_j^1, \quad j = 1,2,...,n$ the distances between the solution and consequtive points of the first iteration, then after the first step of the first iteration is applied, it holds $d_1^1 = d \cdot \cos\left(\angle P_1^1 X P_2^1\right) < d$. A perpendicular line always enters acute angle, which may be zero only if the system has no solutions (parallel hyperplanes). This way we obtain a sequence $d_n^1 < d_{n-1}^1 < ... < d_1^1 < d$. As the procedure is extended in an analogous manner during the following iterations, it is to conclude that the method always converges provided that the system has a solution.

If all angles are right, one single complete iteration is sufficient to reach the exact solution.

The number of required operations

Once the lengths of the vectors perpendicular to the hyperplanes corresponding to the equations of the system are calculated, it is not necessary to re-calculate these again, and this requires $2n^2$ operations. The program does not always passes through the same path during its execution and the various branches require a different number of operations. The highest number of operations is needed when the point O does not belong to any hyperplane, and these intersect at a sharp angle - then one semi-iteration requires $6n^2+3n$ necessary operations. In any other case one semi-iteration requires $4n^2+2n$ operations. To determine the accuracy, the $2n^2$ operations are needed at most. It can be estimated that to complete one iteration, the number of operations required is proportional to n^2. A solution can be reached after m steps. To conclude, it can be stated that the number of operations required by this method is of order n^2.

An example

Let us assume that a following system of linear equations is given:

$$43x_1-11x_2+13x_3-17x_4+19x_5-23x_6+29x_7-31x_8+37x_9-41x_{10} = -496$$
$$41x_1-43x_2+11x_3-13x_4+17x_5-19x_6+23x_7-29x_8+31x_9-37x_{10} = -1008$$
$$37x_1-41x_2+43x_3-11x_4+13x_5-17x_6+19x_7-23x_8+29x_9-31x_{10} = -204$$
$$31x_1-37x_2+41x_3-43x_4+11x_5-13x_6+17x_7-19x_8+23x_9-29x_{10} = -864$$
$$29x_1-31x_2+37x_3-41x_4+43x_5-11x_6+13x_7-17x_8+19x_9-23x_{10} = 0$$
$$23x_1-29x_2+31x_3-37x_4+41x_5-43x_6+11x_7-13x_8+17x_9-19x_{10} = -864$$
$$19x_1-23x_2+29x_3-31x_4+37x_5-41x_6+43x_7-11x_8+13x_9-17x_{10} = 204$$
$$17x_1-19x_2+23x_3-29x_4+31x_5-37x_6+41x_7-43x_8+11x_9-13x_{10} = -1008$$
$$13x_1-17x_2+19x_3-23x_4+29x_5-31x_6+37x_7-41x_8+43x_9-11x_{10} = 496$$
$$11x_1-13x_2+17x_3-19x_4+23x_5-29x_6+31x_7-37x_8+41x_9-43x_{10} = -1008$$

The exact solution of this system is:

x1=11; x2=13; x3=17; x4=19; x5=23; x6=29; x7=31; x8=37; x9=41; x10=43.

In the paper (Srdanov & Stefanović, 2017) the same example has been tested. Then the following report has been received:

The solution is reached in 205 semi-iterative steps. (20 complete iterations) 10.9999 12.9998 16.9998 18.9999 23 29.0001 31.0002 37.0002 41.0001 43.

The method derived here is considerably improved compared to the method in (Srdanov& Stefanović, 2017).

The program developed in accordance with the instructions given in this paper is outlined by the following pseudo-code:

```
int main() {
  double t, br1, im1, Eps = .00001, Accuracy= 1.0;
  int i, j, k, m = -1, m1, check_out = 0, flagX1;
  UploadSystem(A,B);
  for(m = 0; m < 99; m++)
     for(i = 0; i < 100; i++) {Modul1[m] = += A[m][i]*A[m][i];
Modul2[m] += A[m][i]*A[m+1][i];}
  for(i = 0; i < 100; i++) {XD[i] = 0.0; Modul1[m] += A[m][i]*A[m][i];
Modul2[m] += A[0][i]*A[m][i];}
  while (Accuracy > Eps) {
// at first descend to intersection, if possible
     m++;
     if (m == 100) {m = 0; check_out++;}
     m1 = m+1;
     if (m == 99) m1 = 0;
     for(k = 0; k < 100; k++) X0[k] = XD[k];
// perpendicular line to the first hyperplane and intersection with
// the second hyperplane
     if (Modul2 != 0) {
          br1 = 0;
          for(k = 0; k < 100; k++) br1 += A[m1][k]*X0[k];
          t = (B[m1] - br1)/Modul2[m1];
          if (t != 0) for(k = 0; k < 100; k++) X1[k] = A[m][k]*t + X0[k];
          else FlagX1 = 1;}
     else
          {if(t == 0) cout << "THE SYSTEM IS UNDEFINED";
          else cout << "THE SYSTEM IS IMPOSSIBLE "; return 1;}
// the perpendicular line to the second hyperplane and intersection
// with the second hyperplane
      if (Modul1 != 0) {
          br1 = 0;
          for(k = 0; k < 100; k++) br1 += A[m1][k]*X0[k];
          t = (B[m1] - br1)/Modul1[i];
          if (t != 0) for(k = 0; k < 100; k++) X2[k] = A[m1][k]*t + X0[k];
          else flagX2 = 1;}
       else
```

```
                {if(t == 0) cout << "THE SYSTEM IS UNDEFINED";
                 else cout << "THE SYSTEM IS IMPOSSIBLE "; return 2;}
      // forming the line through intersections obtained
             for(k = 0; k < 100; k++) X3[k] = X2[k] - X1[k];
      br1 = 0; im1 = 0;
      for(k = 0; k < 100; k++) {
                    br1 += A[m][k]*X1[k];
                    im1 += A[m][k]*X3[k];   }
      // intersection of the line obtained with the first hyperplane
             t = (B[m] - br1)/im1;
      if (t == 0) {
                   cout << "THE SYSTEM IS IMPOSSIBLE ";
                else
                    if((br1 == B[m]) && (im1 == 0))
                    cout << " THE SYSTEM IS UNDEFINED";
                return 3; }
      else
          for(k = 0; k < 100; k++) XD[k] = X3[k]*t + X1[k];
          which_one += .1;
      // Assesing the accuracy reached
      if (check_out == 2) {
          Accuracy = 0.0;
          for(i = 0; i < 100; i++) Accuracy += abs(XD[i] - XL[i]);
          check_out = 0;
          for(k = 0; k < 100; k++) XL[k] = XD[k];}
                for(i = 0; i < 100; i++) X0[i] = XD[i]; }
            cout << "Finished in k = "<< which_one << " semi-
iterations " << "  The solution is : \n";
      for(k = 0; k < 100; k++) cout << XD[k]<< "  ";
      return 0;
      }
```

After running that program the following report is received:

The solution is reached in 67 semi-iterative steps (6 completed iterations).

11 13 17 19 23 29 31 37 41 43

It may be noted that three times fewer iterations were performed, and the solution obtained is the exact one.

The algorithm proposed here should be significantly expanded and improved in other ways provided the present method is used. For the example chosen, the speed and accuracy were of greater importance than the other issues that were listed at the beginning of this paper, and are followers of all known methods for solving systems of equations.

Therefore, the program was described with the condensed and simplified algorithm, which can be the core of a more complex and detailed serious algorithm.

Conclusion

From the computational point of view, the method proposed here offers an extremely simple procedure. In addition, the proposed method: 1. Requires the number of operations that is feasible by the computer; 2. It does not produce overflow and underflow effects, except in case when the size of solution causes that (when it is impossible to avoid this by any method); 3. The memory usage is proportional to the number n^2 (where n is the number of unknowns); 4. It does not change the initially given coefficients of the system (therefore, it uniformly converges to a solution for each coordinate with a relative error distributed uniformly over all coordinates); 5. If there is a solution, it always converges to it. This procedure may be initiated from any starting point of space solutions. 6. It is easy to assemble an algorithm and allows the determination in (to distinguish between) cases when the system is either impossible or in determinate. 7. It differs from the method in (Srdanov& Stefanović, 2017) as a process that is able to determine if a system is possible, impossible or indeterminate.

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ПРИМЕНЕНИЕ МЕТОДА «ВНЕШНЕЙ СПИРАЛИ» ПРИ РЕШЕНИИ СИСТЕМ ЛИНЕЙНЫХ УРАВНЕНИЙ С БОЛЬШИМ КОЛИЧЕСТВОМ НЕИЗВЕСТНЫХ

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ОБЛАСТЬ: математика, компьютерные науки
ВИД СТАТЬИ: профессиональная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Решение систем линейных уравнений n × n может представлять проблему для компьютера, особенно в тех случаях, когда требуется точное решение, и даже в тех случаях, когда количество уравнений и неизвестных относительно невелико (всего несколько тысяч). Все существующие методы сталкиваются с наименее одной из следующего ряда проблем: 1. сложность вычисления, выраженная количеством соответствующих операций, которые необходимо произвести для получения решения; 2. потенциальная возможность неограниченного роста значений результатов, что приводит к проблемам: overflow и underflow; 3. изменение значений некоторых коэффициентов в исходной системе, что приводит к неустойчивости решения; 4. дополнительные требования вследствие конвергенции; 5. в случаях большого количества уравнений и неизвестных необходимо, чтобы матрица системы была или не слишком наполнена, или была симметричной, либо диагональной, и т.д. В данной работе представлены методы решения системы линейных уравнений с произвольным количеством уравнений и неизвестных, на которых не отражаются перечисленные проблемы.

Ключевые слова: линейная система уравнений, метод «внешней спирали», гиперплоскость.

МЕТОДА „СПОЉАШЊЕ СПИРАЛЕ” ЗА РЕШАВАЊЕ ЛИНЕАРНОГ СИСТЕМА СА ВЕЛИКИМ БРОЈЕМ НЕПОЗНАТИХ

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ОБЛАСТ: математика, рачунарске науке
ВРСТАЧЛАНКА: стручни чланак
ЈЕЗИКЧЛАНКА: енглески

Сажетак:

Решавање линеарног система једначина n × n може бити проблем и за рачунар, поготово ако је потребно тачно решење, чак и када је број једначина и непознат и релативно мали (пар хиљада). Све постојеће методе су оптерећене бар једним од следећих проблема: 1. сложеношћу рачунања израженим кроз број потребних операција које је потребно извршити како би се дошло до решења; 2. потенцијалном могућношћу неограниченог раста величина међу резултата, што узрокује проблеме прекорачења опсега (overflow) и недовољне осетљивости односно прецизности (underflow); 3. променом вредности неких коефицијената у полазном систему, што узрокује нестабилност решења; 4. додатним захтевима, због конвергенције; 5. случајевима великог броја једначина и непознатих који захтевају да матрица система буде: или слабо попуњена, или симетрична, или дијагонална, итд. У овом раду презентује се метода за решавање система линеарних једначина са произвољним бројем једначина и непознатих на коју се наведени проблеми не рефлектују.

Кључне речи: линеарни систем једначина, метод „спољашње спирале", хиперраван.

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TRANSFER OF HEAT AND SPEED OF PLASMA PARTICLES TO POWDER PARTICLES IN THE PLASMA SPRAY PROCESS AT ATMOSPHERIC PRESSURE

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Summary:

For successful powder deposition and a good quality of deposited layers, the following factors are of great importance: uniform powder injection into the plasma jet, transfer of heat and velocity of plasma particles (ions and electrons) to powder particles as well as the temperature and speed of molten powder particles before the collision with the substrate. For each powder type, depending on the distribution of particle granulation (μm) and density (kg/m^3), it is necessary to determine the amount of powder supply (g/min) in the plasma for defined gas flows (l/min), types of plasma gases (Ar, He, H_2, N_2 or their mixtures) and power supply levels (kW). For the transfer of heat and speed of plasma particles to powder particles, there must be an interaction between the ions and electrons from the plasma and the powder particles. For already known plasma jet speed and temperature values at atmospheric pressure, trajectories of individual particles can be calculated using the equations of motion taking into account viscous friction and inertia. The paper describes the relation between the speed of Al_2O_3 powder injection and the velocity of individual Al_2O_3 powder particles in the plasma depending on the distance from the anode opening, as well as the relation between powder granulation and the temperature of the surface of powder particles depending on powder injection and the level of plasma gun power supply at atmospheric pressure.

Keywords: heating, particles, plasma, powder, temperatures, transfer, velocity.

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Introduction

APS - atmospheric plasma spray process is a thermal process of powder deposition which consists of injecting powder particles into the plasma jet whose particles (ions and electrons) have high speed and high temperature values and in which powder particles, molten and plasma sprayed, are deposited on the substrate surface. The plasma spray process can be described as a process of energy transfer to plasma powder particles and the transfer of energy from molten particles onto the substrate on which they are deposited. Therefore, it is very important to uniformly inject powder particles into the plasma and to achieve a good interaction between plasma particles and powder particles as well as an optimal speed and temperature of molten powder particles. Metal surface coating is an important process for many industrial purposes (Mrdak, 2016), (Mrdak, 2017, pp.30-44). The success of depositing plasma spray layers depends on skillful injection of powder particles into the plasma jet so that particles, melted without evaporating and at optimum speed, are properly deformed at the impact with the substrate so that they do not affect the substrate mechanical properties. The temperature of particles in the plasma can be controlled by varying the particle size and their physical - chemical properties, powder flow, the nature of the plasma gas and the gas flow. The process parameters should ensure the production of reproductive quality coatings on metal products for the same purpose. The parameters are based on experimental experience, and relate to: plasma arc current, composition and flow of gases and powder and a distance between a plasma gun from the substrate surface to which a coating is deposited. The general studies of the behavior of powder particles in a plasma jet during a collision with a substrate served as a basis for developing optical sensors used to determine the trajectory of particles in the plasma, as well as to measure speed and temperature of molten particles in the plasma (Vardelle et al, 1996, pp.1093-1099). Experimental studies with such sensors have demonstrated the importance of the injector (powder injector) geometry and a carrier gas flow on powder particle trajectories. For a particular morphology of particles and for a distribution of particle size granulation, particle trajectories in a plasma jet are determined by temperature and speed of particles at the time of collision with a substrate surface, and, consequently, the coating thermomechanical properties (Bianchi et al, 1997, pp.35-47).

With regard to the interaction between plasma jet particles and powder particles, this paper describes: a powder feeder with a vertical

and controlled flow of powder and carrier gas, heat transfer from plasma particles onto Al_2O_3 powder particles, the speed of Al_2O_3 powder particles depending on the speed of powder injection at certain distances from the substrate surface and the temperature of the surface of Al_2O_3 powder particles depending on the powder injection speed and power supply at certain distances. Based on the above, the paper clearly shows that the coating properties can be changed regarding the distribution of particle granulation, the nature of the plasma gas and power supply levels, which is very important for bioinert coatings based on Al_2O_3 ceramics. The aim of the study was to describe the velocity and temperature values of individual powder particles depending on the granulation and the level of plasma gun power supply at atmospheric pressure.

Injection of powder particles into the plasma jet

For a successful deposition of powder by the plasma spray process it is important to ensure uniform injection (feeding) of powder particles into the plasma jet. Different designs of powder feeders have been developed, depending on the powder feed method. The most commonly used powder feeders are those with vertical and controlled flow of powder and powder carrier gas. Powder speed (*Ws*) for vertical transport is calculated from equation (1) (Fauchais et al, 1985, pp.1171-1178), (Xiong et al, 2004, pp.5189-5200).

$$W_s = \frac{g d_p^2 \rho_p}{18 \eta g} \tag{1}$$

Where g is the acceleration of gravity, d_p – the diameter of individual particles, ρ_p – the specific mass of particles for each diameter and η - the dynamic viscosity of the carrier gas. Powder speed always defines a non-dimensional Froude number for powder and carrier gas. The Froude number for powder is calculated from equation (2) (Fauchais et al, 1985, pp.1171-1178)

$$F_{ro} = \frac{W_s}{\sqrt{g d_p}} \tag{2}$$

and for a carrier gas from equation (3),

$$F_{ro} = \frac{V_g}{\sqrt{g d_z}} \tag{3}$$

where W_s is the powder speed, V_g – the mean value of the carrier gas speed through a tube of a diameter d_s. The mean value of the carrier gas speed is calculated from equation (4),

$$V_g = \frac{4D_g}{\pi d_s^{\,2}} \tag{4}$$

where D_g is the share of the carrier gas flow. The minimum carrier gas flow and the capacity are calculated for each tube from the relation between the D_p powder flow and the D_g carrier gas flow, given by equation (5) (Xiong et al, 2004, pp.5189-5200).

$$\mu = \frac{D_p}{D_g} = 3 \cdot 10^{-5} \left(F_{ro}\right)^4 \tag{5}$$

This equation enables the calculation of the maximum flow of powder for a given carrier gas flow rate in a tube of a certain diameter (d). The optimum parameters must be determined for each powder taking into account: mean particle size, particle morphology, specific weight, chemical composition and melting temperature. Powder particles are typically injected directly into the anode or near the plasma jet exit from the anode at certain angles depending on the nozzle design and the powder characteristics. The powder should have a required kinetic energy in order to penetrate into the plasma jet. Penetration of particles is insufficient if the kinetic energy of powder particles is very small - particles move towards cooler plasma zones, remaining unmelted. If the kinetic energy of particles is too high, they pass through the entire plasma jet and also move towards cooler areas. The carrier gas share must be set for the average powder diameter and density as well as for the plasma jet density in order for powder particles to penetrate into the plasma jet axis.

