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HIERARCHICAL CONTROL OF MULTI-AUV SYSTEMS

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Abstract**:** *The paper highlights some approaches to fundamental problems of intelligent control of autonomous underwater vehicles (AUV) groups: logic-based approach to task management for inspection and protection of the water area, hybrid evolutionary models and algorithms for dynamic mission planning, and methods for rigorous analysis of discrete-continuous models of AUVs formations with discrete-event approach to AUV's operational modes switching. Hierarchical three-level architecture of control system is supposed and various models of AUV group functioning at the different control levels are considered.*

KEYWORDS: UNDERWATER VEHICLES, FORMATION CONTROL, LOGICAL CALCULUS, DISCRETE-EVENT SYSTEM, ROUTING PROBLEM, GENETIC ALGORITHM

1. Introduction

The exploration of the World Ocean's space and resources, particularly in the Arctic, is admitted to be one of the main research directions of the third millennium for high-developed countries having access to the sea. A significant role here is given to explorational autonomous underwater vehicles (AUV) with long autonomous functioning time, which are effective and the safest means for underwater research due to the absence of human aboard. Nowadays it is required to improve AUV dynamics, control autonomy and intellectuality to deal with the nondeterministic and unknown environment. At the same time, since it is impossible to predict underwater situations for implementing conventional programmed control, the development of new approaches to AUV groups control is the high priority problem which involves the design of intellectual computer-aided control systems.

The urgency of the group control problem for autonomous mobile robots is acknowledged by a large number of studies conducted in Western Europe, the USA, Japan, China and Russia. Complexity of this problem springs from, on the one hand, the requirement of developing methods and algorithms to control interdependent actions of individual robots achieving a common goal, and on the other hand, the necessity of implementing these actions real-time taking into account the variability of the environment. Hierarchical three-level architecture of control system is typically used to support complex AUVs group behavior. In what follows, we discuss various models of AUV group functioning and various approaches at different control levels implementation, including:

- a logic-based approach to task management for a group of AUV performing inspection and protection of the water area;
- online evolutionary approach for solving the maximum coverage patrol routing problem by a group of AUVs;
- the method for rigorous analysis and synthesis of digital control systems to maintain AUV formations
- a discrete-event approach to switching of operational modes of AUV groups in surveillance missions.

Logical calculus of positively-constructed formulas and discrete-event systems are used at the level of symbolic information processing, hybrid evolutionary models at the planning level, and discrete-continuous models at the execution level.

2. Execution level control algorithms

In this section, we derive sampled-data path-following and decentralized formation-keeping controllers. For this purpose, the dynamic model of AUV is borrowed from [1]. The kinematic and dynamics equations of the vehicle can be defined using a global coordinate frame $\{U\}$ and a body-fixed coordinate frame $\{B\}$. The kinematic equation of the AUV can be written

$$\begin{aligned} \dot{x} &= u\cos(\psi_B) - v\sin(\psi_B), \\ \dot{y} &= u\sin(\psi_B) + v\cos(\psi_B), \\ \dot{\psi}_B &= r, \end{aligned} \tag{1}$$

where x, y are the coordinates of the center of mass of the vehicle, ψ_B denotes the yaw angle, u and v are the surge and sway velocities expressed in $\{B\}$, respectively, and r is the angular yaw rate. Neglecting the equations in heave, roll and pitch, the equations for surge, sway and yaw can be presented [1] as

$$\begin{aligned} \mathsf{F} &= m_u\dot{u} + d_u, \\ 0 &= m_v\dot{v} + m_{ur}ur + d_v, \\ \mathsf{G} &= m_r\dot{r} + d_r, \end{aligned} \tag{2}$$

where $[\mathsf{F}\ \mathsf{G}]^T$ is the vector of force and torque applied to AUV.

To design path-following controller for a AUV, the conception of virtual target is exploited. Define the virtual target as a point P that moves along the path to be followed by the AUV. Associated with P, consider the corresponding Serret-Frenet frame $\{F\}$. As shown in [1] the dynamics of the virtual target in $\{F\}$ can be described by

$$\begin{aligned} \dot{s}_1 &= v_t\cos\psi - \dot{s}_a + \dot{\psi}_F y_1, \\ \dot{y}_1 &= v_t\sin\psi - \dot{\psi}_F s_1, \\ \dot{\psi} &= r + \dot{\beta} - \dot{\psi}_F, \end{aligned}$$

where s_1, y_1 are the coordinates of the vehicle in $\{F\}$, S is the signed curvilinear abscissa of P along the path, $\beta = \arctan(v/u)$ is the side-slip angle, $v_t = (u^2 + v^2)^{1/2}$ is the absolute value of the total velocity vector; $\psi \equiv \psi_B + \beta - \psi_F$, ψ_F is an angle that defines the orientation of F with respect to U ($\dot{\psi}_F = c_c(s_a)\dot{s}_a$), c_c is the path curvature. We suppose that the virtual target moves along the path with a desired speed u_d and there is a restriction on the curvature of the path ($|c_c| \le \bar{c}_c$).

The path-following control problem can be formulated as followers. Given the AUV model (1)-(2) and a path to be followed, derive control laws for the force F and torque G that minimize the steady-state errors in variables y_1, s_1, and ψ.

To solve the problem, the following sampled-data control law is proposed:

$$\begin{aligned} \mathsf{F}(t) = \mathsf{F}_c + \mathsf{F}_s, \quad \mathsf{G}(t) = \mathsf{G}_c + \mathsf{G}_s, \quad t \in T_k \equiv [t_k, t_{k+1}), \\ \mathsf{F}_c = d_u, \quad \mathsf{G}_c = d_r + m_r(\dot{c}_c\dot{s}_a + c_c\ddot{s}_a - \hat{\ddot{\beta}}), \\ \mathsf{F}_s = (k_1\hat{s}_{1k} + k_2\Delta\hat{u}_k, \bar{\mathsf{F}}_s), \\ \mathsf{G}_s = (k_3\hat{y}_{1k} + k_4\hat{\psi}_k + k_5\Delta\hat{r}_k, \bar{\mathsf{G}}_s), \end{aligned} \tag{3}$$

where $t_k = kh$, $k = 0,1,2\ldots$, h is the control step; F_c, G_c are feedforward control terms aimed to cancel terms d_u, d_r in equations (2) and terms $\dot{c}_c\dot{s}_a$, $c_c\ddot{s}_a$, $\ddot{\beta}$ in the equation for variable $\Delta r \equiv r + \dot{\beta} - \dot{\psi}_F$; $\hat{\ddot{\beta}}$ is an estimate of acceleration $\ddot{\beta}$, $\ddot{\psi}_F = \dot{c}_c\dot{s}_a + c_c\ddot{s}_a$; F_s, G_s are feedback control terms, $\bar{\mathsf{F}}_s$, $\bar{\mathsf{G}}_s$ are the shares of maximum control force and torque reserved for stabilization, $\hat{s}_{1k}$, $\hat{y}_{1k}$, $\hat{\psi}_k$, $\Delta\hat{u}_k$, $\Delta\hat{r}_k$ are measurements of

variables s_1, y_1, ψ, Δu @$u-u_d$, Δr sampled at time moment t_k with some additive bounded errors; $(\sigma,\bar{\sigma}) = (\sigma)\min(|\sigma|,\bar{\sigma})$ is the saturation function; k_i are feedback coefficients ($i=\overline{1,5}$).