Transfer of heat from the plasma to powder particles

The transfer of heat from plasma particles (ions and electrons) to powder particles takes place in two successive stages: heat transfer from plasma by convection (hot plasma flow) into powder particles and by conduction (heat transfer by conduction within powder particles). Heat transfer that takes place by plasma particle radiation onto powder particles is negligible. Heat flow (q) transmitted by convection is defined by the Newton's law and is calculated from equation (6),

$$q = \alpha S\left(T_g - T_p\right) \tag{6}$$

where: α – the coefficient of thermal convection between the plasma jet and powder particles, S - the surface of powder particles, T_g – the gas temperature, T_p – the temperature of powder particles. Heat transfer by convection takes place through the particle boundary layer. Heat transfer by conduction inside the particles is calculated from Fourier's equation (7) (Vardelle et al, 1983, pp.236–243),

$$q_t = -\lambda_p \frac{dT}{dx} \tag{7}$$

where: q_t – the heat flow density, λ_p – the coefficient of thermal conductivity, T – the temperature, and x – the distance. Determining the heat flow includes the determination of the variation of temperature and amount of heat transferred depending on time. The coefficient of heat transfer is expressed by equation (8),

$$\alpha = \frac{C_g \eta}{P_r} \frac{Nu}{dp} \tag{8}$$

where: Cg – the specific heat of the plasma gas, η – the viscosity of the gas, dp – the particle diameter, N_u – the Nusselt number, and P_r – the Prandtl number (Xiong et al, 2004, pp.5189-5200), (Chen & Pfender, 1983, pp.97–113). Heat transfer from plasma particles to the injected powder particles in the plasma depends on the type and flow of plasma gases, power supply of plasma guns, thermal conductivity and the granulation of powder particles. The mean value of thermal conductivity is calculated from equation (9) (Bouneder et al, 2009), (Hossain et al, 2009, pp.504–509).

$$K = \frac{1}{T_p - T_s} \int_{T_s}^{T_p} K(s) ds \tag{9}$$

where: K – the gas thermal conductivity, T_p – the plasma temperature, and T_s – the surface temperature of powder particles. At atmospheric pressure, the mean value of thermal conductivity (K) is significantly influenced by hydrogen or a mixture of hydrogen and argon as plasma gases as soon as a temperature above 4000 °C is reached. The influence of the ambient pressure is also important for the mean value of the thermal conductivity of the atmosphere. In the vacuum, at a low pressure of 6.7 kPa, the mean value (K) is lower by 30% as a result of pressure changes. At atmospheric pressure, heat transfer is significantly reduced for the powder particles below a granulation of 15 μm. The same effect is achieved in a vacuum for the particles of 40 μm to 50 μm at a

pressure of 6.7 kPa. Difficult melting of powder particles at low pressure is a result of lower plasma temperature, lower heat transfer coefficient and the Knudsen effect (Chen & Pfender, 1983, pp.97–113).

Speed of powder particles in the plasma at atmospheric pressure

When the distribution of velocity and temperature of the plasma jet at atmospheric pressure is known, the trajectories of individual particles can be calculated using the equations of motion taking into account viscous friction and inertia. A particular attention should be paid to the Knudsen effect that can significantly reduce the speed of particles. The Knudsen number (*Kn*) is determined from equation (10) in which (*L*) is the main free path of a particle, and (*d*) is the diameter of an unmelted particle (Chen, Pfender, 1983, pp.97–113).

$$Kn = \frac{L}{d} \tag{10}$$

At atmospheric pressure, the Knudsen number *Kn* is < 0.01 for particles smaller than 15 μm. The same effect is achieved for particles of about 50 - 60 μm at a low pressure of 6.6kPa. These experimental results were obtained in a plasma jet with a speed of 2-3 M at the nozzle outlet. In order for a jet plasma to carry powder particles, there must occur friction between plasma particles and powder particles. For example, powder particles of tungsten with high specific weight and the size of 50 μm at a distance of 60 mm from the anode opening can hardly reach a speed of 180 m/s, while particles of 18 μm reach a maximum speed of 220 m/s. Most of particles have the least values of velocity and acceleration. It is important to note that the particles with high speed must reach enough high temperature to achieve a good bond with the substrate.

Figure 1 shows the mean values of the speed of Al_2O_3 powder particles of 18 μm in the H_2/N_2(P=29kW) plasma jet depending on the speed of powder injection and the substrate distance (Vardelle et al, 2001, pp.267-284). Powder particles in the plasma have different speed values depending on the speed of injection and the injector's distance from the substrate. The speed of powder particles at distances of 5 cm, 10 cm and 16 cm from the anode opening shows that the injection speed and the distance between the anode and the substrate greatly affect the speed of particles in the plasma. In the plasma jet, the maximum speed is reached by Al_2O_3 particles injected at a rate of 22 m/s, which is the optimum injection rate for the granulation of 18 μm. At a distance of 5

cm, powder particles injected at a speed of 22 m/s reach a maximum speed of 300 m/s.

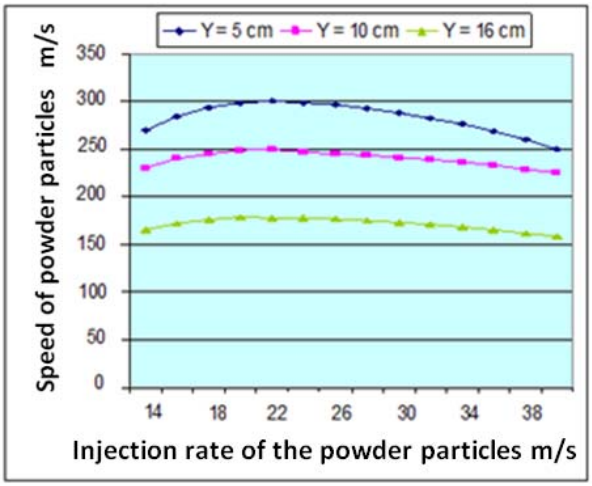

Figure 1 – Speeds particles in the plasma depending on the speed of injection and the substrate distance
Рис. 1 – Скорость частиц в плазме, в зависимости от скорости струи и расстояния между струей и покрытием
Слика 1 – Брзине честица у плазми зависно од брзине инјектирања и одстојања подлоге

The speed of powder particles decreases with the distance. At a distance of 10 cm, particles injected with an optimum speed of 22 m/s reach a maximum speed of 250 m/s, while at a distance of 16 cm they reach a speed of 170 m/s. The optimal speeds of injection of powder particles are directly related to the size of granulation. Optimum injection speed values for Al_2O_3 particles of other dimensions are shown in Table 1 (Vardelle et al, 2001, pp.267-284).

Table 1 – Optimal injection speeds for Al_2O_3 particles of individual granulations
Таблица 1 – Оптимальная скорость нанесения частиц Al_2O_3 отдельных гранулятов
Табела 1 – Оптималне брзине инјектирања честица Al_2O_3 за поједине гранулате

Particle dimensions μm	Speed Injection m/s
18	22
23	20
39	12
46	9

Surface temperature of powder particles

The quality of deposited layers is significantly influenced not only by the speed of powder particles but also by the temperature of the surface of molten powder particles, which depends on the amount of heat transferred from the plasma particles (ions and electrons) to powder particles. Figure 2 shows the surface temperature of Al_2O_3 powder particles with a granulation of 18 μm in the H_2/N_2(P=29kW) plasma jet as a function of the injection speed and the distance from the anode opening. The surface temperature of particles in the plasma jet increases initially at a distance of 4 cm from the anode opening because of heat transfer from plasma particles to powder particles in order to achieve the maximum value at a distance of 8 cm, and then decreases as the distance from the anode opening increases. For the injection speed values of 14 m/s, 20 m/s and 25 m/s, particles reach approximately the same maximum surface temperatures in the range from 2320 °C to 2325 °C. The differences in maximum surface temperatures are small, indicating that the speed of injection does not significantly affect the maximum surface temperature of particles of the same granulation. For achieving the maximum surface temperature in powder particles, the distance from the anode opening is more important than the injection speed (Vardelle et al, 1983, pp.236–243).

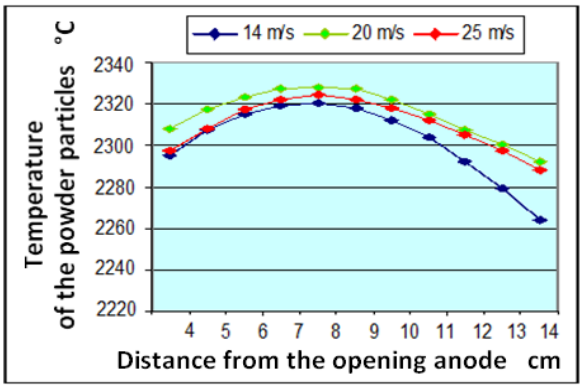

Figure 2 – Temperature of the surface of particles depending on the speed of injection and distances
Рис. 2 – Температура поверхности частиц, в зависимости от скорости струи напыления и расстояния между струей и покрытием
Слика 2 – Температуре површине честица у зависности од брзине инјектирања и одстојања

Figure 3 shows the changes in the surface temperature of Al_2O_3 powder particles of 18 μm injected with an optimum speed into Ar/H_2 plasma with a power of 21kW and 29kW.

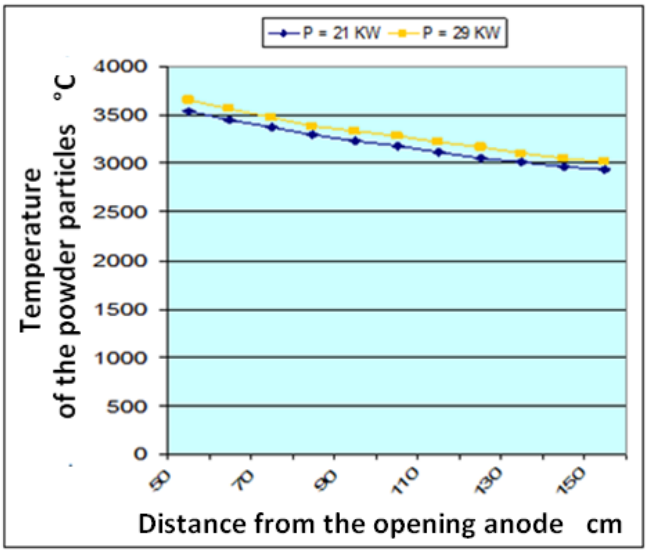

Figure 3 – Surface temperature of Al_2O_3 particles in plasma with a power of 21 and 29 kW

Рис. 3 – Температура поверхности частиц Al_2O_3 в плазме, мощностью 21 и 29 кВт

Слика 3 – Температуре површине честица Al_2O_3 у плазми, снаге 21 и 29 kW

The surface temperature of powder particles is directly related to the plasma gun power supply and the distance from the anode opening. Due to a high energy of the plasma jet, the surface temperature of powder particles is much higher than the melting temperature, which always causes a part of powder to evaporate. The highest temperature on the surface is found in powder at a distance of 50 mm from the andode opening. For the plasma gun power supply of 29kW, powder particles reach a maximum surface temperature of 3650 °C, and for the power supply of 21kW, particles reach a maximum surface temperature of 3550 °C. The influence of the plasma gun power supply on the surface temperature of powder particles is obvious. The increase of the power supply from 21kW to 29kW results in increasing the particle surface temperature difference for about 100 °C. At a distance of 140 cm from the anode opening, the particle surface temperature decreases significantly: the deposition power of 29 kW results in a drop in

temperature of 600 °C, while the deposition power of 21kW leads to the temperature drop of 500 °C. This is why it is essential to determine the site of powder injection and the distance between the substrate and the anode opening for obtaining high quality of deposited layers.

Figure 4 shows the effect of the Al_2O_3 powder particle size on the surface temperature with regard to distance.

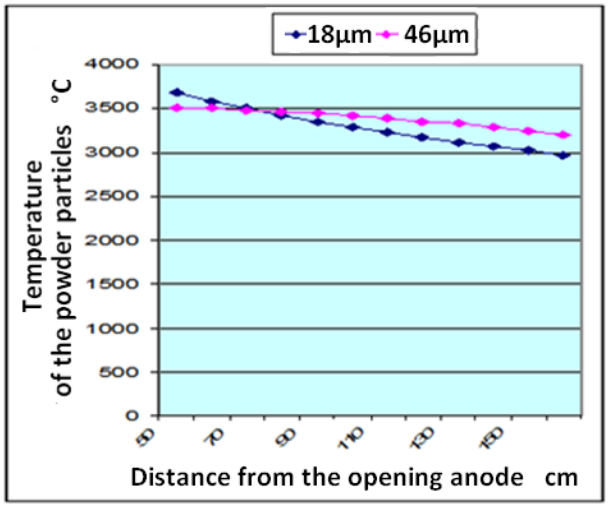

Figure 4 – The effect of the Al_2O_3 powder particle size on the surface temperature
Рис. 4 – Воздействие величины частиц Al_2O_3 порошка на температуру поверхности
Слика 4 – Утицај величине честица праха Al_2O_3 на температуру површине

Particles with a size of 18 µm reach a higher temperature than particles of 46 µm, but they also cool down faster (Fauchais, 2004, p.R86-R108). The particles reach a maximum surface temperature at a distance of 50 mm from the anode opening, and reach the lowest value at a distance of 160 mm. The maximum surface temperature of 3670 °C can be achieved at a particle size of 18 µm and the maximum surface temperature of 3510 °C is achieved at a particle size of 46 µm. With the increase in the distance of 70 cm from the anode opening, the temperature of the particle surface decreases to the same value of 3490 °C, regardless of a large difference in the particle size. Further increase of the distance from the anode opening significantly increases the difference in surface temperature and, at a distance of 160 mm, the temperature is 300 °C (Fauchais, 2004 p.R86-R108) for Al_2O_3 powder of 18 µm.

Figure 5 shows the influence of the plasma gun power supply on the surface temperature of Al_2O_3 particles of 18μm.

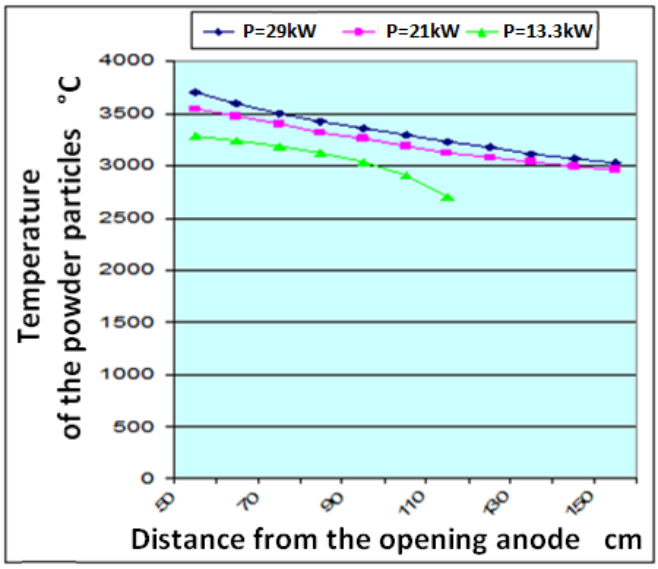

Figure 5 – Effect of the plasma gun power supply on the surface temperature of Al_2O_3 particles
Рис. 5 – Воздействие мощности плазменного распылителя на температуру поверхности частиц Al_2O_3
Слика 5 – Утицај снаге напајања плазма-пиштоља на температуру површине честица Al_2O_3

The highest surface temperature of 3670 ºC is reached by powder particles with a maximum plasma gun power of 29kW. With the decrease of plasma gun power supply to a level of 21kW, the surface temperature of powder particles also decreases for 100 °C at a distance of 50 mm from the anode opening. The difference in the surface temperature of powder particles for these two power supply levels is reduced to a level of 40 °C for a distance of 150 mm from the anode opening. In plasma without hydrogen, the plasma gun power supply is only 13.3kW. The surface temperature of powder particles is much lower at a distance of 50 mm from the anode opening - 3300 °C. This value is lower by 450 °C in relation to the value of the surface temperature of particles deposited with a Ar/H_2 mixture of gases. The plasma jet without hydrogen is much shorter, and the speed values of powder particles and the plasma are lower as well. Due to a shorter plasma jet, the surface temperature of

particles rapidly decreases with a distance from the anode opening and it is only 2750 °C at a distance of 110 mm.

Figure 6 shows the values of the surface temperature of Al_2O_3 powder particles depending on the share of hydrogen as plasma gas for the same level of the plasma gun power supply.

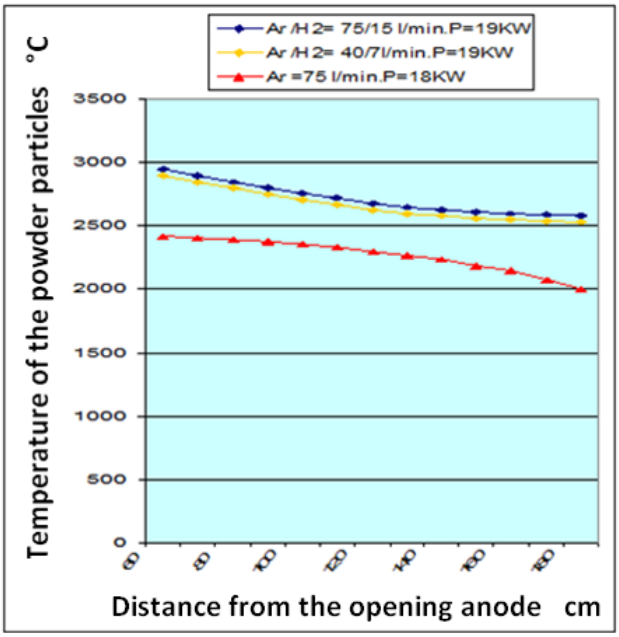

Figure 6 – Effect of H2 on the surface temperature of Al_2O_3 powder particles
Рис. 6 – Воздействие H2 на температуру поверхности частиц порошка Al_2O_3
Слика 6 – Утицај H2 на температуру површине честица праха Al_2O_3

In plasma with pure argon, the surface temperature of powder particles is lower for 500 ºC. At a distance of 60 mm, powder particles have a surface temperature of 2400 °C which drops to a level of 2000 °C at a distance of 170 mm from the anode opening. For the same power supply of 19 kW, the same argon / hydrogen ratio, and two times lower share of hydrogen, powder particles have a lower surface temperature for 50 °C, regardless of the distance from the anode opening.

Conclusion

This paper describes the speed of powder particles for the vertical transport of powder into the plasma jet. It also presents the transfer of

plasma particle (ions and electrons) speed to powder particles as well as the plasma heat transfer to Al_2O_3 powder particles at atmospheric pressure.

Based on the above, the following conclusions can be given.

Powder feeders with a vertical and controlled flow of carrier gas and powder provide a steady supply of powder into the plasma jet and a successful powder deposition on substrates by the plasma spray process.

The heat transfer from plasma particles to powder particles takes place exclusively by convection (hot plasma flow) and conduction (heat conduction) within powder particles, while the heat transfer by plasma radiation to powder particles is negligible.

Injection speed and the distance from the anode to the substrate affect the particle velocity in the plasma to a large extent. For a given granulation, particles reach a maximum speed at a certain distance and then the speed decreases with the distance. Optimal injection speed values are directly related to the size of granulation.

The surface temperature of powder particles in the plasma initially rises to a maximum value at a certain distance due to heat transfer, and then decreases with the distance from the anode opening. Reaching the maximum surface temperature of powder particles is more influenced by by the plasma gun power supply and the distance from the anode opening than by the injection speed.

This document has shown that the properties of Al_2O_3 powder coatings can be changed depending on particle granulation distribution, power supply levels and plasma spray distances.

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ПЕРЕДАЧА ТЕПЛА И СКОРОСТИ ЧАСТИЦ ПЛАЗМЫ ЧАСТИЦАМ ПОРОШКА В ПРОЦЕССЕ ПЛАЗМЕННОГО НАПЫЛЕНИЯ ПРИ АТМОСФЕРНОМ ДАВЛЕНИИ

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Резюме:

Для успешного и качественного нанесения порошкового покрытия, очень важны следующие действия: равномерное впрыскивание порошка в струю плазмы, передача температуры и скорости частиц плазмы (ионов и электронов) частицам порошка и температура и скорость расплавленных частиц порошка до соприкосновения с основанием. По каждому виду порошка в зависимости от распределения грануляции частиц (μm) и плотности (кг/м3) необходимо определить количество порошка (г/мин) в плазме для определения потока газов (л/мин), видов плазменных газов (Ar, He, H2, N2 или их смеси) и уровня мощности (кВт). Для того чтобы осуществилась передача тепла и скорости частиц плазмы на частицы порошка должно произойти взаимодействие между ионами и электронами плазмы и частицами порошка. В случае, если известны скорость и температура плазменной струи при атмосферном давлении, то можно рассчитать траекторию отдельных частиц с помощью уравнений движения, учитывая вискозное трение и инерцию. В данной работе представлены скорость напыления порошка Al_2O_3 и скорость отдельных частиц порошка Al_2O_3 в плазме, в зависимости от расстояния от анодного отверстия, а также связи грануляции порошка и температуры поверхности частиц порошка, в зависимости от впрыска порошка и уровня мощности плазменного распылителя при атмосферном давлении.

Ключевые слова: нагрев, частицы, плазма, порошок, температура, передача, скорость.

ПРЕНОС ТОПЛОТЕ И БРЗИНЕ ЧЕСТИЦА ПЛАЗМЕ НА ЧЕСТИЦЕ ПРАХА У ПЛАЗМА-СПРЕЈ ПРОЦЕСУ НА АТМОСФЕРСКОМ ПРИТИСКУ

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Сажетак:

За успешно депоновање праха и добар квалитет депонованих слојева од великог значаја је равномерно инјектирање праха у млаз плазме, пренос топлоте и брзине честица плазме (јона и електрона) на честице праха, као и температура и брзина истопљених честица праха пре судара са подлогом. За сваки тип праха, у зависности од расподеле гранулације честица (μm) и

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густине (kg/m^3), неопходно је одредити количину дотура праха (g/min) у плазми за дефинисане протоке гасова (l/min), типове плазма гасова (Ar, He, H_2, N_2 или њихове мешавине) и нивое снаге (kW). Да би дошло до преноса топлоте и брзине честица плазме на честице праха, мора доћи до интеракције између јона и електрона из плазме и честица праха. За познате брзине и температуре млаза плазме на атмосферском притиску могу се израчунати путање појединих честица применом једначине кретања, узимајући у обзир вискозно трење и инерцију. У раду је приказана веза између брзине инјектирања праха Al_2O_3 и брзине појединих честица праха Al_2O_3 у плазми у зависности од одстојања отвора аноде, као и веза гранулације праха и температуре површине честица праха у зависности од инјектирања праха и нивоа снаге напајања плазма пиштоља на атмосферском притиску.

Кључне речи: загревање, честице, плазма, прах, температуре, пренос, брзине.

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APPLICATION OF SMALL AND MICRO COGENERATION UNITS

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Abstract:

By 1973, low oil prices had provided the production of relatively cheap electricity. A sudden increase in gas prices caused a need for developing energy technologies as well as a need for increasing the efficiency of power plants. At the same time, increased environmental awareness as well as the awareness of the growing scarcity of energy sources required greater attention to preserving the environment and the existing resources, so small and micro cogeneration plants become efficient and competitive energy producers. The United States and Canada are currently lagging behind Europe and Japan in relation to the development of micro cogeneration units, partly because of differences in heating systems, energy prices and political framework. In accordance with the Kyoto Protocol, Japan is obliged to reduce its global warming i.e. gas emissions by 6% of the 1990 level. However, CO2 emissions continue to grow, which means that it is currently estimated that Japan must reduce emissions by 14% to meet the goal. Japan should promote all possible ways to effectively reduce CO2 emissions. In this regard, it continues to give support to micro cogeneration marketing, especially for models suitable for residential buildings. It is estimated that, in the next few years, energy production by cogeneration will reach 75% of the total production at the European level. In Italy, ecological energy makes 30% of the total consumption, in the Netherlands 33%, and in Denmark and the UK it is almost completely present.

Key words: micro cogeneration, small cogeneration.

Introduction

Cogeneration is the process of a combined production of heat and electricity. The reasons for the application of CHP plants are economic in nature and originate in energy efficiency. In practice, the maximum

degree of efficiency that can be achieved when it comes to electrical power is 40%, and the rest of the useful energy is used for heating (Pehnt et al, 2006).

Decentralised installations for a combined production of heat and electricity can achieve a total degree of efficiency of 90%. There has been a significant increase in a total degree of efficiency in relation to the degree of usefulness of 36% achieved by centralized condensation plants for electricity production (Despotović & Babić, 2007).

Achieving sustainable development in the energy sector requires specific quality changes to be undertaken. This includes limiting the use of resources of fossil fuels and reducing emissions by 50-80% by 2050, i.e. their adverse impact on climate change.

Directive 2004/8/EC obliges the Member States to carry out an analysis of the potential of cogeneration efficiency in their country and to establish a system of incentives to apply cogeneration. For either small (< 1MWe) or micro (< 50kWe) cogeneration installations, the directive states that it is necessary to ensure a high level of efficiency for each new capacity. The directive clarifies that high efficiency must provide primary energy saving of at least 10% compared to separate production of heat and electricity.

Small and micro cogeneration plants

Today, there are several technologies used in cogeneration plants such as piston engines, gas turbines, Stirling engines and fuel cells. Advances in technology (Rosato & Sibilio, 2013, pp. 478-491) as well as a general trend towards smaller manufacturing units have led to an increased interest in small cogeneration units, in hope that they will be able to provide electricity and thermal energy for individual objects (de Paepe et al, 2006, pp. 3435-3446).

Small cogeneration plants driven by gas engines with internal combustion are fully adapted to the needs of consumers; they use 88% of natural gas energy, thus providing cheaper and better energy, as well as long-term planning of costs, all of which is in accordance with the strictest European environmental standards (Said et al, 2005, pp. 259-262).

The EU directive on cogeneration defines micro cogeneration as a unit with a maximum capacity smaller than 50kWe, while in Germany, micro cogeneration systems are those under 15kWe for the following reasons: these systems are clearly intended for use in family homes, apartment buildings, small businesses, or hotels (Pehnt et al, 2006).

Examples of commercially available CHP units

CHP units with piston engines are commercially available and are manufactured in many different companies around the world. The market leader is the German company Senertec. A Senertec model known as Dachs generates 5.5 Kwe and 14 kW of thermal energy (Figure 1) (Cummins Inc, 2014).

Figure 1 – Senertec Dachs
Рис. 1 – Senertec Dachs
Слика 1 – Senertec Dachs

Figure 2 – PowerPlus Ecopower
Рис. 2 – PowerPlus Ecopower
Слика 2 – PowerPlus Ecopower

Other companies that produce micro cogeneration units are Power Plus with a 4.7 kWe Ecopower module which is able to modulate the capacity of 5 kWe and 15 kWe, and Vector-based CoGen (US), which uses a Kawasaki engine for combustion. According to the product specification, the Vector CoGen unit reached an electrical efficiency of

about 28 to 34 percent and an overall energy efficiency between 70 and 79%.

In Japan, YANMAR, Sanyo and AISIN companies have also developed technology with piston engines to produce micro cogeneration units.

There is an interesting development of a Honda small 1 kWe system for family houses called Ecowill (Figure 3). This Honda's cogeneration unit uses the GE160V, the world's smallest engine on natural gas. The system is based on one Otto engine and a system for the control and reduction of NOx emission concentration (Pehnt et al, 2006).

Figure 3 – Honda Ecowill
Рис. 3 – Honda Ecowill
Слика 3 – Honda Ecowill

One of the technologies suitable for cogeneration is the application of gas turbines or micro-turbines. One of the advantages of using turbines in relation to modern engines with internal combustion is extremely low emission of harmful gases. They can use both liquid and gaseous fuel, i.e. fossil or renewable energy sources. Microturbine capacity ranges from 30 kW to 350 kW.

It is also possible to use biogas and waste gases (gases of refineries, industry) as fuel. However, the biogas chemical composition affects the operation of turbines - biogas must meet requirements i.e. percentage content of the composition of the gases that make up biogas must be adequate.

The Kawasaki company offers gas turbines from 0.61 MWe (Figure 4) which emit less than 3 ppm NOx.

Figure 4 – KAWASAKI Gas Turbine Europe
Рис. 4 – KAWASAKI Gas Turbine Europe
Слика 4 – KAWASAKI Gas Turbine Europe

Figure 5 – CAPSTONE Turbines
Рис. 5 – CAPSTONE Turbines
Слика 5 – CAPSTONE Turbines

The CAPSTONE Turbine (USA) is a microturbine with a capacity of 65 kW, which can use biogas as fuel and can reach 29% of electrical efficiency and 62% of total efficiency (Figure 5).

Stirling engines are still in the testing phase, but there are also some commercial ones that could soon be in serial production: e.g. the WhisperTech company (New Zealand) is developing Stirling engines called WhisperGen, with a capacity of up to 1.2 kWe and 8 kW of heat energy.

The Swiss company GmbH focuses on making Stirling engines of 1. 1kWe.

As for systems with a capacity exceeding 1 kWe, the German companies Solo (Figure 7), Mayer and the CLA and Sunmachine (Figure 6) are involved in the development of Stirling engines.

Figure 6 – Sunmachine
Рис. 6 – Sunmachine (Stirling двигатель)
Слика 6 – Sunmachine (Stirling мотор)

Figure 7 – Solo
Рис. 7 – Solo (Stirling двигатель)
Слика 7 – Solo (Stirling мотор)

The advantage of using these systems is that they can use biomass (Alanne et al, 2014, pp. 1-10), solar power, wind or fossil fuels as a source of energy. This flexibility and high engine efficiency mean that these systems can be used for a long term period. In addition, it is necessary to reduce the cost of these systems to make them commercially competitive with other cogeneration technologies. A typical

CHP units with a 7.5 kWe Stirling engine costs approximately €2600/kWe.

KWB, from Austria, has developed a Stirling engine using pellet as a heat source. Its capacity is 1 kWe.

Dutch Enatec (Figure 8) is developing a Stirling engine with a capacity of 1 kWe (4-35 kWt). The Enatec company is concentrated on the use of fossil fuels for Stirling units.

Microgen (Figure 9) from the UK has developed one of the first small CHP units for individual homes. The unit is small and quiet enough so that it can be mounted in the kitchen. It has a capacity of 1.1 and kWe 15-36 kWt. It is designed to use natural gas as fuel, and an oil version is in preparation. The overall efficiency is rated at 90%.

Figure 8 – ENATEC
Рис. 8 – ENATEC
Слика 8 – ENATEC

Figure 9 – The cross-section of the cogeneration plant, Microgen company
Рис. 9 – Поперечное сечение когенерационной установки компании „Microgen»
Слика 9 – Попречни пресек когенерационог постројења фирме Microgen

Steam turbines are not generally intended for use in small cogeneration plants, but are suitable for remote heating systems.

The Czech company TED produces a series of Micro-CHP plants that typically use natural gas as a fuel, but some have been modified to use biogas. There are eight models that use biogas (< 1MWe), from a range of models from 23 kWe (42 kWt) to 300 kWe (370 kWt). These units have efficiency between 76 and 85% (Figures 10 and 11).