The formation control strategy considered here is based on the leader-follower approach [2, 3]. Focusing on a given leader-follower pair, denote the leader as l and the follower as f. Considering the leader as a virtual target for its follower, one can derive a kinematic model of the leader-follower pair in coordinates (s_1, y_1) as

$$\dot{s}_1 = v_{tf}\cos(\psi_{Wf}-\psi_{Wl}) - v_{tl} + \dot{\psi}_{Wl}y_1,$$
$$\dot{y}_1 = v_{tf}\sin(\psi_{Wf}-\psi_{Wl}) - \dot{\psi}_{Wl}s_1,$$
$$\dot{\psi}_{Wf} = r_f + \dot{\beta}, \quad (\psi_W \equiv \psi_B + \beta).$$

Let a desired position of the follower with respect to the leader in coordinates (s_1, y_1) be defined by vector $[s_1^*, y_1^*]^T$. The control law that provides stabilization of the desired position of the follower with respect to the leader can be defined as in (3) except for the feedback control terms defined as

$$\mathsf{F}_s = \mathrm{sat}(k_1\Delta\hat{s}_{1k} + k_2\Delta\hat{u}_{lfk}, \overline{\mathsf{F}}_s),$$
$$\mathsf{G}_s = \mathrm{sat}(k_3\Delta\hat{y}_{1k} + k_4\Delta\hat{\psi}_{lfk} + k_5\Delta\hat{r}_{lfk}, \overline{\mathsf{G}}_s),$$

where $\Delta\hat{s}_{1k}$, $\Delta\hat{u}_{lfk}$, $\Delta\hat{y}_{1k}$, $\Delta\hat{\psi}_{lfk}$, $\Delta\hat{r}_{lfk}$ are estimates of $\Delta s_1 \equiv s_1 - s_1^*$, $\Delta u_{lf} \equiv u_l - u_f$, $\Delta y_1 \equiv y_1 - y_1^*$, $\Delta\psi_{lf} \equiv \psi_{Wf} - \psi_{Wl}$, $\Delta r_{lf} \equiv \dot{\psi}_{Wf} - \dot{\psi}_{Wl}$ at time moment t_k computed using measurements of the state vector of the follower and estimates of the state variables of the leader at t_k sent by the leader at t_{k-1} and received by the follower during the time interval T_{k-1}. As before, we need to design feedback coefficients k_i, $i=\overline{1,5}$.

The parameters of the proposed sampled-data control algorithms are synthesized with the use of sublinear vector Lyapunov functions (see, e.g., [4]). When designing controllers, we take into account uncertainties of the AUV's parameters, measurement errors, constraints on the control force and torque. Numerical computations have been performed for formations of large-sized AUVs. Simulation results for a circle-shaped formation is shown in Fig 1.

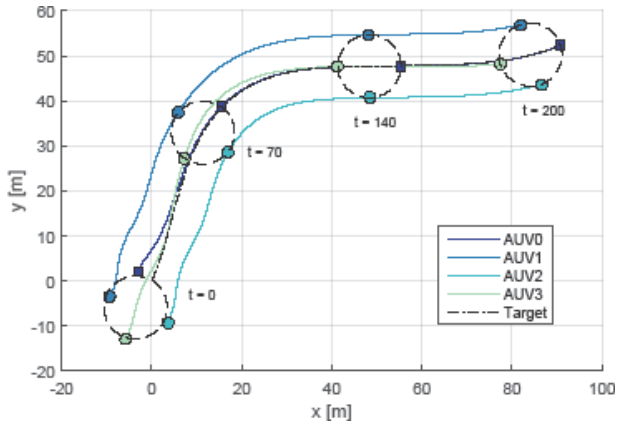


Fig. 1. *Formation trajectory*

The behavior of multi-AUV system in such missions as surveillance, monitoring, seafloor mappling, is rather complicated and includes the number of modes of operations where designed controllers are applied. As far as continuous dynamics of the leader and follower AUVs describes their predefined modes, switching between different modes of operation may be described in terms of discrete-event models. We propose discrete-event system (DES) and build supervisors for the top-level control of AUV operational modes switching as a reaction on environment changes, previous and current modes. Supervisory control theory (SCT) developed for discrete-event systems in 1980s [5], nowadays becomes powerful instrument in robotics applications. Recent implementations include single robots, robot groups [6] and robots formation control, swarm robotics [7], robots fights, etc. Considered as discrete-event system, system functioning is described with sequences of events, or words of some formal language. To implement SCT for AUVs formation control, first generators describing switching of a leader's and followers' operational modes are constructed. Then language specifications on DES behavior are constructed, determining required system functioning due to some constraints. Supervisor providing this specification designed after that. For reduction and proving of properties of constructed supervisors results from [8] are intensively used.

3. Heterougeneous AUVs group routing

During search and survey missions within specified water area a number of corresponded underwater works should be accomplished collaborative by AUVs assigned to that territory. In general, it is a vehicle routing problem (VRP) of task allocation and path planning under specific spatio-temporal constraints imposed by the uncertain nature of water environment and by inaccuracy of the measuring devices. In many real cases, like patrolling and guarding, taking samples and measurements, etc., underwater tasks require not the single but the periodic attendance of AUVs at scheduled intervals. Moreover, vehicles in the group may differ by their functionality (on-board equipment) which make them able to perform only specific sub-sets of tasks among all tasks of the mission. Thus, it is a problem of considerable practical interest to effectively route the heterogeneous group of AUVs in multi-objective missions of long-duration [9]. The problem of planning such a mission is to find a feasible group route ensuring, as far as possible, the well-timed and periodic execution of the majority of mission tasks. We propose a formalized AUVs group routing problem for the class of periodic multiobjective missions and suggest a hybrid evolutionary approach to address it effectively.

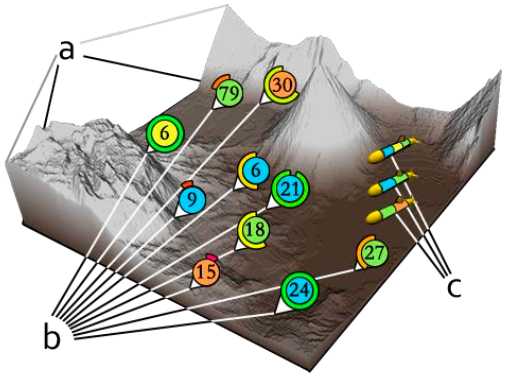


Fig. 2. *Schematic representation of the periodic multiobjective mission for the heterogeneous AUVs group*

Group mission planning is carried out: in an enclosed water area with a known seabed profile (Fig. 2, a); for a given finite set of control points (tasks) within allocated the water area (Fig. 2, b); by a heterogeneous group of multiple AUVs (Fig. 2, c); under a certain set of restrictions.

Depending on the equipment required to execute corresponded underwater works, each control point is assigned to one of the *task type* (colored circles on Fig. 2, b). Each control point also receives its *periodicity value* (numbers inside circles on Fig. 2, b) due to its predefined priority. Periodicity value defines the desired duration of a time interval between two successive attendances of any allowed AUVs. Color bars around each circle on Fig. 2, b represents remaining time interval to execute corresponded task in time.

The group of AUVs consists of functionally different vehicles, which may differ as by their cruising speed and range of hydro-acoustic communication channel, as by the set of on-board equipment (colored sections on Fig. 2, c). Thus, each vehicle is allowed to execute only those tasks that require affordable type of equipment. Group coordination here is provided only by transferring data between robots. Complete data alignment within the group could be achieved only if each pair of vehicles would be able to

transfer data to each other directly or through other AUVs. In what follows the group routes are called *communicatively stable* if they guarantee the ability to align data regularly. *Communication stability* requirement arises due to the dynamic nature of underwater missions: some unexpected changes may occur in real time, making it necessary to adjust the current route (re-plan) in order to maximize the group efficiency in new conditions. The effectiveness of the group work is determined by regularity of scheduled tasks executions. Thus, the routing problem is to find a feasible communicatively stable group route that provides the minimum time of AUVs late attendance.

For a broad class of VRP there are no algorithms to solve it in polynomial time, which leads to the class of approximation algorithms allowing obtaining rational sub-optimal solutions in low computational time. We suggest a hybrid evolutionary approach featuring specialized genetic operators and solutions improvement heuristics to address both the expectable large-size of the problem and spatio-temporal constraints that primarily arise from the AUVs heterogeneity. Among the proposed heuristics are: three different construction heuristics (random sequential insertion and two parallel insertions) to ensure the initial population of solutions to both cover a significant portion of the search space and contain a variety of good solutions; two different variants of crossover and a multimode mutation. All heuristics are constructed to ensure the ultimate affordability of all vehicles to execute their routes. Group communication stability is also guaranteed by special verifying procedure. We also use the adaptation mechanism based on the ant colony optimization to vary inner parameters of the algorithm in order to maximize its efficiency on different steps of processing in those cases when some genetic operators begin to work significantly better than others do.

The high efficiency of the suggested approach is shown through a series of simulation studies in the simulation framework "AUV Mission Planner".

2. The top-level control using PCFs logical calculus

Intellectualization of knowledge representation and processing on the top-level of AUV control system may be effectively based on the automated theorem proving (ATP) in the original machine-oriented language and logical calculus of positively constructed formulas (PCF). The PCF calculus was developed to solve control theory problems and described in detail in [10], and as the complete ATP method with functional symbols was introduced in [11]. Due to some features, the PCF calculus allows one to combine automatic proving with special heuristics (human knowledge and experience) customized for every given problem. Applying PCFs for planning the actions of AUVs, plans are constructed automatically while applying deduction of task specifications from the specification of functional capabilities of the AUVs. A question-answering procedure of the inference search significantly reduces restrictions of the logical approach to planning and control. Compared to other logical means of formalizing a subject area and deductions search, the PCF calculus has the advantages of expressiveness combined with compact knowledge representation, "natural" parallel processing, large-blockness, the least combinatorial complexity of deductions, and high compatibility with heuristics.

As an example of the PCF method usage we consider an approach to problem solving formalization for groups of autonomous underwater vehicles (AUVs) as the fragment of some centralized control system which continuously monitoring certain underwater area. Action sequences for AUVs and their groups are generated as a result of a first-order logic inference in automatic or interactive mode.

Let's consider the example of PCFs method application to describe and solve the following problem. Imagine a fragment of a centralized control system of groups of autonomous underwater vehicles that are continuously monitoring certain underwater area. Let's consider that there are two groups of autonomous robots (a_1 and a_2) in the area. Groups are composed of robots with different functionalities united in the likeness of tasks it can handle (for example, identification, sampling and manipulation, etc.). The groups control is maintained by the means of acoustic communication network with some central server (CS), that is allocated on the support ship. The CS operates automatically under the supervision of a human operator who can change group tasks and goals. Next, consider PCF language specifications of robots and CS as a possible parts of a larger system specification, focusing here on achieving a common goal of the two groups that will be reached in stages. It is required to achieve sub-goals to complete each stage. The completing or the inability to complete sub-goals is defined by events in the deductions search of formulas that specify the functionality of robot groups. If there is no way to complete a sub-goal, then a communication with CS is taking place to request re-planning. Sub-goals that are possible in our statement of the problem: object identification; carrying out additional actions with the object (sampling, communication); conducting defensive operations; loading of an object; docking with the object.

Groups of robots specifications in some initial moment of abstract time is described by the following base subformula:

$$\exists s_1, s_2, a_1, a_2, S(s_1), S(s_2), A(a_1), A(a_2), T(0)$$

Here $S(s_i)$ denote the set of atoms defining the state of groups $A(a_i)$.

The current functioning and tasks for groups are described by following questions to the base subformula:

$$\forall t\ T^*(t) - \exists\ T(t+1)$$

$$\forall x, t\ Patrol(t, s_i, a_i), T(t), See^{\#}(x)\ -\ \exists\ Find(t, x)$$

$$\forall x, t\ Find(t, x) - \exists\ \boxed{Task(t, x, a_i}$$

The first formula in the list of questions is the our method of the time moment counting in PCFs. It uses the atom with the symbol *, which means that if there is a successful answer to a question, then the corresponding atom must be removed from the base of facts. Thus, from the initial moment of time, in the cycle of the questions answering procedure, *T(1)* is added to the base instead of *T(0)*. Further, if the base is not refuted, *T(2)* will be added, and so on.

The second question, assume that one of the groups has the capability to detect objects. This option is checked with the help of the computational predicate *See(x)* denoted hereinafter in formulas by the symbol #. Truth values of the computational predicates are not established by the logical inference but by the actual state of environment. Thus, if detection sensors trigger successfully, the fact *See(Obj)* – a symbolized definition of the detected object – is added to the base. Then, for example, at time moment *n*, the second question has the answer, and the fact *Find(n, Obj)* will be added to the base.

Framed atom in the third question indicates the achievement of one of the sub-goals and the end of the deduction search. The communication with the CS is taking place. In our case, there is a request to the CS for further instructions after the object detection. The atom *Task(n, Obj, a_i)* is sent to the base of facts of the CS. This behavior is handled by the following question that might present in the list of questions on the CS:

$$\forall t, x\ Task(t, x, a_i) - \exists \boxed{Identify(x, a_i)}$$

After this question is answered, the fact *Identify (Obj, a_i)* will be sent to the coordinator of the group which sent the request. The system's further work is related with the study of the detected object. The first step is to determine whether the found object can present any danger. Suppose that the given task can be handled by group a_1. If there is no danger, the group a_2 can proceed to the task by robots with the ability to capture photos and videos.

Any object found in the area can be considered hazardous if it is moving and is not a local fauna representative, or if it contains any hazardous materials (pollution, underwater mines). For this task, there must be the following question subformulas in the list of questions of the a_1 group coordinator:

$$\forall x\ Identify(x, a_1) \begin{cases} \exists\ Moving^{\#}(x), NoAnswr^{\#}(x), NotFish^{\#}(x) \\ \exists\ Contamination^{\#}(x) \\ \exists\ Mine^{\#}(x) \end{cases}$$

$$\forall x\ Moving(x), NoAnswr(x), NotFish(x) - \exists \boxed{Danger_1(x, a_1)}$$

$$\forall x\ Contamination(x) - \exists \boxed{Danger_2(x, a_1)}$$

$$\forall x\ Mine(x) - \exists \boxed{Danger_3(x, a_1)}$$

The first question in this list splits the base, each new base subtree will correspond to the type of danger. Atoms with the symbol # request the corresponding sensors. In case of the negative analysis of the object, corresponding atoms in the base are removed (replaced by the constant *true*). According to the problem statement, only the one of the last three questions in the list can be answered, if it did, the deduction search stops and the type of danger – *$Danger_j$ (Obj, a_1)* –

is sent to the CS. If the deduction search fails, the group a_1 returns to the normal functioning, and the CS sends the task for the photo and video shooting to the group coordinator of a_2, which processes it with questions:

$$\forall x, t\ PhotoVideo(x, a_1), T(t) \begin{cases} \exists\ Photo(x, t) \\ \exists\ Video(x, t+1) \end{cases}$$
$$\forall x, t\ Photo^{\#}(x, t), T(t)$$
$$\forall x, t\ Video^{\#}(x, t+1), T(t)$$

The deduction search of two new bases will be successful, one after another. The first, at some moment *T(n)*, there will be a photo shoot as a result corresponding question application in the bottom list. After that, the second base's time will change to *T(n + 1)* and it will be possible to answer the last question, refuting the base and thereby completing the deduction search. The end of the deduction search means the achieving another sub-goal.