The units are designed to work with the content of methane between 55-65%, but the absolute minimum is 50%. The pressure in the combustion chamber is in the range from 1.5 to 10 kPa. 22 kW is scheduled for operation of 4,000 hours per year.

Figure 10 – Modlany, CZ, TEDOM Cento 150 SP BIO 150 kWe, 192 kWt
Рис. 10 – Modlany, CZ, TEDOM Cento 150 SP BIO 150 kWe, 192 kWt
Слика 10 – Modlany, CZ, TEDOM Cento 150 SP BIO 150 kWe, 192 kWt

Figure 11 – Petruvky, CZ, TEDOM Cento T 300 SP 300 kWe, 370 kWt
Рис. 11 – Petruvky, CZ, TEDOM Cento T 300 SP 300 kWe, 370 kWt
Слика 11 – Petruvky, CZ, TEDOM Cento T 300 SP 300 kWe, 370 kWt

BODERUS, from Belgium, produces Micro-CHP units (Figure 12) that use biogas and natural gas. Commercially available units are in a range of capacities from 10 to 383 kWe. For units using biogas, the minimum criteria for chemical composition of bio gas are set, primarily for a methane content of 80%. These units achieve 94% efficiency and are designed to operate for 8,000 hours per year (Cummins Inc, 2014).

Figure 12 – BODERUS
Рис. 12 – BODERUS
Слика 12 – BODERUS

The Italian ENERGIA NOVA company (Figure 13) produces small gas engines for CHP units of 20 kWe, 47 kWt, based on the FIAT 1200 cc engine. The overall efficiency is 97% (29% - electric power, 68% - heat power). Maintenance is recommended after every 1,500 operating hours. NOx emission is very low. An ENERGIA NOVA report says that users can save up to 40% of fuel per year using this CHP system.

Figure 13 – ENERGIA NOVA
Рис. 13 – ENERGIA NOVA
Слика 13 – ENERGIA NOVA

Figure 14 - COGENCO (300kWe)
Рис. 14 – COGENCO (300kWe)
Слика 14 – COGENCO (300kWe)

COGENCO (Figure 14), headquartered in the UK, produces and sells CHP biogas units. Cogeneration units are from 116 to 1750 kWe and from 186 to 1,737 kWt.

TOPEC BV (Figures 15, 16), from the Netherlands, produces small-CHP biogas units from 100 to 1000 kWe. A TOPEC report states that fuel saving is about 30%, and the overall efficiency is 90% (Cummins Inc, 2014).

Figure 15 – TOPEC BV (190 kWe)
Рис. 15 – TOPEC BV (190 kWe)
Слика 15 – TOPEC BV (190 kWe)

Figure 16 – TOPEC BV (340 kWe)
Рис. 16 – TOPEC BV (340 kWe)
Слика 16 – TOPEC BV (340 kWe)

Techno-economic analysis of the application of CHP technologies

Investment costs for maintenance and costs of CHP technology and condensation boilers can be found in Table 1 (http://www.erec.org).

Table 1 – Investment and maintenance costs of CHP plants
Таблица 1 – Стоимость инвестиций и содержания ТЭС
Табела 1 – Цене инвестиција и одржавања CHP постројења

	Installation price (€)	The cost of maintenance (€/y)
Senertec	13750	100
Ecopower	11750	100
Solo	25000	75
Whispertech	9000	75
Idatech	140000	35
Condensing boiler	2000	35

A feasibility analysis is done for a QSK60 plant as an illustration, based on the existing prices of energy products (Zukić et al, 2005, pp. 259-262).

Table 2 – QSK60 Specification
Таблица 2 – Спецификация QCK60
Табела 2 – Спецификација QCK60

Gas-generator set QSK60		1.16 MWe
Annual exploitation		8000 sati
The total investment	500 €/kWe	580.000 €
Operating and maintenance costs		7 €/MWhe
Electrical efficiency	33 – 40%	38%
Thermal efficiency	40 – 50%	47%
Gas prices		16 €/MWh
Heat versus gas costs		1.1
Price of electricity	2,5 / 3,5	36 €/MWhe
The government initiative	10 / 25 €/MWhe	0 €/MWhe

Table 2 provides the input data and the plant costs (Zukić et al, 2005, pp. 259-262).

Table 3, on the one hand, shows the total cost of the exploitation by MWh of electricity produced, and, on the other hand, shows the costs of a classic, separate production. After about 5.5 years, the return on investment is completely achieved. Note that this is a facility meant to operate over 100, 000 hours (Said et al, 2005, pp. 259-262).

Table 3 – Example of assessing the cost-effectiveness
Таблица 3 – Пример прогноза экономической эффективности
Табела 3 – Пример процене исплативости

Gas	39.5 €/MWhe	Heat	21.8 €/MWhe
Service	7 €/MWhe	Electric energy	36 €/MWhe
Back-up	0 €/MWhe	Initiative	0 €/MWhe
	46.5 €/MWhe		57.8 €/MWhe
Bonus	11.3 €/MWh		104.864 €/year
The cost-effectiveness coefficient	18.08%		
Period of cost-effectiveness	5.53 years		

Therefore, in addition to energy efficiency and environmental acceptability, small CHP plants are economically viable in the current circumstances. The government initiative can help to reduce the time and cost effectiveness to two or three years, because, in circumstances where care is taken of strategy of use of natural resources, clean and efficient technologies, this system is additionally subsidized for every MWh produced.

Conclusion

Micro cogeneration is a technology of the future. It will definitely find its wider application in Serbia if the Republic of Serbia decides to keep up with global energy trends. Creating favorable conditions for the realization of wider application would mean arranging legislative framework, desirable new forms of financing, and the price of electricity purchase should be included as well as environmental components.

CHP plants in Serbia could make three times more energy for heating, so the existing number of approximately 450,000 central heating customers could rise to more than one million. This would save 52% of primary energy and pollutant emissions would be reduced by 72% compared to the production of electricity from power plants and boiler heat.

Stirling engines as part of CHP plants have the best possibility of primary energy saving and CO2 emission reduction.

Solid biomass remains the main potential for a wide application for cogeneration systems at small and micro levels. The development of biogas supply systems should be developed to meet different

requirements in terms of the chemical composition of biogas and its impurities. Gas originating from biomass and used in gas engines or gas turbines is another area of interest to small and medium-sized cogeneration plants. The Stirling engine combined with a pellet burner offers a solution that should be soon available.

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ПРИМЕНЕНИЕ МАЛЫХ И МИКРО-КОГЕНЕРАЦИОННЫХ УСТАНОВОК

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Резюме:

До 1973 года низкие цены топлива позволяли производство относительно недорогой электроэнергии. Однако резкий рост цен на топливо привел к разработке новых энергетических технологий и к повышению эффективности установок. Одновременно, повышение экологической осведомленности, в том числе и осознание проблемы исчерпаемости природных энергоресурсов, требовали повышенного внимания к охране окружающей среды и оставшихся ресурсов, таким образом малые и микро-ТЭЦ стали конкурентоспособными и более востребованными в области энергопромышленности. США и Канада на сегодняшний день в этом плане отстают от европейского и японского развития микрогенерации, частично из-за различий в системе отопления, стоимости электроэнергии и в связи с политическими рамками. Подписанием Киотского протокола, Япония обязалась сократить воздействие на глобальное потепление, то есть, выбросы на 6% от общего уровня выбросов за 1990 год. Однако уровень выбросов CO2 все еще продолжает расти, а это значит, что в настоящее время Япония для достижения своей цели должна сократить выбросы на 14%. В данной связи Япония пропагандирует все возможные способы эффективного снижения выбросов CO2. Япония будет активно продолжать поддерживать маркетинг микрогенерации, особенно модели, подходящие для отопления жилых зданий. Прогнозируется, что в ближайшие несколько лет в Европе производство электроэнергии с помощью когенерации достигнет 75% от общего объема производства в целом. Так, например, в Италии производство возобновляемой энергии составляет 30% от общего объема потребления; в Нидерландах – 33%; а Дания и Великобритания почти полностью перешли на данный вид энергопроизводства.

Ключевые слова: микро-когенерация, малые ТЭЦ.

ПРИМЕНА МАЛИХ И МИКРОКОГЕНЕРАЦИОНИХ ПОСТРОЈЕЊА

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ОБЛАСТ: хемијске технологије
ВРСТА ЧЛАНКА: стручни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

До 1973. године ниске цене горива омогућавале су производњу релативно јефтине електричне енергије. Нагли пораст цена горива изазвао је потребу за развијањем енергетских технологија и повећањем ефикасности постројења. Истовремено, повећана еколошка свест, као и сазнање о све сиромашнијим изворима енергије, захтевало је посвећење веће пажње очувању околине и преосталих ресурса, па су мала и микрокогенерациона постројења постала ефикасни и конкурентни произвођачи енергије. Сједињене Државе и Канада тренутно су у заостатку у односу на развој европских и јапанских микрокогенерација, делимично због разлика у системима грејања, цене енергије и политичких оквира. Кјото протоколом Јапан је у обавези да смањи своје глобално загревање, односно емисију гасова за 6% од нивоа из 1990.године. Ипак, емисија CO_2 и даље расте. Процењује се да Јапан мора да смањи емисију за 14% како би испунио циљ, као и да промовише све могуће начине да ефикасно смањи емисију CO_2. С тим у вези, Јапан ће наставити да даје подршку маркетингу микрокогенерације, посебно оних модела који су погодни за стамбене објекте. Процењује се да у неколико наредних година производња енергије когенерацијом достигне 75% укупне производње на нивоу целе Европе. Еколошка енергија у Италији чини 30% укупне потрошње, у Холандији 33%, а у Данској и Великој Британији готово је потпуно заступљена.

Кључне речи: микрокогенерација, мала когенерација.

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Употреба полуаутоматских пушака и пушака са системом мануелног репетирања при полицијским акцијама

Решавање сложених кризних ситуација, у којима се претпоставља активан отпор и употреба средстава принуде, данас се, по правилу, поверава елитним полицијским и/или војним јединицама. Модалитет употребе у конкретном случају зависи од мноштва фактора, као што су: познато чињенично стање ситуације, позитивноправни прописи који уређују надлежност, механизам ангажовања конкретне јединице (или више њих), расположиви ресурси у одређеном тренутку и томе слично.

Јасно је да су интервенције ове врсте веома различите, па је врло важно да им се не приступа шаблонски, без обзира на то колико сличне могу бити са претходним случајевима. Ипак, могуће је направити разлику између полицијских и војних акција, са посебном напоменом да данашњи безбедносни изазови утичу и на то да се ове разлике ублажавају, те да се све интензивније увежбавају и заједничке интервенције војних и полицијских јединица, ради што ефикаснијег одговора на претње које константно еволуирају.

Врхунски стрелци у полицијским акцијама

Основни циљ ангажовања елитних јединица за специјалне намене јесте остваривање предности у кризној ситуацији и њено решавање у најкраћем могућем року. Планирање остварења оваквог циља почива на претпоставци да су оператори посебно обучени и опремљени. Организације јединица за специјалне намене, по правилу, подразумевају и специјалистичке, снајперистичке групе или тимове, који, наравно, обједињавају посебно обучене врхунске стрелце – квалификоване снајперисте.

У вези са термином снајпер у теорији се често води расправа о његовом етимолошком пореклу и оправданости употребе. Сматра се да долази из енглеског језика, од речи „snipe" (шљука). Због релативно мале величине, изузетне летачке брзине и покретљивости ових птица, ловци на њих сматрани су одличним стрелцима и називани „sniper" (ловац на шљуке, шљукар у буквалном преводу). Данас се овај израз користи за означавање врхунских стрелаца, специјалиста снајперизма, али и за њихово оружје („sniper rifle"). Срећу се и изрази попут „marksman", „sharpshooter", односно „precision rifle", када се ради о оружју. Независно од назива, реч је о врхунским стрелцима, који су по принципу добровољности у оквиру конкретне јединице комплетирали специјалистичке курсеве из области прецизног гађања и распоређени у

оквиру специјалистичке групе или тима. Такође, треба напоменути да није ретко да план и програм обуке припадника конкретне јединице подразумева и основну снајперистичку обуку, коју, у овом случају, пролазе сви оператери, али вештине и знања оних при снајперистичким групама свакако су на много вишем нивоу.

Специјалиста наоружан полуаутоматском пушком „SIG Sauer 716", у калибру 7,62×51 mm NATO. Фото: Милош Јевтић

У случају ангажовања, улога специјалисте снајперизма је веома значајна. Пре доласка преговарачког тима и интервентних снага, уколико је то могуће, специјалиста се распоређује у непосредној близини кризне ситуације ради осматрања и/или извиђања, тј. прикупљања информација о тренутном чињеничном слању, те њиховог прослеђивања организованом кризном штабу. На основу личне процене специјалиста, када год је то могуће, самостално бира своју позицију са које има довољно добар преглед околине, односно заклон. Информације које може проследити могу се односити на конфигурацију терена и инфраструктуре уколико је присутна, посебно врсту објекта, број и распоред прозора, врата, степеништа, а понекад и присутних лица унутар објеката и у непосредној близини. У случају извођења динамичког упада, специјалиста пружа подршку упадној групи или тиму, посебно током приласка објекту и упада. Према речима искусних оператера, он је „око које покрива и чувар својих колега".

Специјалисти организовани као снајперски пар. Фото: Милош Јевтић

Кад год је могуће, а врло често када су у питању полицијске акције, специјалисти се ангажују у пару. Снајперски пар чине двојица врхунских стрелаца, а један има улогу осматрача. Организовање и ангажовање снајперских тројки је чешћи случај при извођењу војних акција, односно операција. Тројку, по правилу, чине двојица специјалиста опремљених системима за прецизно гађање, а трећи члан тројке, такође врхунски стрелац, углавном је опремљен оружјем веће ватрене моћи – лаким митраљезом или аутоматском пушком. Његов задатак је да обезбеђује снајперисте током прилаза мети/метама или покрива њихово извлачење. У пракси се употреба тројки везује, углавном, за сложеније и обимније операције.

Наоружање специјалиста

Примарно наоружање специјалисте снајперизма је, наравно, пушка за прецизно гађање. Зависно од потреба интервенције, односно афинитета појединца, као секундарно наоружање може се одабрати полуаутоматски пиштољ, аутомат или оружје за личну заштиту (енг. personal defense weapon – PDW), дакле углавном компактнији системи, релативно мале масе. Одабир конфигурације наоружања врши се, када год је то могуће, на основу претпостављених потреба и познатих чињеница конкретног задатка. Специјалиста се углавном ангажује у

урбаној, односно руралној средини, што умногоме утиче на одабир система за примарно наоружање. На пример, ради извођења дејстава у руралном окружењу искусни специјалиста углавном бира оружје јачег калибра, због претпоставке да се мете могу налазити на већим даљинама.

Систем „Barrett M-95", у моћном калибру 12,7 mm, на задужењу при Специјалној бригади Војске Србије. Фото: Милош Јевтић

Популарни калибри су свакако .*338 Lapua Magnum*, као и моћни 12,7 mm. Са друге стране, у случају ангажовања у урбаном окружењу, углавном се бирају пушке средњег калибра, са врхунском прецизношћу. Међу специјалистима су веома популарни системи у калибру .308 *Winchester*, за који многи сматрају да је идеалан за средње даљине. Наравно, на одабир калибра утичу и други фактори, попут присуства цивилног становништва у рејону акције или операције. Тако, специјалиста може одлучити да користи јачи калибар и на средњим даљинама, ако је потврђено да у рејону нису присутни цивили, које би могао угрозити паљбом. Пројектил .*338 Lapua Magnum* лако ће пробити зид скоро сваког објекта, те унети озбиљан немир код противника. Имајући у виду терминалну балистику, тај калибар има довољно енергије да и на даљинама већим од 2500 метара елиминише мету.

Врсте система

Када је реч о пушкама за прецизно гађање данас се сви системи могу поделити у две велике групе: оне са системом мануелног репетирања (тзв. репетирке) и полуаутоматске системе, при чему обе имају одређене предности и недостатке.

Основна предност система са мануелним репетирањем (енг. bolt action) односи се на чињеницу да се сва енергија која се створи сагоревањем барутног пуњења преноси на пројектил који се креће кроз ожлебљену цев оружја, која је, по правилу, дужа у поређењу са цевима код полуаутоматских система. Самим тим, систем са мануелним репетирањем омогућава дејствовање на већим даљинама, уз изузетну прецизност поготка. Код полуаутоматских система знатајан део енергије при сагоревању барутног пуњења одлази на покретање радних делова механизма оружја, умањујући кинетичку енергију пројектила. То, наравно, не значи да се полуаутоматски системи не могу користити за дејства на већим даљинама. Примера ради, поменути чувени системи „*Barrett",* у серији „M-82" и калибру 12,7×99 mm NATO (.50 BMG) на добром су гласу у свету.

Пушка за прецизно гађање „Sako TRG 42", са системом мануелног репетирања у калибру .338 Lapua Magnum. Фото: Милош Јевтић

Брзина паљбе између „bolt action” и полуаутоматских система је, наравно, различита. Употреба „bolt action” система је оправданија када се претпоставља ангажовање једне мете, или врло малог броја мета, док се употреба других јавља као бољи избор у случају присуства већег броја мета, односно када треба демонстрирати већу ватрену моћ.

Независно од врсте принципа рада пушчаног система, квалитетна пушка за прецизно гађање мора објединити одлична ергономска решења, посебно кундака са амортизером трзаја и удобном образином, затим глатко окидање и, наравно, врхунску прецизност. Пушка за прецизно гађање се, без изузетака, користи у конфигурацији са оптичким нишаном. На тржишту је присутно више реномираних произвођача попут „Schmidt & Bender”, са веома популарним моделима серије „Police Marksman II”, а у широј употреби су и модели произвођача „NightForce”, затим „KAHLES”, „Vortex”, „Steiner”, „Leupold” и др. Може се употребити и посебан рачунар који за стрелца прорачунава корисне параметре. С обзиром на то да је у питању високоосетљиви електронски уређај, његова употреба у случају динамичнијих радњи је ограничена. За високу прецизност неопходан је што стабилнији ослонац приликом гађања, па се у ту сврху може монтирати и тзв. бипод, тј. двоножни подесиви ослонац.

Пушчани системи, као и пропратни оптички и електронски уређаји константно се усавршавају, дајући тако и врхунским стрелцима већи значај и потенцијал. Иако је, наравно, доступност висококвалитетних система императив у увећавању капацитета јединица за специјалне намене, највреднији ресурс и даље остаје високообучен специјалиста чијим знањем и вештинама ова софистицирана опрема даје пун потенцијал.

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Русија престигла Америку у електронском рату[1]

Америчке оружане снаге признају да су руске инвестиције у вођење електронског рата веће од оних које је Запад до сада уложио у ту област

Приликом међународног сајма наоружања, одржаног у Москви током септембра 2017. године, руски војно-индустријски комплекс приказао је стотине копнених, ваздушних и поморских система, а потписани су уговори у вредности од скоро 170 милијарди америчких долара.

На сајму су приказани и најновији системи за вођење електронског рата: *Vitebsk*, *Krasuha* и *Moskva.*

Руске дневне новине *Svobodnaya Pressa* објавиле су анализу руских система за електронско ратовање, истичући њихову употребу на последњим војним вежбама „Запад 2017". Чланак наводи да је руска супериорност у овим системима не само квантитативна већ и квалитативна. Током последње деценије више од десет нових система прошло је тестирање и разне евалуације: *Borisoglebsk-2*, *Algurit*, *Rtut-BM,* I*nfauna*, *Krasuha-4*, *Moskva-1*, *Parodist*, *Lorandit-M*, *Leer-3*, *Lesochek*, *Less, Magnyi-REB*, *Pole-21, Hibini* и *Vitebsk*. Међу њима су и системи намењени за локалне акције кратког домета чији је циљ заштита летелица, бродова и војника у одређеним оперативним рејонима, затим системи за

[1] September 19, 2017 The National Interest

неутрализовање експлозивних детонатора у импровизованим експлозивним направама. Листа укључује и снажне системе са широм зоном операција, као што су *Krasuha-4* и *Moskva-1*. У чланку се наводи да су бар два система израђена „по принципима који до сада нису употребљавани у радио-инжењерингу". Није више потребно поседовати велике комплексе радијационих антена са јаким изворима напајања ради потискивања непријатељевих радио-сигнала у целом спектру. Данас модерни начини откривања и процесуирања омогућава овим системима да добију тачну копију непријатељевог сигнала и затим генеришу лажни сигнал који шаљу аналогним путем по параметрима битним за противудар. То значи „да се непријатељу враћа лажни сигнал у искривљеној форми", што се назива „неенергетском интерференцијом".

Чланак у дневном листу *Svobodnaya Pressa* наводи и да систем *Moskva-1,* који је развила компанија KRET, спроводи радио-технички обавештајни рад: скупља информације о изворима електромагнетског зрачења у радијусу од 400 км, укључујући изворе зрачења од авиона, самонаводећих ракета, мобилних и стационарних система ваздушне заштите, радио-одашиљача и других објеката који емитују радио-таласе. Ови сигнали се анализирају и класификују према својим изворима. У случају масовног напада према непријатељу, прикупљене информације се одашиљу према девет система за електронски рат, који „ослепљују" противника тако што генеришу сметње, а ти подаци се даље шаљу руским снагама за одбрану ваздушног простора. Тачне спецификације у погледу карактеристика и техничких детаља овог система су војна тајна. Међутим, у случају масовног непријатељевог напада, *Moskva-1* помаже у прикупљању података о свим његовим циљевима који су потребни за њихово откривање, препознавање и праћење. Ова информација је изузетно важна за системе електронског ратовања, јер ови ометачи добијају информацију о противничким системима којом могу извршити њихово оптимално потискивање у одређеном електронском опсегу.

Подаци добијени од система *Moskva-1* корисни су за системе противваздушне ракетне одбране, укључујући и најновији систем S-400 који има исти радијус откривања противника као и *Moskva-1.* У случају непријатељевог напада, S-400 „види" објекат и одређује његову брзину и смер лета, док систем *Moskva-1* има могућност идентификације циља, што значи да може да одреди да ли се ради о ракети или авиону, па чак и о типу летелице или ракете, што умногоме олакшава пресретање. Све донедавно није било могуће сместити систем таквих могућности на возило са три шасије. Овакав развој омогућила је транзиција са аналогних на дигиталне технологије. У овом случају дошло је до значајног раста брзине компјутерског процесуирања, што је омогућило увођење нових, напреднијих алгоритама за обраду података.

У чланку се даље наводе детаљи система *Krasuha-4,* такође базираног на дигиталним технологијама, намењеног одбрани командних места, као и индустријских и административних комплекса. Систем врши потискивање електронског зрачења стационарних и мобилних објеката користећи ефекте интерференције у смислу разликовања противничких и савезничких сигнала у области операција система *Krasuha-4.* Систем је у могућности да „ослепи" не само противничке ловце и бомбардере већ и земаљске радаре, летелице AWACS, па чак и шпијунске сателите с обзиром на то да је радијус дејства система 300 км у вертикали и хоризонтали. Развој система *Krasuha-4,* започет је 1995. године, а усвојен је у наоружање руских оружаних снага тек 2012. године.

Током 2015. године систем *Krasuha-4* постављен је у руској војној бази *Khmeimim,* у Сирији. Током напада америчких крстарећих ракета на аеродром сиријске војске различити медији су известили да је систем успео да скрене неке од ракета *Томахавк* са циља. Критичари су се одмах успротивили овој анализи, јер се ова крстарећа ракета наводи путем геолокације и не користи радар за своје вођење него оптоелектронски систем високе резолуције. Ипак, у чланку се наводи да је систем *Krasuha-4* своје дејство усмерио на електронске склопове ракете. Ови системи били су употребљени у великом број руских војних вежби у одбрани циљева које су „нападали" ловци бомбардери Su-24 и Su-34 који нису налазили циљеве заштићене поменутим системом, па су се враћали у базе необављеног задатка.

Трећа технологија коју помиње дневни лист *Svobodnaya Pressa* односи се на систем *Vitebsk.* Ради се одбрамбеном систему намењеном хеликоптерима Mi-8 у одбрани од преносивих противваздухопловних ракета. Овај систем могу користити и јуришни авиони и хеликоптери у мисијама напада на копнене циљеве. Опремљен је инфрацрвеним и ултраљубичастим уређајима за проналажење смера испаљивања ракета, опремом за откривање ласерског и радарског озрачивања, оптоелектронским уређајем за заслепљивање, уређајем за ометање радара и опремом за отпуштање лажних циљева; другим речима – одбрани од интерференције свих активних и пасивних радара, термалних, ласерских и оптоелектронских уређаја.

Руске оружане снаге раде и на другим системима за електронско ратовање који би били способни за брзу и ефикасну акцију против све модернијих западних беспилотних система. Једна од таквих технологија је и недавно најављени *Repellent* који је пројектован за откривање и неутрализовање беспилотних летелица на даљинама до 35 км, дању и ноћу, за време лошег времена, а може дејствовати чак и на температурама нижим од минус 45 степени. Систем *Repellent* првенствено је намењен борби против ројева минијатурних беспилотних летелица које тренутно убрзано усавршавају америчке оружане снаге.

Развој овог система иде у правцу смањивања габаритета, тако да ће у будућности бити преносивог облика.

Руски развој и употреба оваквих различитих система за електронско ратовање никако не одговара америчким и НАТО снагама. Године 2016. дошло се до закључка да је Пентагон запоставио електронско ратовање и на тај начин омогућио Русији стицање знатне предности. Американци су закључили да руске оружане снаге имају чете, батаљоне, па чак и бригаде са одговарајућом опремом и посебним ланцем командовања које су посвећене електронском ратовању. Након тога, током 2017. године, америчке оружане снаге почињу интензивно да раде на овој технологији како би сустигли руски напредак у овој области. Америчка војска тражи да све беспилотне летелице великог домета добију могућност електронског ратовања. Русија је недавно, у близини украјинског ратишта, употребила беспилотне летелице типа *Orlan-10* које имају могућност ометања мобилних телефона. Чини се да је овај систем у употреби и у Сирији.

Иако Америка предузима крупне кораке у овој области, велики број разноврсних напредних руских уређаја за електронски рат представиће велики проблем америчким и НАТО снагама, нарочито ако се узме у обзир да ефикасна употреба уређаја за електронско ратовање до два пута повећава потенцијал копнених оружаних снага, а умањује могућност губитка авиона и до шест пута.

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Убрзано опремање[2]

Поновно интересовање за копнене операције обухвата обнављање искустава стечених за време хладног рата, Првог и Другог ирачког рата и операција на Балкану. До тога долази након сукоба у Украјини и први пут, после две деценије, долази до опремања европских армија за директан сукоб једнаких војних снага. Такође, долази до промене приоритета од заштите и концепта преживљавања оружаних снага, што је био приоритет у Авганистану, до концепта повећане убојитости

Тенковски топови

Тенкови, односно тенковски топови, остају на првој линији одбране у европским армијама. Иако је технологија развоја тенковских топова највише фокусирана на развој муниције и модернизовање постојећих пројекта, упоредо тече и развој следеће генерације топова.

[2] Jane's Defence Weekly 15 November 2017

Програм модернизовања немачког тенка *Leopard 2A7V* обухвата унапређење основног наоружања и то тако што ће тенкови *Leopard 2A4* бити унапређени на стандард 2A7V са новим топом L55A1 компаније *Rheinmetall*. Овај топ има за 20% већи притисак од постојећег топа L55 када се користи муниција новог типа. Поред тога, нова верзија топа L55A1 поседује и модернизовани систем за избацивање празне чауре.

Током септембра 2017. године компанија *Rheinmetall* објавила је потписивање уговора за модернизацију 104 немачких тенкова *Leopard 2* – 68 2A4, 16 2A6 и 20 2A7 на стандард 2A7V, што подразумева уградњу новог топа L55A1. Модернизовани тенкови биће опремљени новим термалним уређајима, ласерским даљиномерима, унапређеним компјутерима за управљање ватром и контролним конзолама. Испоруке првих модернизованих тенкова *Leopard 2A7V* очекују се током 2020. године.

У међувремену, иако британски програм за продужење животног века тенка *Challenger II* (Life Extension Programme – LEP) не покрива модернизовање олученог тенковског топа 120 мм L55 (познатог под ознаком L30A1), врло је вероватно да ће то бити урађено преко посебног програма британског министарства одбране. Министарство одбране је претходно извршило процену адекватности топа глатке цеви 120 мм на основу сада отказаног програма унапређења убојитости тека *Challenger II.*

Понуда компаније *Rheinmetall* у оквиру програма LEP састоји се од опционе инсталације топа глатке цеви 120 мм L55 који би омогућио тенку *Challenger II* испаљивање једноделних тенковских граната, укључујући и поткалибарна зрна са пенетраторима (APFSDS). Како није преостао велики број граната 120 мм за топ са олученом цеви L30A1 које је производила сада угашена фабрика *Birtley* која је пословала у оквиру компаније *BAE Systems,* то ће омогућити гађање новом муницијом која се производи у Немачкој и САД и представљати добродошло унапређење за топ тенка *Challenger II*. Међутим, постоји могућност да британско министарство одбране ипак задржи постојећи топ са олученом цеви због могућих високих трошкова који би настали изменом куполе.

У јуну 2016. године компанија *Rheinmetall* открила је нови топ са глатком цеви од 130 мм под ознаком L51. Ово оруђе могло би бити коришћено у новој генерацији основног копненог борбеног система (*Main Ground Combat System* – MGCS) који би могао да од 2035. године замени тенкове *Leopard 2* и *Leclerc*. Топ L 51 је знатно убојитији од постојећег топа 120 мм са притиском у комори топовске цеви од 880 МПа. Компанија *Rheinmetall* тврди да овакво повећање притиска, уз коришћење дужих пенетратора, обезбеђује 50% већу пробојност оклопа у поређењу са постојећим топовима од 120 мм.

Challenger II (Life Extension Programme – LEP)

Ова компанија пројектовала је и нову генерацију граната типа APFSDS, под ознаком KE2020, која има полусагорљиву чауру, ново пропулзивно пуњење и нови дуги пенетратор од волфрама. С обзиром на то да кинетичка зрна велике брзине, као што су APFSDS, имају одличан ефекат против активних система заштите, највероватније да ће развој оваквих граната представљати тренд у следећим годинама. Поред тога, компанија развија и нову високоексплозивну, ваздушно-распрскавајућу гранату DM12 која ће увести још већи спектар напада.

Русија, држава која је узета као пример потенцијалног противника европских армија, за свој тенк *Armata* T-14 развила је топ 125 мм глатке цеви 2A82 који може испаљивати више различитих пројектила, укључујући и *Vacuum-1,* гранату типа APSFDS чији је пенетратор дужине 900 мм и ваздушно-распрскавајућу гранату *Telnik*. Обе гранате развијене су за употребу у топу 2A82. Постоје разне спекулације у вези с тим да Русија планира у будућности опремање тенка T-14 новим топом од 152 мм 2A83 којим би био опремљен и нови ловац тенкова BAM. Такав топ био је развијен за програм тенка T-95 (Object 195), али за сада нема доказа да је такво оперативно оруђе у употреби.

Кинетички уместо вођеног пројектила

У току је дебата која се тиче употребе муниције са кинетичком енергијом против миниције са хемијском енергијом за напад на

оклопљене циљеве Предност кинетичких пројектила је њихова велика брзина и могућност пробоја конвенционалног оклопа. То је довело да развоја нових пројектила типа APSFDS, као што су гранате DM63A1 и Orbital ATK M829A4 компаније *Rheinmetall*. Упоредни развој вођене муниције довео је до развоја вођених ракета које се лансирају из тенковског топа којим је могуће гађати осетљиве тенковске области као што су врх куполе или трупа.

Кинетички пројектили у теорији нуде краћи борбени ангажман у поређењу са вођеним пројектилима и омогућавају већи број ангажованих и „уништених" циљева с обзиром на већи број граната у борбеном комплету и брже испаљивање. Већа брзина кинетичких пројектила (5 маха) омогућава им и заобилажење већине система за активну заштиту који нису у стању да довољно брзо открију, класификују и одговоре против надолазећег пројектила. Европске армије су у процесу набавке већег броја модерних кинетичких пројектила, а нарочито Пољска, која захтева комплетну замену својих противтенковских граната DM33A2.

Предност вођених пројектила је у том што им се експлозивно дејство не смањује приликом лета до удаљене мете. С друге стране, вођени пројектили су спорији и, према томе, осетљивији на дејство активних система за заштиту, али их је могуће наводити или могу бити самонавођени на осетљиве делове тенка.