The presented statements describe some "life cycle" of two groups of robots. Further, by analogy, we can describe all possible situations and circumstances of the area's environment in the system. The plans of actions of the system are built and performed in automatic or interactive mode during the inference search. This example demonstrates a common approach to the planning problem using the method of PCFs.

5. Conclusion

In this paper various approaches to AUV group control on the different level of hierarchical control system were briefly discussed. Integration of the listed methods and algorithms into the one control system and its implementation in real life applications is the future work. The reported study was partly funded by RFBR according to the research project no.16-29-04238.

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DIGITAL TRANSFORMATION DISRUPTIVE THREATS IDENTIFICATION

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Abstract: *Modern gadgets or IoTs miniaturization and embodiment into new technological users are inevitably producing numerous opportunities and disruptive threats towards digital transformation of their lifestyle, behaviour and understandings. The paper outlines a snapshot of user beliefs implemented in an analytical system model. The obtained results, matching with numerical stochastic simulations is further given in regards to potential disruptive threats proactive identification. Possible further verification is finally discussed.*

Keywords: DIGITAL TRANSFORMATION, DISRUPTIVE THREATS, SYSTEM ANALYSIS, STOCHASTIC VALIDATION, INTERACTIVE VERIFICATION

1. Introduction

The Fourth digital revolution is already a fact that is producing numerous opportunities. They are enormous, and so is the projected growth of Internet of Things (IoT) – the number of connected "things" is expected to be between 20 and 30 billion by the year 2021 [1], [2]. At the same time, together with the opportunities - new threats emerge [3]. In this context it is important to note the ubiquitous role of innovations for the societal development acceleration and establishment of new 'ecosystem' of living. This practically, generates a disruptive transformation to the social well-being and industry that from a technological view point is rather challenging [4].

Two important facts have to be noted here: speed and scale. With the new hardware and software technologies, interactive progress and IoT integration, during the next decade the surrounding digital world will become a mixture of living organisms and technology interacting on a new, unknown so far level. Here is important to note here the results for the societal dynamic transformation from human factor perspective in the digital age [5].

Further on, in the paper, a modelling approach for exploring these phenomena from a security perspective, together with possible results proactive validation are presented.

2. Exploration Approach

The main idea of the presented approach for exploring the societal dynamic transformations in the new digital age is to (i) proactively implement expert beliefs into a system model. Results are (ii) further validated for future expectations, using stochastic machine simulation. These ideas though rather flexible are lacking easy comprehensive accuracy criteria definition, concerning their futuristic address. In regard to the disruptive challenges proactive identification, a useful mechanism could be (iii) verification support via hybrid interactive simulation.

2.1. System Modelling

The idea for system modelling, using expert beliefs is generally implementing, with some data presented in [6], and is further aggregated in disruptive technologies sense, using the approach for model graphical and analytical representation built-in I-SCIP-SA software environment [7].

All model entities are marked with labeled round rectangles, interconnected bilaterally. Weight and time parameters are used for resulting entities classification (visualized as indexed balls) into a four-sector (green – 'buffering', red – 'active', blue – 'passive' and yellow – 'critical') 3D Sensitivity Diagram (SD), using: Influence (x), Dependence, (y). Additional, 'active' (white, positive z values) and 'passive' (grey, negative z values) reassessment for each of the entities in a certain sector, regarding Sensitivity (z) is also accomplished.

A practical modelling result of 'Digital Society', disruptive effect from 'Advanced Interfacing' , 'E-Tradings', 'Autonomous Robots', 'Smart Services', 'AI Devs' and 'Interactive Webs', concerning 'Transformed Reality' is given in Figure 1a.

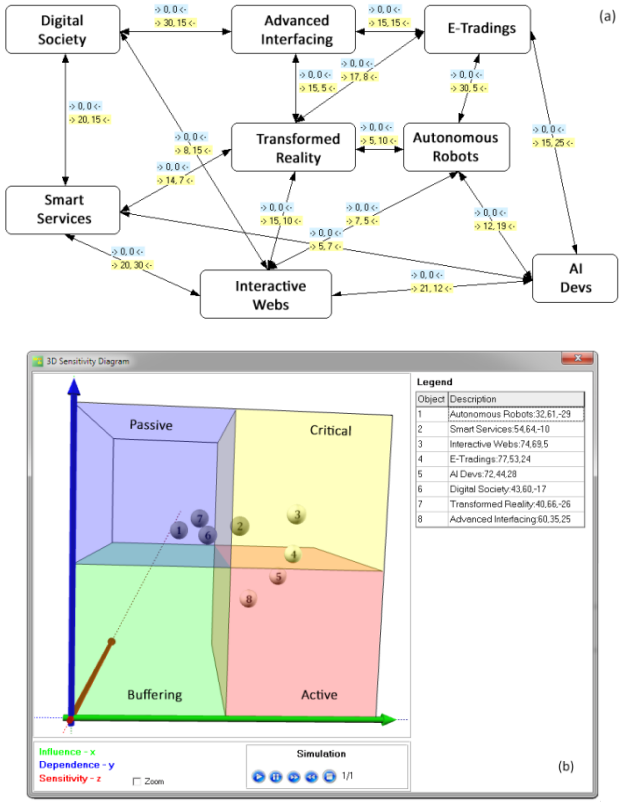


Figure 1. *A system model for disruptive threats exploration in the new transformed digital reality (a) and the resulting sensitivity diagram (b).*

The resulting SD (see Figure 1b) is producing the following classification for model potential sources of disruptive threats: critical: 'Smart Services' – '2', 'Interactive Webs' – '3' and 'E - Tradings' – 4; active: 'AI Devs' – '5' and 'Advanced Interfacing' – 8; passive: 'Autonomous Robots' – '1', 'Transformed Reality' – '8' and 'Digital Society'. No buffering entities were used.

A further results probabilistic assessment is accomplished as the identified threats would be interesting for future dynamics trends evolution.

2.2. Probabilistic Assessment

Due to the subjective and static nature of results from section 2.1, the studied processes have to be considered and in the dynamic context. This practically, could be achieved, following the ideas

from [8], implementing both expert beliefs and development trends as a priori landscape.

Additional further validation via agent-based simulation of possible hybrid attacks towards selected relations of a certain entity of interest is performed. This provides a posteriori simulated probabilities change by assessing hypothetical evolution scenarios.

Five trends have been considered ('Smart Services', 'Digital Society', 'Transformed Reality', 'Autonomous Robots', 'AI Devs'), regarding 'Interactive Webs' from the presented in section 2.1. model.

A resulting simulation from Matlab R2011b environment, using Beta distribution with five-years' time horizon is provided in graphical form on Figure 2.

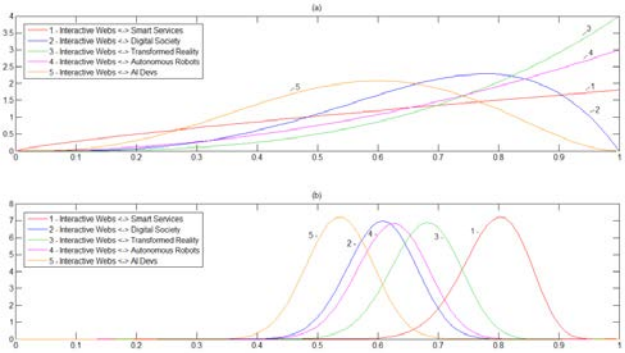


Figure 2. *A generalization of experts' a priori (a) and simulated a posteriori (b) probabilities for hybrid attacks to 'Interactive Webs'.*

According to the presented simulation results, 'Smart Services', 'Transformed Reality', 'Autonomous Robots' and 'Digital Society' (see Figure 2) are expected to be most probable (M > 0.5) for future hybrid attacks in the new, mixed and transformed digital reality environment, still giving uncertainty to 'AI Devs'.