Вођени пројектили лансирани из цеви топа, као што су украјински *Falarick* 90 и 105 који се лансирају из топова нижег калибра *Cockerill* LCRS90MP и CT-CV 105HP, повећавају учинак таквих топова на циљане мете. Пољска је представила ново оклопно возило *Wilk* (вук) верзију оклопног возила *Rosomak* 8X8 опремљеног куполом *Cockerill* CT-CV 105HP.

Када се ради о топовима већег калибра, ласерски вођени пројектили *Konus* 120 mm и *Kombat* 125 mm омогућавају пробој до 700 и 750 мм ваљаног челика и то иза експлозивно-реактивног оклопа. *Kombat* је предвиђен за употребу са украјинских тенкова T-72AMT, T-84 и BM *Oplot*. Руска вођена ракета 9K119M *Refleks* води се са тенкова T-80BVM и T-90M, односно из њихових топова типа 2A46M1 и 2A46M-4. Западно-европске државе још нису развиле компатибилне пројектиле, него су концентрисане на развој вођених противтенковских ракета.

Wilk (вук) верзија оклопног возила Rosomak 8X8, опремљеног куполом Cockerill CT-CV 105HP

Тестна вожња руског тенка T-90M

Противтенковско вођено наоружање

Француска вођена ракета средњег домета *Missile Moyenne Portee* (ММР) пројектована је као преносиво оружје, али се може монтирати и на возило. Ова ракета замениће ракету *Javelin* у наоружању француске војске.

У току је интеграција ракете ММР на куполу *Nexter Systems* Т40, а прва пробна гађања биће одржана током 2018. и 2019. године. Ова купола биће уграђена на вишенаменско оклопно возило *Jaguar* 2020. године. Ракета ММР понуђена је и Аустралији у оквиру њеног програма Land 400 Phase 2.

Турска компанија FNSS приказала је своју противтенковску даљински управљану куполу – *Anti-Tank Remote Controlled Turret* (ARCT) током маја 2017. године. Овом куполом биће наоружана нова генерација турских противтенковских возила. Купола ће имати пар противтенковских вођених ракета (ПТВР), руски *Kornet-E* или турски *OMTAS,* као и митраљез 7.62 мм.

Русија предвиђа уградњу ПТВР типа *Kornet* на своја тактичка возила типа 92 9Р163-3 *Tigr*, на куполу *Epoch* којом је опремљено борбено возило пешадије *Bumerang*, гусеничар *Kurganets* и тешко борбено возило пешадије Т-15. Предвиђа се пораст броја оклопних и других возила на којима ће бити омогућено монтирање противтенковских вођених ракета *Kornet*-P/E и *Kornet* D/EM .

Чланице НАТО-а које су у последње две деценије биле ангажоване у асиметричним операцијама против побуњеника сада се убрзано враћају на конвенционалне противоклопне концепције због „појачаних претњи" са истока изазваних сукобима у Украјини. Европски и неевропски добављачи траже профит у овој ситуацији. Израелска компанија *Rafael* преко *Eurospike,* своје компаније у Европи, покушава да прода своје противтенковске вођене ракете типа *Spike* на источноевропском тржишту. Очекује се да ће поменута компанија потписати уговор са Литванијом о опремању литванских возила *Boxer* ракетама *Spike Long Range,* а већ је потписала уговор са Хрватском о опремању осам хрватских оклопних модуларних возила. Компанија агресивно наступа и на тржиштима Словеније и Румуније. Исто ради и компанија *Raytheon/Lockheed Martin* која је већ уговорила продају својих ПТВР *Javelin* Чешкој, Естонији и Литванији.

Ракете и даљински управљане оружне станице

Иако је противоклопна борба примарна ставка у модернизацији оружаних снага европских држава, ради се и на попуњавању празнине између ПТВР и оружја мањег калибра, као што су аутоматски топови и ракете.

Ракета CiRit 70mm турске компаније *Roketsan,* првобитно намењена за употребу на авионима, прилагођена је употреби на систему који је монтиран на возило. Ради се о систему који испаљује ракете са полуактивним системом вођења са четвороцевним лансером. Овакав лансер монтиран је на тактичко оклопно возило *Nurol makina* у конфигурацији 4X4.

Сличан систем монтиран је на лако извиђачко возило *Supacat* са ракетама 70 мм из серије *Nammo* M282.

Поред лаких ракетних система, у Европи се све више развијају даљински управљане оружне станице (ДУОС). Турска компанија *Otokar* приказала је своју ДУОС *Mizrak* са стабилизованим аутоматским топом MK44 од 30 мм и паром ПТВР типа L-UMTAS. Слично решење представља и купола *Bozok*-25 MKT опремљена топом M242 од 25 мм који знатно повећава ватрену моћ оклопног транспортера пешадије *Arma* у конфигурацији 6X6.

Словеначка компанија *Valhalla Turret* недавно је објавила да ради на развоју даљински управљане оружне станице *Hildgard* 57 *Medium Remote Gun System* опремљене топом L/76.6 са руског вучног противваздушног топа S-60. Ова ДУОС може се поредити са руским системом AU-220M *Baikal.*

Увођење топа 40 мм са телескопском муницијом CTAS (Case-Telescoped Armament Systems) у наоружање оклопног борбеног возила, типа британског *Ajax* и француског *Jaguar* EBRC, довешће до велике промене у ватреној моћи овог типа оклопних возила. Граната од 40 мм има чак четири пута већу експлозивну снагу од гранате 30 мм. Велика Британија је поручила чак неколико стотина оваквих топова којима ће бити наоружана оклопна возила *Scout* и *Warrior.*

Слојевито преживљавање

Са развојем убојитости топова и ракета развијају се и нови типови оклопа, активни системи заштите и други облици опреме који чине „слојевито преживљавање".

Концепт „слојевитог преживљавања" описује концентричне слојеве заштите око возила. Први слој је „не буди виђен" којим се маскира оклопно борбено возило. Други слој представљао би концепт „не буди погођен" и ту ускачу „меки" и „тврди" системи за активну заштиту који се користе за одбрану од надолазећих пројектила као што су ПТВР и ракете. Трећи слој био би „не буди пробијен", а фокусира се на отпорност оклопа на пенетрацију бојеве главе вођене ракете или кинетичког пројектила. Последњи слој је „не буди уништен", који служи за умањење штете по возило и посаду у случају пробијања возила ракетом или кинетичким пројектилом.

Развој у области првог слоја „не буди виђен" креће се у правцу управљања откривљивим зрачењима са возила у областима инфрацрвеног, радарског и звучног спектра. Компанија *Saab* развила је мобилни прекривач *Barracuda Mobile System* (MCS) који би могао да се користи у возилима специјалних јединица, а могао би бити понуђен и Аустралији у оквиру програма Land 400 Phase 2.

Мобилна прекривка Barracuda Mobile System (MCS) на тенку Leopard 2

Британска армија одлучила је да набави прекривке типа *Barracuda за* своја возила *Ajax* који ће у овом случају бити саставни део опреме возила. Тенкови *Leopard* 2, у саставу оружаних снага Канаде, Данске и Немачке, биће опремљени овим маскирним системом.

По питању следећих слојева заштите, француска компанија *Nexter Systems* одлучила је да своје борбено возило пешадије *Vehicule Blinde de Combat d infanterie* (VBCI) опреми решеткастим оклопом ради заштите од ракета ручних бацача. Ова возила биће опремљена и системом за ометање импровизованих експлозивних направа и додатним заштитним оклопом испод возила.

Велика Британија се, по традицији, ослања на оклоп као примарни елемент преживљавања возила, често на штету мобилности. Оклопно

возило *Warrior* добило је нови модуларни оклоп са додатком керамичких легура.

Пољска је у међувремену развила две модернизоване верзије тенка Т-72, ознака PT-17 и PT-91M2. Тенк PT-17 опремљен је модуларним композитним оклопом са плочама на предњој и задњој страни, као и на бочним деловима тенка, затим решеткастим оклопом на задњој страни, оклопним страницама које покривају точкове и системом за упозоравање од ласерског зрачења OBRA-3. Тенк PT-91M2 опремљен је додатним решеткастим оклопом који се налази на задњој страни куполе и трупа, без бочних оклопних страна, али и без модуларних оклопних плоча. Уместо тога, тенк је опремљен експлозивно-реактивним оклопом типа ERAWA-1 и ERAWA-2 на бочним странама и на куполи, који умањују пенетрацију кумулативних пројектила и до 70%.

Када се ради о системима активне заштите, треба рећи да европске државе почињу да развијају нове технологије, али и да модификују постојеће системе. Немачка је приказала свој мултифункционални самозаштитни систем (Multifunction Self-Protection System – MUSS) који је намењен заштити нових борбених возила пешадије *Puma*. Овај „меки" систем заштите користи систем упозоравања од ласерске озрачености и ултраљубичасти оптички детектор откривања лансирања ракета ради праћења и категоризације ПТВР, мултиспектралне димне гранате које се лансирају са возила с циљем да маскирају и ометају надолазећи противтенковски пројектил.

Поред тога, један број европских земаља инвестира у технологије „чврстих" активних система заштите. Немачка компанија ADS пројектовала је „чврсти" активни систем заштите под ознаком активни систем заштите. Овај уређај пресреће надолазеће ракете на даљинама од 1 до 2 метра од заштићеног возила путем испаљивања противмера. Свака од лансираних противмера састоји се од три експлозивна пуњења која пресрећу пројектиле из више праваца, укључујући и оне који нападају врх куполе.

Систем је успешно тестиран против широког спектра оружја, укључујући руски ПТВР *Kornet*, ручни ракетни бацач RPG-7, амерички ПТВР TOW2, шведски ПТВР BILL 1, као и ручни ракетни бацач AT4. Систем је испробан у више од 300 ватрених тестова у којима је пресрео три руска ПТВР *Kornet*, 535 ракета RPG-7 и пет ПТВР TOW2. Откривање надолазећих пројектила извршено је у 95% случајева, док је пресретање успешно извршено у 85 до 90% случајева са ПТВР и у 80% случајева када су питању ракете ручних ракетних бацача.

Овај активни систем одбране (АСД) већ је продат Малезији за употребу на њиховим тенковима *Leopard 2SG*. Немци тврде да је њихов АСД чак ефикаснији од израелског система *Trophy* који је једини тестиран у ратним условима.

Vučković, D., SAVREMENO NAORUŽANJE I VOJNA OPREMA / MODERN WEAPONS AND MILITARY EQUIPMENT, pp.452-464

Турска компанија *Aselsan* наставља са развојем свог „чврстог" система активне одбране *Akkor* који је планиран за уградњу у нови домаћи тенк *Altay,* иако то још није званично одлучено. Систем је могуће уградити и на друга оклопна возила која се налазе у арсеналу турске војске.

Током децембра 2016. године Холандија је склопила уговор са компанијом *BAE Systems* ради уградње израелског „чврстог" система активне одбране *Iron Fist* на своја борбена возила пешадије CV9035, а прво такво возило приказано је 2017. године. Она је прва европска земља која је уградила систем активне одбране на своја борбена возила пешадије.

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ПОЗИВ И УПУТСТВО АУТОРИМА
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ПОЗИВ И УПУТСТВО АУТОРИМА О НАЧИНУ ПРИПРЕМЕ ЧЛАНКА

Упутство ауторима о начину припреме чланка за објављивање у *Војнотехничком гласнику* урађено је на основу Акта о уређивању научних часописа, Министарства за науку и технолошки развој Републике Србије, евиденциони број 110-00-17/2009-01, од 09. 07. 2009. године. Примена овог Акта првенствено служи унапређењу квалитета домаћих часописа и њиховог потпунијег укључивања у међународни систем размене научних информација. Засновано је на међународним стандардима ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999 и ISO 5122, односно одговарајућим домаћим стандардима.

Војнотехнички гласник / Vojnotehnički glasnik / Military Technical Courier (втг.мо.упр.срб, www.vtg.mod.gov.rs, ISSN 0042-8469 – штампано издање, e-ISSN 2217-4753 – online, UDC 623+355/359) јесте мултидисциплинарни научни часопис Министарства одбране Републике Србије, који објављује научне и стручне чланке, као и техничке информације о савременим системима наоружања и савременим војним технологијама. Часопис прати јединствену интервидовску техничку подршку Војске на принципу логистичке системске подршке, области основних, примењених и развојних истраживања, као и производњу и употребу средстава наоружања и војне опреме, те остала теоријска и практична достигнућа која доприносе усавршавању свих припадника српске, регионалне и међународне академске заједнице, а посебно припадника Министарства одбране и Војске Србије.

Министарство просвете, науке и технолошког развоја Републике Србије, сагласно одлуци из члана 27. став 1. тачка 4), а по прибављеном мишљењу из члана 25. став 1. тачка 5) Закона о научноистраживачкој делатности („Службени гласник РС”, бр. 110/05, 50/06-испр. и 18/10), утврдило је категоризацију Војнотехничког гласника, за 2016. годину:

за област технолошки развој:

– на листи часописа за материјале и хемијске технологије:

категорија водећи научни часопис националног значаја **(М51)**,

– на листи часописа за електронику, телекомуникације и информационе технологије:

категорија научни часопис националног значаја **(М52)**,

– на листи часописа за машинство:

категорија научни часопис националног значаја **(М52)**,

за област основна истраживања:

– на листи часописа за математику, рачунарске науке и механику:

категорија научни часопис националног значаја **(М52)**.

Усвојене листе домаћих часописа за 2016. годину могу се видети на сајту Војнотехничког гласника, страница *Категоризација часописа* (Министарство просвете, науке и технолошког развоја Републике Србије још увек није објавило званичну категоризацију научних часописа за 2017. годину).

Детаљније информације могу се пронаћи и на сајту Министарства просвете, науке и технолошког развоја Републике Србије.

Подаци о категоризацији могу се пратити и на сајту КОБСОН-а (Конзорцијум библиотека Србије за обједињену набавку).

Категоризација часописа извршена је према Правилнику о поступку и начину вредновања и квантитативном исказивању научноистраживачких резултата истраживача, који је прописао Национални савет за научни и технолошки развој (Службени гласник РС, број 38/2008).

У складу са овим правилником и табелом о врсти и квантификацији индивидуалних научноистраживачких резултата (у саставу Правилника), објављени рад у Војнотехничком гласнику вреднује се са 2 бода (категорија М51) и 1,5 бод (категорија М52).

Часопис се прати у контексту Српског цитатног индекса – СЦИндекс (база података домаћих научних часописа) и Руског индекса научног цитирања (РИНЦ). Подвргнут је сталном вредновању (мониторингу) у зависности од утицајности (импакта) у самим базама и, посредно, у међународним (Clarivate Analytics) цитатним индексима. Детаљи о индексирању могу се видети на сајту Војнотехничког гласника, страница *Индексирање часописа*.

Војнотехнички гласник омогућава и примењује Creative Commons (CC BY) одредбе о ауторским правима. Детаљи о ауторским правима могу се видети на сајту часописа, страница *Ауторска права и политика самоархивирања*.

Радови се предају путем онлајн система за електронско уређивање АСИСТЕНТ, који је развио Центар за евалуацију у образовању и науци (ЦЕОН).

Приступ и регистрација за сервис врше се на сајту www.vtg.mod.gov.rs, преко странице *АСИСТЕНТ* или *СЦИНДЕКС*, односно директно на линку aseestant.ceon.rs/index.php/vtg.

Детаљно упутство о регистрацији и пријави за сервис налази се на сајту www.vtg.mod.gov.rs, страница *Упутство за е-Ур: Електронско уређивање – АСИСТЕНТ*.

Потребно је да се сви аутори који подносе рукопис за објављивање у Војнотехничком гласнику региструју у регистар ORCID (Open Researcher and Contributor ID), према упутству на страници сајта *Регистрација за добијање ORCID идентификационе шифре*.

Војнотехнички гласник објављује чланке на српском, руском и енглеском језику (arial, српска ћирилица или српска латиница, величина слова 11 pt, проред Single).

Поступак припреме, писања и уређивања чланка треба да буде у сагласности са *Изјавом о етичком поступању* (http://www.vtg.mod.gov.rs/izjava-o-etickom-postupanju.html).

Чланак треба да садржи сажетак са кључним речима, увод, разраду, закључак, литературу и резимеа са кључним речима на енглеском и руском језику (без нумерације наслова и поднаслова). Обим чланка треба да буде око једног ауторског табака (16 страница формата А4 са проредом Single), а највише 24 странице.

Чланак треба да буде написан на обрасцу за писање чланка, који се у електронској форми може преузети са сајта на страници *Образац за писање чланка*.

Наслов

Наслов треба да одражава тему чланка. У интересу је часописа и аутора да се користе речи прикладне за индексирање и претраживање. Ако таквих речи нема у наслову, пожељно је да се придода и поднаслов. Наслов треба да буде преведен и на енглески и руски језик.

Ови наслови исписују се испред сажетка на одговарајућем језику.

Текући наслов

Текући наслов се исписује са стране сваке странице чланка ради лакше идентификације, посебно копија чланака у електронском облику. Садржи презиме и иницијал имена аутора (ако аутора има више, преостали се означавају са „et al.“ или „и др.“), наслове рада и часописа и колацију (година, волумен, свеска, почетна и завршна страница). Наслови часописа и чланка могу се дати у скраћеном облику.

Име аутора

Наводи се пуно име и презиме (свих) аутора. Веома је пожељно да се наведу и средња слова аутора. Имена и презимена домаћих аутора увек се исписују у оригиналном облику (са српским дијакритичким знаковима), независно од језика на којем је написан рад.

Назив установе аутора (афилијација)

Наводи се пун (званични) назив и седиште установе у којој је аутор запослен, а евентуално и назив установе у којој је аутор обавио истраживање. У сложеним организацијама наводи се укупна хијерархија (нпр. Универзитет одбране у Београду, Војна академија, Катедра природно-математичких наука). Бар једна организација у хијерархији мора бити правно лице. Ако аутора има више, а неки потичу из исте установе, мора се, посебним ознакама или на други начин, назначити из које од наведених установа потиче сваки од наведених аутора. Афилијација се исписује непосредно након имена аутора. Функција и звање аутора се не наводе.

Контакт подаци

Адреса или е-адреса свих аутора даје се поред имена и презимена аутора.

Категорија (тип) чланка

Категоризација чланака обавеза је уредништва и од посебне је важности. Категорију чланка могу предлагати рецензенти и чланови уредништва, односно уредници рубрика, али одговорност за категоризацију сноси искључиво главни уредник.

Чланци у часописима се разврставају у следеће категорије:

Научни чланци:

1. оригиналан научни чланак (рад у којем се износе претходно необјављивани резултати сопствених истраживања научним методом);

2. прегледни чланак (рад који садржи оригиналан, детаљан и критички приказ истраживачког проблема или подручја у којем је аутор остварио одређени допринос, видљив на основу аутоцитата);

3. кратко или претходно саопштење (оригинални научни рад пуног формата, али мањег обима или прелиминарног карактера);

4. научна критика, односно полемика (расправа на одређену научну тему, заснована искључиво на научној аргументацији) и осврти.

Изузетно, у неким областима, научни рад у часопису може имати облик монографске студије, као и критичког издања научне грађе (историјско-архивске, лексикографске, библиографске, прегледа података и сл.) – дотад непознате или недовољно приступачне за научна истраживања.

Радови класификовани као научни морају имати бар две позитивне рецензије.

Ако се у часопису објављују и прилози ваннаучног карактера, научни чланци треба да буду груписани и јасно издвојени у првом делу свеске.

Стручни чланци:

1. стручни чланак (прилог у којем се нуде искуства корисна за унапређење професионалне праксе, али која нису нужно заснована на научном методу);

2. информативни прилог (уводник, коментар и сл.);

3. приказ (књиге, рачунарског програма, случаја, научног догађаја, и сл.).

Језик рада

Језик рада може бити српски, руски или енглески.

Текст мора бити језички и стилски дотеран, систематизован, без скраћеница (осим стандардних). Све физичке величине морају бити изражене у Међународном систему мерних јединица – SI. Редослед образаца (формула) означава се редним бројевима, са десне стране у округлим заградама.

Сажетак (апстракт) и резиме

Сажетак (апстракт) јесте кратак информативан приказ садржаја чланка који читаоцу омогућава да брзо и тачно оцени његову релевантност. У интересу је уредништава и аутора да сажетак садржи термине који се често користе за индексирање и претрагу чланака. Саставни делови сажетка су циљ истраживања, методи, резултати и закључак. Сажетак треба да има од 100 до 250 речи и треба да се налази између заглавља (наслов, имена аутора и др.) и кључних речи, након којих следи текст чланка. Ако је рад написан на српском или руском језику, пожељно је да се, поред сажетка на српском и руском, даје и сажетак у проширеном облику на енглеском језику – као тзв. резиме (summary). Овакав резиме треба да буде на крају чланка, након одељка Литература. Важно је да резиме буде у структурираном облику, а његова дужина може бити до 1/10 дужине чланка (опширнији је од сажетка са почетка чланка). Почетак овог резимеа може бити преведени сажетак (са почетка чланка), а затим треба да следе преведени главни наслови, поднаслови и основе закључка чланка (литература се не преводи). Потребно је да се у структурираном резимеу преведе и део текста испод наслова и поднаслова, водећи рачуна да он буде пропорционалан њиховој величини, а да одражава суштину. Након резимеа на енглеском језику (проширеног сажетка) додаје се његов превод на српском, да би редакција извршила проверу и лектуру.

Кључне речи

Кључне речи су термини или фразе које адекватно представљају садржај чланка за потребе индексирања и претраживања. Треба их додељивати ослањајући се на неки међународни извор (попис, речник или тезаурус) који је најшире прихваћен или унутар дате научне области. За нпр. науку уопште, то је листа кључних речи Web of Science. Број кључних речи не може бити већи од 10, а у интересу је уредништва и аутора да учесталост њихове употребе буде што већа. Кључне речи дају се на језику на којем је написан чланак (сажетак) и на енглеском језику. У чланку се пишу непосредно након сажетка, односно након резимеа.

Систем АСИСТЕНТ у ту сврху користи специјалну алатку KWASS: аутоматско екстраховање кључних речи из дисциплинарних тезауруса/речника по избору и рутине за њихов одабир, тј. прихватање односно одбацивање од стране аутора и/или уредника.

Датум прихватања чланка

Датум када је уредништво примило чланак, датум када је уредништво коначно прихватило чланак за објављивање, као и датуми када су у међувремену

достављене евентуалне исправке рукописа наводе се хронолошким редоследом, на сталном месту, по правилу на крају чланка.

Захвалница

Назив и број пројекта, односно назив програма у оквиру којег је чланак настао, као и назив институције која је финансирала пројекат или програм, наводи се у посебној напомени на сталном месту, по правилу при дну прве стране чланка.

Претходне верзије рада

Ако је чланак у претходној верзији био изложен на скупу у виду усменог саопштења (под истим или сличним насловом), податак о томе треба да буде наведен у посебној напомени, по правилу при дну прве стране чланка. Рад који је већ објављен у неком часопису не може се објавити у Војнотехничком гласнику (прештампати), ни под сличним насловом и измењеном облику.

Табеларни и графички прикази

Пожељно је да наслови свих приказа, а по могућству и текстуални садржај, буду дати двојезично, на језику рада и на енглеском језику.

Табеле се пишу на исти начин као и текст, а означавају се редним бројевима са горње стране. Фотографије и цртежи треба да буду јасни, прегледни и погодни за репродукцију. Цртеже треба радити у програму word или corel. Фотографије и цртеже треба поставити на жељено место у тексту.

За слике и графиконе не сме се користити снимак са екрана рачунара програма за прикупљање података. У самом тексту чланка препоручује се употреба слика и графикона непосредно из програма за анализу података (као што су Excel, Matlab, Origin, SigmaPlot и други).

Навођење (цитирање) у тексту

Начин позивања на изворе у оквиру чланка мора бити једнообразан.

Војнотехнички гласник за референцирање (цитирање и навођење литературе) примењује Харвардски систем референци, односно Харвардски приручник за стил (Harvard Referencing System, Harvard Style Manual). У самом тексту, у обичним заградама, на месту на којем се врши позивање, односно цитирање литературе набројане на крају чланка, обавезно у обичној загради написати презиме цитираног аутора, годину издања публикације из које цитирате и, евентуално, број страница. Нпр. (Petrović, 2012, pp.10–12).

Детаљно упутство о начину цитирања, са примерима, дато је на страници сајта *Упутство за Харвардски приручник за стил*. Потребно је да се позивање на литературу у тексту уради у складу са поменутим упутством.

Систем АСИСТЕНТ у сврху контроле навођења (цитирања) у тексту користи специјалну алатку CiteMatcher: откривање изостављених цитата у тексту рада и у попису референци.

Напомене (фусноте)

Напомене се дају при дну стране на којој се налази текст на који се односе. Могу садржати мање важне детаље, допунска објашњења, назнаке о коришћеним изворима (на пример, научној грађи, приручницима), али не могу бити замена за цитирану литературу.

Листа референци (литература)

Цитирана литература обухвата, по правилу, библиографске изворе (чланке, монографије и сл.) и даје се искључиво у засебном одељку чланка, у виду листе референци. Референце се не преводе на језик рада и набрајају се у посебном одељку на крају чланка.

Војнотехнички гласник, као начин исписа литературе, примењује Харвардски систем референци, односно Харвардски приручник за стил (Harvard Referencing System, Harvard Style Manual).

Литература се обавезно пише на латиничном писму и набраја по абецедном редоследу, наводећи најпре презимена аутора, без нумерације.

Детаљно упутство о начину пописа референци, са примерима, дато је на страници сајта *Упутство за Харвардски приручник за стил*. Потребно је да се попис литературе на крају чланка уради у складу са поменутим упутством.

Нестандардно, непотпуно или недоследно навођење литературе у системима вредновања часописа сматра се довољним разлогом за оспоравање научног статуса часописа.

Систем АСИСТЕНТ у сврху контроле правилног исписа листе референци користи специјалну алатку RefFormatter: контрола обликовања референци у складу са Харвардским приручником за стил.

Пропратно писмо (само за ауторе из Републике Србије и по посебном захтеву уредника)

Поред чланка доставља се пропратно писмо у којем треба истаћи о којој врсти чланка се ради, који су графички прилози (фотографије и цртежи) оригинални, а који позајмљени.

У пропратном писму наводе се и подаци аутора: име, средње слово, презиме, чин, звање, е-маил, адреса послодавца (ВП), кућна адреса, телефон на радном месту и кућни (мобилни) телефон, рачун и назив банке, СО места становања, број личне карте и ЈМБ грађана.

Сви радови подлежу стручној рецензији.

Списак рецензената Војнотехничког гласника може се видети на страници сајта *Списак рецензената*. Процес рецензирања објашњен је на страници сајта *Рецензентски поступак*.

Адреса редакције:
Војнотехнички гласник,
Браће Југовића 19, Дом Војске Србије,
11000 Београд,
e-mail: vojnotehnicki.glasnik@mod.gov.rs.

Главни и одговорни уредник
мр *Небојша* Гаћеша, дипл. инж.
nebojsa.gacesa@mod.gov.rs,
http://orcid.org/0000-0003-3217-6513,
тел.: војни 23-720 (011/3201-720),
011/3241-311, 064/8080-118

ПРИГЛАШЕНИЕ И ИНСТРУКЦИЯ ДЛЯ АВТОРОВ О ПОРЯДКЕ ПОДГОТОВКИ СТАТЬИ

Инструкция для авторов о порядке подготовки статьи к опубликованию в журнале «Военно-технический вестник» разработана в соответствии с Актом о редактировании научных журналов Министерства науки и технологического развтия Республики Сербия, № 110-00-17/2009-01 от 09.07.2009 г. Применением этого Акта, в первую очередь, обеспечивается совершенствование качества отечественных жуналов и их более полного включения в международную систему обмена научной информацией. Инструкция соответствует международным стандартам ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999, ISO 5122 и соответствующим отечественным стандартам.

Военно-технический вестник (**Vojnotehnički glasnik / Military Technical Courier**), втг.мо.упр.срб, www.vtg.mod.gov.rs/index-ru.html, ISSN 0042-8469 – печатное издание, e-ISSN 2217-4753 – online, UDK 623+355/359, является мультидисциплинарным научным журналом Министерства обороны Республики Сербия, который публикует научные и профессиональные статьи, а также техническую информацию о современных системах вооружения и современных военных технологиях. Журнал следит за единой межвидовой технической поддержкой вооруженных сил, основанной на принципах системной логистики, за прикладными и инновационными научными исследованиями, в том числе, в области производства вооружения и военной техники, и за прочими теоретическими и практическими достижениями, которые способствуют профессиональному росту представителей сербского, регионального и международного академического сообщества, и особенно военнослужащих Министерства Обороны и Вооружённых сил Республики Сербия.

Министерство образования, науки и технологического развития Республики Сербия, согласно решению принятому в соотвествии со ст. 27 абзац 1, пункт 4 и по полученному толкованию ст. 25 абзац 1 пункт 5 Закона о научно-исследовательской деятельности («Службени гласник РС», № 110/05, утверждило категоризацию «Военно-технического вестника» за 2016 год:

Категории в области технологического развития:

– Область материалов и химической технологии:

ведущий научный журнал национального значения **(M51)**,

– Область электроники, телекоммуникаций и информационных технологий: научный журнал национального значения **(M52),**

– Область механики:

научный журнал национального значения **(M52)**.

Категории в области основных исследований:

– Область математика, компьютерные науки, технические науки:

научный журнал национального значения **(M52)**.

Информацию относительно категоризации за 2016 год можно посмотреть на странице сайта «Военно-технического вестника» *Категоризация Вестника* (Министерством просвещения, науки и технологического развития Республики Сербия пока не производилось официальное ранжирование научных журналов за 2017 год.).

Более подробную информацию можно найти на сайте Министерства образования, науки и технологического развития Республики Сербия.

Информацию о категоризации можно посмотреть и на сайте КОБСОН-а (Консорциум библиотек Республики Сербия по вопросам объединения закупок).

Категоризация Вестника проведена согласно Положению о порядке и способе категоризации научно-исследовательских результатов, утвержденного Национальным комитетом по науке и технологиям (Службени гласник РС, № 38/2008).

В соответствии с вышеуказанным Положением и табличкой с показателями классификации и категоризации индивидуальных научно-исследовательских результатов (являющейся неотъемлемой частью Положения), работа, опубликованная в «Военно-техническом вестнике», оценивается следующим способом: 2 балла (категория М51) и 1,5 баллов (категория М52).

Журнал соответствует стандартам Сербского индекса научного цитирования (СЦИндекс/SCIndeks) - наукометрической базы данных научных журналов Республики Сербия, а также Российского индекса научного цитирования (РИНЦ). Журнал постоянно подвергается мониторингу и оценивается количественными наукометрическими показателями отражающими его научную ценность, в т.ч. опосредованно в международных индексах цитирования (Clarivate Analytics).

С информацией об индексировании можно ознакомиться на странице сайта журнала *Индексирование вестника*.

«Военно-технический Вестник» обеспечивает читателям возможность открытого доступа, в соответствии с положениями об авторских правах, утвержденными Creative Commons (CC BY). С инструкцией об авторских правах можно ознакомиться на странице *Авторские права и политика самоархивирования*, перейдя по ссылке http://www.vtg.mod.gov.rs/index-ru.html.

Работы представляются путём online системой e-Ур: Электронное издательство - ASSISTANT, запущенной Центром поддержи развития образования и науки (ЦПРОН).

Права доступа и регистрация в системе оформляются по адресу http://www.vtg.mod.gov.rs/index-ru.html, через страницу *ASSISTANT* или *СЦИНДЕКС* (aseestant.ceon.rs/index.php/vtg).

С инструкцией по регистрации и праву доступа можно ознакомиться по адресу http://www.vtg.mod.gov.rs/index-ru.html, на странице *Инструкция по e-Ур: Электронное издательство ASSISTANT*.

Все авторы, предоставляющие свои рукописи на публикацию в редакцию журнала «Военно-технический вестник» должны пройти регистрацию в реестре ORCID (Open Researcher and Contributor ID), в соответствии с инструкцией на странице сайта *Регистрация в реестре ORCID для присвоения идентификационного кода*.

«Военно-технический вестник» публикует статьи на сербском, русском или английском языках (Arial, шрифт 11 pt, пробел Single).

Процесс подготовки, написания и редактирования статьи должен осуществляться в соответствии с принципами *Этического кодекса* (http://www.vtg.mod.gov.rs/etichyeskiy-kodyeks.html).