2.3. Results Verification

This final stage was organized, using an interactive hybrid simulation gamming approach, following the experience from [9]. The ideas were practically implemented into CYREX 2017 (see Figure 3), involving university, academic, NGO and industrial participants [10].

The main objective was to experimentally study the future of digitally transformed reality threats and challenges, using different smart gadgets, biomonitoring, popular social networks, cloud services, encryption and original training methodological framework.

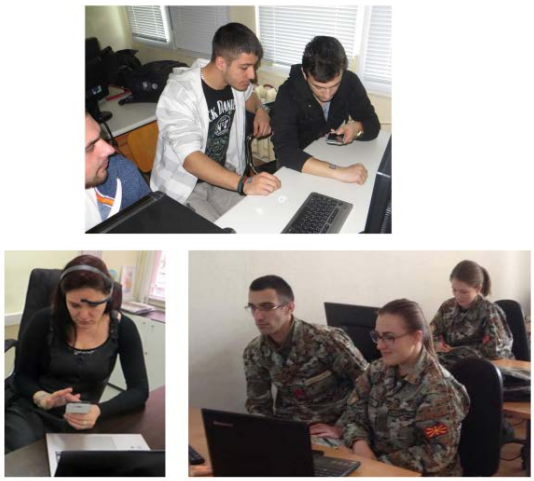


Figure 3. *Moments of CYREX 2017 verification event [10].*

Generally, the overall verification results have shown a significant interest from the participants' side, regarding the improvised transformed reality, innovative gadgets and gaming exploration approaches. Additionally, though distributed by nature the CYREX 2017 was rather realistic, useful and intriguing according to the participants self-reporting.

4. Conclusion

The described exploration idea of digital world disruptive hybrid threats identification is producing a useful address toward future societal digital progress, encompassing both human and machines complex mixture in a new transformed reality. Being to some extent subjective the presented results are just outlining the near future plausible expectations, providing at the same time a reliable fundament for analysis and complex hybrid threats origins understandings. The further given validation and verification of the obtained results are finally establishing a valuable moment to the proposed initial system modelling ideas.

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HYBRID ENERGY MICROSYSTEMS ENHANCED BY SOLAR PV ENERGY

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Keywords: HYBRID ENERGY MICROSYSTEMS, E-BIKE, SUPERCAPASITOR,

1. Introduction

PhotoVoltaic (PV) and wind technologies are getting matured and nowadays they provide energy flows for utility power grids. However, it is widely-known that they exhibit strong nonlinear electrical characteristics variable with weather conditions and level of solar light illumination. After the boom of photovoltaic and wind power installations in Europe and in Bulgaria an urgent need of short-term and long-term energy storage is revealed. Power injection in the grid produced by small decentralized power generators occurs as a sharp problem of energy balancing that focus the attention on the stability of power systems and the search for new ways to overcome fluctuations. A simple and intuitive method to mitigate these instabilities is to use energy storage devices in the power system architecture. In recent years, the researchers' emphasis is transferred from energy generation to energy storage importance. Research interests have been focused on innovative hybrid systems with dynamic power flow management - heterogeneous generators with various peak power capacities, new type batteries, hydrogen fuel cells, stacks of supercapacitors or hybrid combinations of them.

Traditional electrical energy storage systems as Sealed Lead-acid and NiCd batteries are less attractive because of heavy weight and a relatively low energy density, and the latter suffers from capacity loss caused by shallow discharge cycles, termed as the memory effect.

On the other hand, supercapacitor technology namely, electrochemical double layer capacitors (EDLC), is a developing and promising technology in the energy storage applications. It is expected to bridge the gap between electrolytic capacitors and rechargeable batteries. Efficient energy storage in EDLC capacitors is a result of highly developed surface area of the electrodes and charge carrier separation in thin layers of macro-, meso- and micro-porous carbon material. The merits of supercapacitors arise from their high power capability based on ultra-low internal resistance, wide operating temperature range of -40oC to +65oC, and high cycling capability (>106 cycles).

The aim of the present work is to test hybrid concepts for energy generation and energy storage in real cases. Two options for decentralized hybrid microsystems are discussed - a hybrid energy system for a building in urban environment and a hybrid bike to move in cities with heavy traffic. The energy management and storage systems contain two elements - an energy storage - battery pack and/or a supercapacitor stack and a renewable generator – solar, wind or human-assisted.

Hybridization concept:

The main target of hybridization of different energy technologies is to improve the system efficiency, to find a way to reduce the environmental pollution from carbon emission and reduce operating costs for transportation systems. The main objective of integrating batteries and supercapacitors is to create a hybrid energy storage system (HESS) with high energy density and power density in vehicular or stationary power system architecture. Efficiency will be improved if peak power demand will be provided by the supercapacitor, while the average power demand will be complete by the battery.

For industrial applications, supercapacitors have become more accepted as high power buffers in combination with conventional lead-acid batteries or advanced chemistry batteries. Unfortunately battery designed to attain maximum energy density in most cases require a sacrifice in power capability. It has been recognized that combining carbon/carbon supercapacitors and batteries would significantly reduce the stress on the batteries in heavy applications in which the batteries are subject to high current pulses in both charge and discharge.

In transportation, the supercapacitors can provide burst power during vehicle acceleration and recover energy during regenerative braking. Similar examples can be found in telecommunications during short transmissions and long stand-by. In the short ranges, the supercapacitors would greatly reduce the power demands on the battery and extend its life cycle.

2. Hybrid energy micro-system for urban building

Recent smart energy systems look beyond the already traditional solar or wind energy applications. More frequently they use several energy sources in one system which means – new Hybrids and higher energy efficiency. We present here small hybrid energy system utilizing solar and wind energy, battery energy storage and grid-connection technologies. The block diagram at Figure 1 below illustrates the main system components. The novelty in this microsystem is the ability to store energy or inject the localy–generated energy into the building grid in a proper moment reducing by this way the office electricity bill.

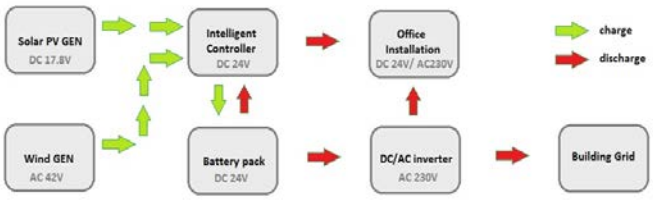


Fig. 1 *Block diagram of Solar/ Wind office microsystem.*

The hybrid prototype is equipped with 720 Wp PV generator, 600W vertical-axes wind generator along with a battery bank of 2.4kWh (100Ah, 24Vdc). The PV rooftop generator consists of 3 standard PV modules (240Wp, c-Si) connected in parallel and protected using additional high-power rectifying diodes and intelligent 24Vdc charge controller. At Figure 2 below photos of the installation are presented.

The wind turbine is Maglev-type [1],[2] Vertical Axis Wind Turbine (VAWT) which combines magnetic levitation AC motor with S-type of Savonius rotor and 3 air-foil Darrieus blades to maximize the electrical output performance. Maglev generators use magnetic suspension technology based on NdFeB magnets. As can be seen at Figure 3, it creates frictionless, efficient, far-out-sounding motors which provide excellent rotational stability, eliminating vibration, typical wobble, shaking and noise. All these factors are important for noiseless urban building applications.



Fig. 2 *General view of hybrid (solar and wind) system.*

The solar and wind generator are working in complimentary regime because typically the solar peak generation is in daylight while the wind has e maximum generation in nighttime. Hence, the resultant combined energy generation covers the energy needs of a small office in urban area.