Статья должна содержать аннотацию с ключевыми словами, введение, основную часть, выводы, список использованной литературы и резюме с ключевыми словами на английском языке (без нумерации заголовков и подзаголовков). Объём статьи не должен превышать один авторский лист (16 страниц формата А4 с пробелом Single).

Статья должна быть набрана на компьютере с использованием подготовленного редакцией макета, который можно скачать на странице сайта *Правила и образец составления статьи*.

Заголовок

Заголовок должен отражать тему статьи. В интересах журнала и автора необходимо использовать слова, удобные для индексации и поиска. Если такие слова не содержатся в заголовке, то желательно их добавить в подзаголовок. Заголовок должен быть переведён на английский язык. Название заголовка (подзаголовка) пишется перед аннотацией на соответствующем языке.

Текущий заголовок

Текущий заголовок пишется в титуле каждой страницы статьи с целью упрощения идентификации, в первой очереди копий статьей в электронном виде. Содержит в себе фамилию и инициал имени автора (в случае если авторов несколько, остальные обозначаются с «et al.» или «и др.»), заголовки работы и журнала (год, объем, тетрадь, начальная и заключительная страница). Заголовки журнала и статьи могут приводиться в сокращенном виде.

ФИО автора

Приводятся полная фамилия и полное имя (всех) авторов. Желательно, чтобы были приведены инициалы отчеств авторов. Фамилия и имя отечественных авторов всегда пишутся в оригинальном виде (с сербскими диакритическими знаками), независимо от языка, на котором написана работа.

Наименование учреждения автора (аффилиация)

Приводится полное (официальное) наименование и местонахождение учреждения, в котором работает автор, а также наименование учреждения, в котором автор провёл исследование. В случае организаций со сложной структурой приводится их иерархическая соподчинённость (напр. Военная академия, Кафедра военных электронных систем, г. Белград). По крайней мере, одна из организаций в иерархии должна иметь статус юридического лица. В случае если указано несколько авторов, и если некоторые из них работают в одном учреждении, нужно отдельными обозначениями или каким-либо другим способом указать в каком из приведённых учреждений работает каждый из авторов. Аффилиация пишется непосредственно после ФИО автора. Должность и специальность по диплому не указываются.

Контактные данные

Электронный адрес автора указываются рядом с его именем на первой страницы статьи.

Категория (тип) статьи

Категоризация статьей является обязанностью редакции и имеет особое значение. Категорию статьи могут предлагать рецензенты и члены редакции, т.е. редакторы рубрик, но ответственность за категоризацию несет исключительно главный редактор. Статьи в журнале распределяются по следующим категориям:

Научные статьи:

1. оригинальная научная статья (работа, в которой приводятся раньее неопубликованные результаты собственных исследований, полученных научным методом);

2. обзорная статья (работа, содержащая оригинальный, детальный и критический обзор исследуемой проблемы или области, в который автор внёс определённый вклад, видимый на основе автоцитат);

3. краткое сообщение (оригинальная научная работа полного формата, но меньшего объёма или имеющая предварительный характер);

4. научная критическая статья (дискуссия-полемика на определённую научную тему, основанная исключительно на научной аргументации) и научный комментарий.

Однако, в некоторых областях научная работа в журнале может иметь форму монографической студии, а также критического издания научного материала (историко-архивного, лексикографического, библиографического, обзора данных и т.п.) – до тех пор неизвестного или недостаточно доступного для научных исследований. Работы, классифицированные в качестве научных, должны иметь, по меньшей мере, две положительные рецензии.

В случае если в журнале объявляются и приложения, не имеющие научный характер, научные статьи должны быть сгруппированы и четко выделены в первой части тетради.

Профессиональные статьи:

1. профессиональная работа (приложения, в которых предлагаются опыты, полезные для совершенствования профессиональной практики, но которые не должны в обязательном порядке быть обоснованы на научном методе);

2. информативное приложение (передовая статья, комментарий и т.п.);

3. обзор (книги, компьютерной программы, случая, научного события и т.п.).

Язык работы

Работа может быть написана на сербском, русском или английском языке.

Текст должен быть в лингвистическом и стилистическом смысле упорядочен, систематизирован, без сокращений (за исключением стандартных). Все физические величины должны соответствовать Международной системе единиц измерения – СИ. Очередность формул обозначается порядковыми номерами, с правой стороны в круглых скобках.

Аннотация (абстракт) и резюме

Аннотация (абстракт) является кратким информативным обзором содержания статьи, обеспечивающим читателю быстроту и точнось оценки её релевантности. В интересах редакции и авторов, чтобы аннотация содержала термины, часто используемые для индексирования и поиска статьей. Составными частями аннотации являются цель исследования, методы и заключение. В аннотации должно быть от 100 до 250 слов, и она должна находится между титулами (заголовок, ФИО авторов и др.) и ключевыми словами, за которыми следует текст статьи. Если работа написана на сербском или русском языке, желательно, чтобы кроме аннотации на сербском и русском, была бы предоставлена и аннотация в расширенном виде на английском языке – в качестве т.н. резюме (summary). Такое резюме должно находиться в конце статьи, после раздела Литература. Важно, чтобы резюме было в структурированном виде, и его длина может составлять до 1/10 длины статьи (оно более обширно, чем аннотация из начала статьи). Началом данного резюме может быть переведенная аннотация (из начала статьи), а затем должны следовать переведенные главные заголовки, подзаголовки и основы заключения статьи (литература не переводится). В структурированном резюме

нужно перевести часть текста под заголовком и заголовком, принимая во внимание, чтобы оно было пропорционально их размеру и в то же время отражала суть.

Ключевые слова

Ключевыми словами являются термины или фразы, адекватно представляющие содержание статьи, необходимое для индексирования и поиска. Ключевые слова необходимо выбирать, опираясь при этом на какой-либо международный источник (регистр, словарь, тезаурус), наиболее используемый внутри данной научной области. Число ключевых слов не может превышать 10. В интересах редакции и авторов, чтобы их частота встречи в статье была как можно большей. Ключевые слова даются на языке, на котором написана статья (аннотация), и на английском языке. В статье они пишутся непосредственно после аннотации (в начале), т.е. после резюме (в конце).

Программа ASSISTANT предоставляет возможность использования сервиса KWASS: автоматическое фиксирование ключевых слов из источников/словарей по выбору автора/редактора.

Дата получения статьи

Дата, когда редакция получила статью; дата, когда редакция окончательно приняла статью к публикации; а также даты, когда были предоставлены необходимые исправления рукописи, приводятся в хронологическом порядке, как правило, в конце статьи.

Выражение благодарности

Наименование и номер проекта, т.е. название программы, в которой статья возникла, как и наименование учреждения, которое финансировало проект или программу, приводятся в отдельном примечании, как правило, внизу первой страницы статьи.

Предыдущие версии работы

В случае если статья в предыдущей версии была изложена устно (под одинаковым или похожим названием, например, в виде доклада на научной конференции), сведения об этом должны быть указаны в отдельном примечании, как правило, внизу первой страницы статьи. Работа, которая уже была опубликована в каком-либо из журналов, не может быть напечатана в «Военно-техническом вестнике» ни под похожим названием, ни в изменённом виде.

Нумерация и название таблиц и графиков

Желательно, чтобы нумерация и название таблиц и графиков были исполнены на двух языках (на языке работы и на английском). Таблицы пишутся таким же способом как и текст и обозначаются порядковыми номерами с верхней стороны. Фотографии и рисунки должны быть понятны, наглядны и удобны для репродукции. Рисунки необходимо делать в программах Word или Corel. Фотографии и рисунки надо поставить на желаемое место в тексте. Для создания изображений и графиков использование функции снимка с экрана (скриншота) не допускается. В самом тексте статьи рекомендуется применение изображений и графиков, обработанных такими программами, как: Excel, Matlab, Origin, SigmaPlot и др.

Ссылки (цитирование) в тексте

Оформление ссылок на источники в рамках статьи должно быть однообразным. «Военно-технический вестник» для оформления ссылок, цитат и

списка использованной литературы пользуется Гарвардской системой (Harvard Referencing System, Harvard Style Manual). В тексте в скобках приводится фамилия цитируемого автора (или фамилия первого автора, если авторов несколько), год издания и по необходимости номер страницы. Например: (Petrović, 2010, pp.10-20). Рекомендации о способе цитирования размещены на странице сайта *Инструкция по использованию Гарвардского стиля*. При оформлении ссылок, цитат и списка использованной литературы необходимо придерживаться установленных норм.

Программа ASSISTANT предоставляет при цитировании возможность использования сервиса CiteMatcher: фиксирование пропущенных цитат в работе и списке литературы.

Примечания (сноски)

Примечания указываются внизу страницы, на которой находится текст, к которым они относятся. Примечания (сноски) могут содержать менее важные детали, дополнительные объяснения, указания об использованных источниках (напр. научном материале, справочниках), но не могут быть заменой процедуры цитирования литературы.

Литература (референции)

Цитированной литературой охвачены, как правило, библиографические источники (статьи, монографии и т.п.) и она представляется исключительно в отдельном разделе статьи, в виде референций.

Литературные источники не переводятся на язык работы.

«Военно-технический вестник» для оформления списка использованной литературы применяет Гарвардскую систему (Harvard Style Manual). В списке литературы источники даются в алфавитном порядке фамилий авторов или редакторов. Рекомендации о способе цитирования размещены на странице сайта *Инструкция по использованию Гарвардского стиля*. При оформлении списка использованной литературы необходимо придерживаться установленных норм.

Программа ASSISTANT при оформлении списка литературы предоставляет возможность использования сервиса RefFormatter: контроль оформления списка литературы в соответствии со стандартами Гарвардского стиля.

Нестандартное, неполное и непоследовательное приведение литературы в системах оценки журнала считается достаточной причиной для оспаривания научного статуса журнала.

Все рукописи статей подлежат профессиональному рецензированию.

Список рецензентов «Военно-технического вестника» можно посмотреть на странице сайта *Список рецензентов*. Процесс рецензирования описан на странице сайта *Правила рецензирования*.

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The instructions to authors about the article preparation for publication in the *Military Technical Courier* are based on the Act on scientific journal editing of the Ministry of Science and Technological Development of the Republic of Serbia, No 110-00-17/2009-01 of 9th July 2009. This Act aims at improving the quality of national journals and raising the level of their compliance with the international system of scientific information exchange. It is based on international standards ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999 and ISO 5122 and their national equivalents.

The Military Technical Courier / Vojnotehnički glasnik (www.vtg.mod.gov.rs/index-e.html, втг.мо.упр.срб, ISSN 0042-8469 – print issue, e-ISSN 2217-4753 – online, UDC 623+355/359) is a multidisciplinary scientific journal of the Ministry of Defence of the Republic of Serbia. It publishes scientific and professional papers as well as technical data on modern weapon systems and military technologies. The journal covers inter-service technical support to the Army on the principle of logistic system support; fundamental, applied and development research; production and use of weapons and military equipment as well as other theoretical and practical achievements leading to professional development of all members of Serbian, regional and international academic communities, members of the Ministry of Defence and the Army of Serbia in particular.

Pursuant to the decision given in Article 27, paragraph 1, point 4, and in accordance with the acquired opinion given in Article 25, paragraph 1, point 5 of the Act on Scientific and Research Activities (Official Gazette of the Republic of Serbia, No 110/05, 50/06-cor and 18/10), the Ministry of Education, Science and Technological Development of the Republic of Serbia classified the Military Technical Courier for the year 2016

in the field technological development:
– on the list of periodicals for materials and chemical technology,
category: leading scientific periodical of national interest **(M51)**,
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category: scientific periodical of national interest **(M52)**,
in the field fundamental research:
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The approved lists of national periodicals for the year 2016 can be viewed on the website of the Military Technical Courier, page *Journal categorization* (The Ministry of Education, Science and Technological Development of the Republic of Serbia has not yet published the official evaluation of scientific journals for 2017).

More detailed information can be found on the website of the Ministry of Education, Science and Technological Development of the Republic of Serbia.

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In accordance with the Regulations and the table about types and quantification of individual scientific and research results (as a part of the Regulations), a paper published in the *Military Technical Courier* scores 2 (two) points (category M51) and 1,5 (one and a half) point (category M52).

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Manuscripts are submitted online, through the electronic editing system ASSISTANT, developed by the Center for Evaluation in Education and Science – CEON.

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All authors submitting a manuscript for publishing in the Military Technical Courier should register for an ORCID ID following the instructions on the web page *Registration for an ORCID identifier*.

The Military Technical Courier publishes articles in Serbian, Russian or English, using Arial and a font size of 11pt with Single Spacing.

The procedures of article preparation, writing and editing should be in accordance with the *Publication ethics statement* (http://www.vtg.mod.gov.rs/publication-ethics-statement.html).

The article should contain the abstract with keywords, introduction, body, conclusion, references and the summary in English language (without heading and subheading enumeration). The article length should not exceed 24 pages of A4 paper format.

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Classification of articles is a duty of the editorial staff and is of special importance. Referees and the members of the editorial staff, or section editors, can propose a category, but the editor-in-chief has the sole responsibility for their classification.

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Language

The article can be in Serbian, Russian or English.

The grammar and style of the article should be of good quality. The systematized text should be without abbreviations (except standard ones). All measurements must be in SI units. The sequence of formulae is denoted in Arabic numerals in parentheses on the right-hand side.

Abstract and summary

An abstract is a concise informative presentation of the article content for fast and accurate evaluation of its relevance. It is both in the Editorial Office's and the author's best interest for an abstract to contain terms often used for indexing and article search. The abstract describes the purpose of the study and the methods, outlines the findings and state the conclusions. A 100- to 250- word abstract should be placed between the title and the keywords with the body text to follow. Besides an abstract in Serbian and Russian, articles in Serbian and Russian are advised to have a summary in English, at the end of the article, after the Reference list. The summary should be structured and long up to 1/10 of the article length (it is more extensive than the abstract). It can start with the translated Serbian or Russian abstract from the beginning of the article with translated main headings, subheadings and major conclusions to follow (Reference list is not translated). The structured summary should also contain the proportional informative parts of the text below the headings and subheadings.

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For this purpose, the ASSISTANT system uses a special tool KWASS for the automatic extraction of key words from disciplinary thesauruses/dictionaries by choice and the routine for their selection, i.e. acceptance or rejection by author and/or editor.

Article acceptance date

The date of the reception of the article, the dates of submitted corrections in the manuscript (optional) and the date when the Editorial Board accepted the article for publication are all given in a chronological order at the end of the article.

Acknowledgements

The name and the number of the project or programme within which the article was realised is given in a separate note at the bottom of the first page together with the name of the institution which financially supported the project or programme.

Article preliminary version

If an article preliminary version has appeared previously at a meeting in a form of an oral presentation (under the same or similar title), this should be stated in a separate note at the bottom of the first page. An article published previously cannot be published in the *Military Technical Courier* even under a similar title or in a changed form.

Tables and illustrations

All the captions should be in the original language as well as in English, together with the texts in illustrations if possible. Tables are typed in the same style as the text and are denoted by Arabic numerals at the top. Photographs and drawings, placed appropriately in the text, should be clear, precise and suitable for reproduction. Drawings should be created in Word or Corel.

For figures and graphs, proper data plot is recommended i.e. using a data analysis program such as Excel, Matlab, Origin, SigmaPlot, etc. It is not recommended to use a screen capture of a data acquisition program as a figure or a graph.

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Citation in the text must be uniform. The Military Technical Courier applies the Harvard Referencing System given in the Harvard Style Manual. When citing sources within your paper, i.e. for in-text references of the works listed at the end of the paper, place the year of publication of the work in parentheses and optionally the number of the page(s) after the author's name, e.g. (Petrovic, 2012, pp.10-12). A detailed guide on citing, with examples, can be found on Military Technical Courier website on the page *Instructions for Harvard Style Manual*. In-text citations should follow its guidelines.

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Footnotes are given at the bottom of the page with the text they refer to. They can contain less relevant details, additional explanations or used sources (e.g. scientific material, manuals). They cannot replace the cited literature.

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In journal evaluation systems, non-standard, insufficient or inconsequent citation is considered to be a sufficient cause for denying the scientific status to a journal.

All articles are peer reviewed.

The list of referees of the Military Technical Courier can be viewed at website page *List of referees*. The article review process is described on the *Peer Review Process* page of the website.

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