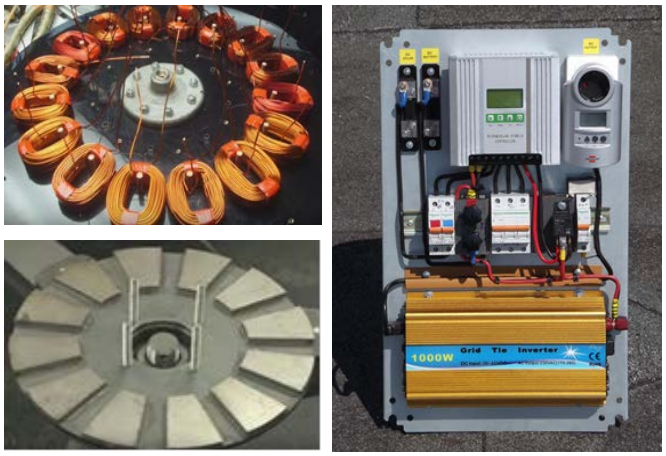


Fig. 3 *BLDC motor, charge controller and grid-connected inverter.*

In the application the produced energy is store in battery block and later injected in the building grid intentionally, depending on the needs of the office equipment and labor force. In Table 1 results on power generation in three typical days is summarized.

Table 1: *Solar/Wind power generation.*

CASE STUDY: Three case studies were conducted to determine the effect of amount of battery power drawn during typical sunny day, windy day and cloudy day to determine a suitable amount of battery power for real case studies.			
Case	***Into Grid (9.00 - 17.00h)***	***Averages PV prod.***	***Averages Wind prod.***
Case 1: (high solar, no wind) PV and batteries are connected to the system. The demand limit occurs for 3 hours from 17:00 to 20:00. To keep the total consumption below demand limit, the EM algorithm has reduced non-critical loads.	3.6 kW	448 W/h	2 W/h
Case 2: (low solar, small wind) PV and batteries are connected to the system but the battery is not charging. The inverter still injects into the grid. The use of RE system in this case resulted in lower amount of load reduction for shorter periods.	2.0 kW	226 W/h	24 W/h
Case 3: (no solar, middle wind) PV, Wind turbine and batteries are connected to the system but the battery is not charging. The inverter still injects into the grid. The use of RE system in this case resulted in lower amount of load reduction for very short periods.	1.2 kW	20 W/h	128 W/h

The basic result of power generation in urban area for our climatic conditions pointed out that the effect of wind power generation is below 19% while the solar PV generates approx. 81% of the total amount of produced electricity.

In future developments, the office microsystem will be enhanced by web-connected energy management systems (EMS) to control the power injection into the grid only at moments of “peak price” tariff.

3. Hybrid urban e-BIKE

Many e-bike users experience the limited battery lifetime as a problem for more wide range applications. Our e-bike is designed to give students an interesting tool to analyze human, solar and motor power in a complimentary way. This part of the paper describes the design and shows the first test results of a hybrid energy storage e-bike with a 5kW hub motor, a 50Wp c-Si PV module, a 60V,18Ah battery and a 500F,16V superCaps stack.

3.1 E-bike concept

The authors are inspired by conceptual all-weather bike designed by Torkel Dohmer (2008). The developed e-bike platform consists of a motor, battery stack, solar generator, superCAPs stack and corresponding DC-DC converters [3], [4]. During normal operation on the road, DC energy from battery supplies a rim-incorporated BLDC motor. The battery is charged in motion by additional solar PV module. Other innovative feature is regenerative braking through supercapacitor energy storage [5]. Regenerative braking recovers much of the kinetic energy of the vehicle. It is an option for additional charging, because in fact the reverse current could not be fully used due to charging limits of the battery. Excess current could be absorbed by superCAPs. User-controlled charging of superCAPs while cycling improves charging fluctuations and increases the e-bike efficiency.

3.2 SuperCAPs energy storage

Charging process of superCaps is different from charging batteries. The superCAPs may not be overcharged! The applied power supply should limit the maximum operating voltage over the superCAP module. The other reason is the supercaps are difficult to charge in SOC =0% by conventional chargers but the PV module fits well to charge them in nearly zero voltage at Isc point of

operation. Typical industry load voltages are 3.3, 5, and 12 V while the largest supercapacitors have cell voltages of 2.7 V. Reaching industry voltage levels would require multiple supercapacitors in series. Supercapacitors in series require a protection circuit for voltage balancing, so called battery management system (BMS), during charging to prevent internal breakthrough. This irreversible degradation is caused by the overvoltage across a capacitor exceeding the rated voltage of 2.7V on the cell.

3.3 Design and implementation of hybrid e-bike (velo-EV)

The focus of this design is a low-cost hybrid-e-bike to be created that can be repeated easily. Only system performance is discussed without details on underneath software and hardware technologies. This application of solar PV module combined with supercapacitors is designed to show their versatility and feasibility as a power source for any portable system.

The velo-EV used in this experimentation is a two wheels prototype designed and realized in research units of Bulgarian Academy of Sciences. A drawing and a photo of the implemented velo-EV are presented at Figure 4.

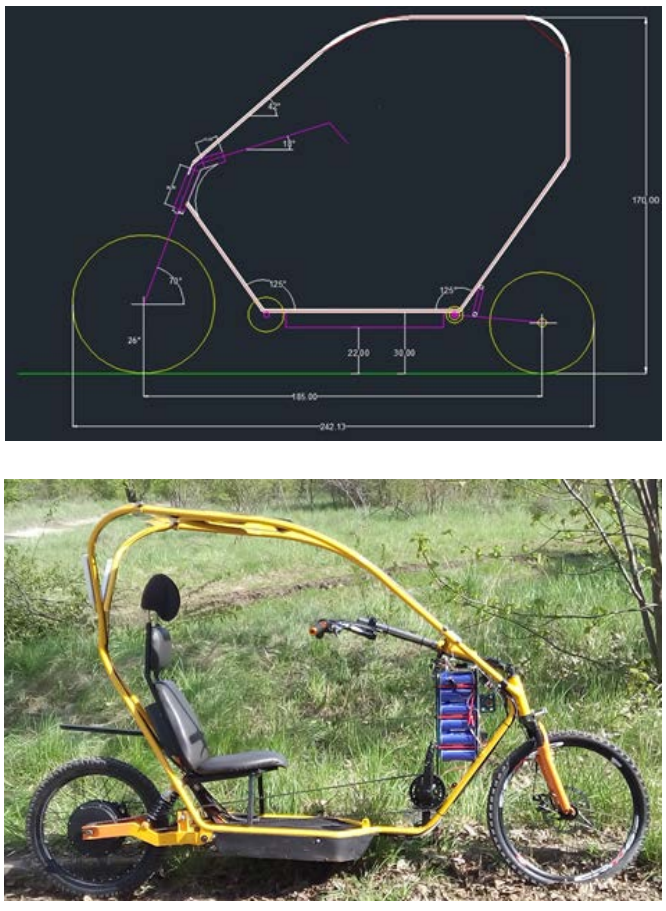


Fig. 4 *Solar e-Bike concept and prototype.*

The starting configuration is a thin iron-tube chassis with a roof, rim-integrated BLDC motor, AGM lead-acid batteries and a supercapacitor stack. The battery block is mounted at the bottom of the platform between the wheels in order to be charged or replaced easily. The lower location of the battery increases the mechanical stability during bike motion. Highly efficient PV module (50Wp, 22% eff) consisting of back-contact c-Si solar cells is mounted on the roof. With this configuration, a very flexible hybrid energy system has been obtained.

A summary of specifications of the BLDC motor, presented at Figure 5, and controller can be found below in Table 2 and Table 3. Brushless DC motor attached into the wheel use a rotating permanent NdFeB magnets in the rotor, and stationary electrical magnets on the motor housing. A motor controller converts DC to AC driving impulse trains. The control strategy is based on current regulation loop using a powerful DSP and high-power n-channel MOSFETs.



Fig. 5 *Rim-integrated BLDC motor.*

Table 2: *Electrical specifications of BLDC motor*

Max voltage & power	Windings	Max torque	RPM
72Vdc, 5000W	4T x20, 180^{0}C Cu	190 N.m	700@72V
Max loading	Max speed	Rotor Position control	Net weight
150 kg	70km/h	2 x Hall sensors head	11.0 kg

Table 3: *Electrical specifications of drive controller*

Voltage range	Max DC current	FET drive current form	Speed limit
48-72V	120A, programmable	True -sine	Soft controlled
Soft Access	Gear control	Max Reverse Brake current	Weight
Cable & Bluetooth	Electronic switch	200A, programmable	2.5 kg

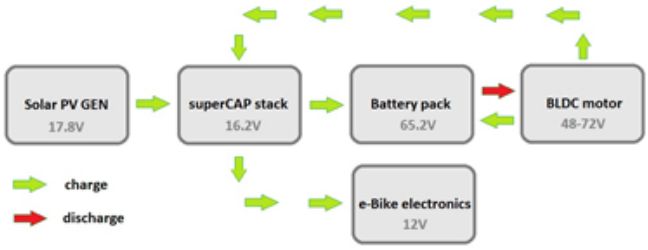


Fig. 6 *Solar e-Bike block diagram.*

The velo-EV, with approx. weight of 42 kg has been equipped with a BLDC electrical motor with permanent magnets operating at 48-72V and 5 kW of peak power. The battery system is composed by 5 units of AGM-12v, with 65.2V in total and capacity of 18 Ah

and the total energy is 108 Wh. The main specifications of AGM lead-acid batteries per unit are weight of 5.97kg, internal resistance - 20 mOhms. The batteries can operate in any orientation excluding upside-down with a max discharge current - 10s - 119A, 5 min - 89A, 60 min - 20A.

The chosen supercapacitors are six MAXWELL 2.7V, 3000 farads Boostcap3000P® ,connected in series and protected by battery management system (BMS), as can be seen in Figure7.

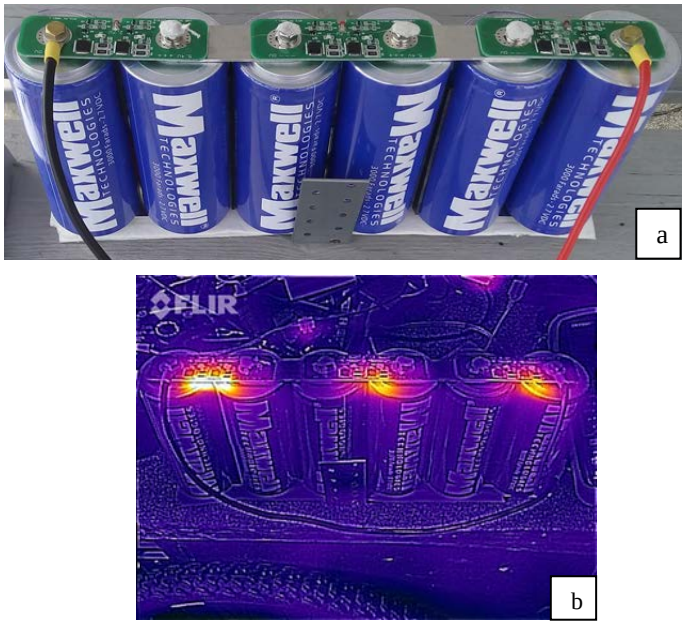


Fig. 7 *Photos of SuperCAPs stack (a) and infrared image of overvoltage BMS activation (b).*

Due to the absence of chemicals, supercapacitors can charge and discharge faster and without degradation [6],[7]. They can withstand temperature changes, shocks, and vibrations better than most batteries.

Cmax= 3000F/2.7V Emax = (Ceq x Umax2) / 2 =>Emax = 10.93 kWh Eeff= 3.28 kWh

Cblock = 500F/ 16.2V =>Emax = 65.61 kWh Eeff= 19.69 kWh

ESR= 0.4 mOhms Pdischarge = Umax2/ 4ESR => Pdischarge= 164 kW

DoD = 33% Umin = (1-DoD) Umax

Uncharged supercapacitors (U_{min}=0) appear as a virtual short to voltage-fed power supplies, not allowing to be directly charged by connecting them to conventional CC/CV power chargers. Having the stack voltage of 16.2V exceed the standard12V options will benefit the output power manipulation and DC-DC converter's efficiency.

During normal operation - driving mode - the battery stack is discharged by BLDC motor. The charging cycle is ensured by SolarGen and superCAP stack or by motor charging during regenerative braking. There are 3 levels of DC voltages and 3 types of DC-DC converters for energy flows corresponding to 3 energy sources - PV module, superCAPs and Battery stack. Separate DC_DC converters with different output voltages were built to provide energy flows and a stable autonomous power source for all electronics on the hybrid e-bike.

In stationary mode the charging process could be performed by solar PV and by external 72V DC charging station.

The SolarGen, superCAP stack and Battery stack voltages are monitored in 3 different displays during bike driving. The digital communication among components is implemented as an open LAN which consists of three main subsystems: motor controller monitoring, currents flow supervision and Bluetooth communication.

During normal operation on the road a data logging unit receives sensors signals from the BLDC motor inverter, the battery and the PV module. Real-time data can be displayed to an Android tablet using Bluetooth or to a Windows laptop using USB link.

3.4 Design considerations

Three foreseeable obstacles became apparent: - mechanical stability of the frame construction, superCAPs charger and DC-DC converters circuits safety.

General schematics look nice on paper or on screen but may not be feasible on a testing field/board.

The motor has enough power to drive the vehicle, the driver and carry relevant equipment but mechanical vibrations occur in the front suspension of the bike. Due to weight of the battery block frame construction and front brake should be reinforced.

High voltage spikes occurred in the cables between motor and drive controller which deteriorate the power supply of electronics. Hence, the charging circuit had to be redesigned and manually tested for functionality and performance.

The supercapacitors used in the stack are heavily charged and they can produce sparks if not isolated properly. This meant creating a safe and portable enclosure around the supercapacitors and power circuitry had to be taken into account.

3.5 Charge testing

Due to virtual short in empty supercap it is hard to provide enough voltage to the stack. Initially overcoming this problem involved attaching an external charged battery to the supercapacitor stack and draining the battery into the stack. For our proof of concept we chose to test our supercapacitor stack using PV module. In principle, the short circuit condition in PV module is not dangerous for the module because the internal current generator is limited and the generated power is dissipated. We attempted connecting uncharged supercap stack directly to the MPPT charge controller of a solarPV module. We tested successfully the charge/discharged cycle in a sunny day with high level of sunlight illumination.

3.6 Drive testing

Testing of the vehicle was performed at Research complex II of the Academy in Sofia. A photo of the first driving is presented at Figure 8. Unfortunately, at the moment of writing, the completed e-bike has not been tested thoroughly yet. Some initial tests have been performed, and the initial results look promising.



Fig. 8 *First test driving.*

The maximum speed during our test was over 35.0 km/h, without pedaling! With one full superCap and battery charge, the initial test showed the e-bike trip has a range of 54 km. Further testing will have to be done to explore the limits of the braking system recharge. In the initial tests reverse brake has been switched-off by the software.

The driving cycles are acceleration phase, mild drive, deceleration phase. Speed and distances have been measured by external Android phone @ GPS applications.

Two additional tests have been performed for the battery storage (BS) and the hybrid storage-Battery / Supercapacitors (HESS). The difference in terms of range is about 37 km BS versus 54 km with HESS. Higher values of internal resistances of lead-acid batteries lead to higher voltage drop during accelerations and shorter drive distance. These are much smoothed with SuperCAPs. The implementation of superCAPs in the power system has provided significant performance improvements. Totally, a 1.2V voltage drop of the battery pack has been observed after 45 min round trip test.

Conclusion

The hybridization of small power generators and energy storage devices has reached a level for daily use and offers new energy-efficient solutions in power engineering. Small Solar/Wind generators can be incorporated in the existing urban infrastructure.

A stable open EV platform to test the use of superCAPs in e-bike has been succesfully developed. The hybrid bike, nor the energy storage systems, exhibited any problems under the test conditions. The use of superCAPs together with the lead acid battery of velo-EV has the advantage of improving the behavior of the lead-acid batteries. SuperCAPs have vast advantages when it comes to acceleration, fast charging and long life. The effect of PV roof is observable on SuperCAPs charging. A fast charger for the superCaps, a data logging and visualization unit were all developed from scratch, only using low cost power electronics. In the near future the evaluation of the superCap e-bike concept for daily use will be started.

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HYDRAULIC AND THERMOTECHNICAL MEASUREMENTS TO DETERMINE THE EFFICIENCY OF AN INNOVATIVE SOLAR THERMAL COLLECTOR

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Abstract: *There are many variants of solar collectors on the market with their advantages and disadvantages. The innovative solution of solar thermal collector has been done to increase efficiency and improve design. The new constructive solution presents good combination of an attractive design and appropriate constructive materials with special geometric shapes. Hydraulic and thermotechnical tests of this collector showed high hydraulic and structural stability. The main disadvantage is selective electrochemical coat and further development of the solar collector will be in order to improve observed disadvantages.*

Keywords: SOLAR THERMAL PANEL, EFFICIENCY, HEAT CONVERSION, ABSORPTION SURFACE

1. Introduction

The popularity of solar heating systems is increasing for several reasons. These systems are reliable, adaptable and pollution-free, because the renewable solar energy is used. The solar thermal panels have been used in solar installations for preparing hot water, for supplementary heating of the different facilities, as a support to classic heating system, for heating of water in swimming pools, etc.

The reason why solar energy has not been exploited sufficiently so far can certainly be found in its relatively low density compared to conventional sources, and in the fact that for its "capturing" and conversion relatively big solar surface should be installed which requires significant investment. This is why this investment is a privilege of richer individuals and countries, which however, after a relatively short repayment period, provides free of charge and clean energy throughout its useful life. The ways of "capturing" solar energy are diverse. This paper focuses on an innovated technical solution of a solar collector designed for heat conversion, that is to say, primarily for hot water preparation. Photovoltage collectors that perform conversion of solar into electric energy also have a significant role as far as application is concerned.

2. Technical and geometric characteristics of the absorber

There are many variants of Solar Thermal Panels in the market mainly constructed with copper pipes and flat absorbers with different quality of absorption surface. Taking into account advantages and disadvantages of existing solutions, in order to increase efficiency and improve the design, the innovative solution of solar thermal panel has been produced.

This new solar thermal panel presents integration of attractive design and appropriate constructive materials with special geometric shapes. Panel is made of special aluminum lamellas in series connection, placed in aluminum thermal-insulated box. The aluminum was chosen for making the absorber because it is significantly lighter than copper. Weight of system is certainly something that should be taken into account, primarily because of the load on the roof structure, which can be significant, especially if a considerable number of panels are placed on the roof. Aluminum also has good technical characteristics in the sense of heat conducting and the possibility of applying appropriate long-term surface protection. The shape and the profile of lamella make the original absorber, and its design has a number of advantages compared to the usual technical solutions. A significant effort has been made to find the geometric profile of ribbed lamella. The surface protection was made by way of special procedure of electrochemical protection, thus obtaining a high quality selective surface of absorber.

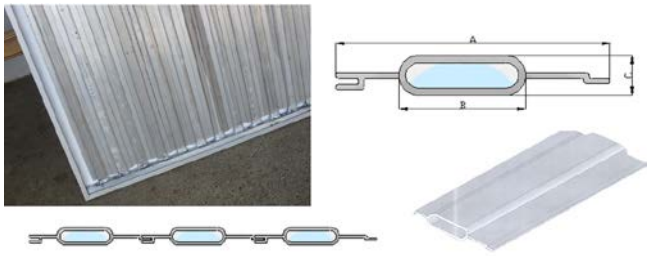


Fig. 1 *Absorber surface of solar panel with a schematic connection of absorber lamellae (cross-section).*

3. Hydraulic and thermotechnical tests of solar thermal panel

In order to determine the hydraulic and thermal characteristics of this new solution the solar panel was required to perform appropriate tests. Hydraulic and thermotechnical tests of solar thermal panel were made on Mechanical Engineering Faculty, University of Nis according to standard SRPS M.F5.110, SRPS M.F5.001 and SRPS M.F5.050, with regard to EN 12975 and EN 12976.

Table 1: *Technical data of solar panel "Solarmont"*

Product	Unit	Receiver of solar energy "Solarmont"
Dimension	mm	910x1980x72
Cover		pamplex glass one sided
Frame and sealing		extruded Al- profile, EPDM rubber
Working medium		water-glycol
Absorber		Al- profile with electrochemical layer
Absorber surface, net	m^2	1,75
Weight of empty receiver	kg	40,0
Water quantity	L	5,0
Nominal flow	kg/h	124
Maximum working pressure	bar	6
Maximum working temperature	°C	100

On the Figure 2 is showed scheme of the measuring line with next elements: 1, 2 Solarimeter, 3 Thermometer at the entrance, 4 Flowmeter, 5 Transparent tube, 6 Filter, 7 Temperature controller, 8 Valve, 9 Pump, 10 Expansion vessel, 11 Safety valve, 12 Venting valve, 13 Thermometer at the exit, 14 Insulation, 15 Gate valve, 16 Anemometer, 17 Ambient temperature.

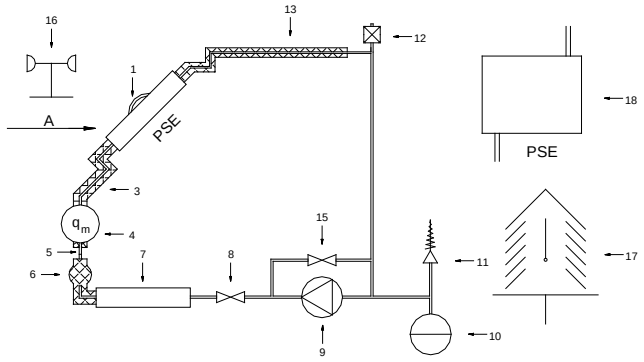


Fig. 2 *Scheme of the measuring line.*



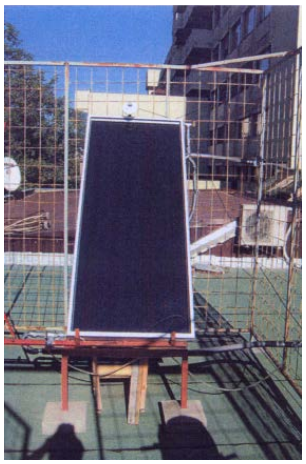


Fig. 3 *Part of the measuring line for hydraulic and thermotechnical tests of solar thermal panel.*

4. Results of thermal performance

In order to determine the efficiency of the solar panel it is necessary to calculate the following:

Table 2: *Parameters to determine the efficiency*

Mass flow, kg/s	$q_m = 0.03$
Temperature difference	$\Delta T = T_i - T_e$
Average temperature	$T_m = T_i + \frac{\Delta T}{2}$
Arithmetic average temperature difference	$\Delta T_{sr} = \frac{T_i - T_e}{2} - T_a$
Reduced temperature difference	$T^* = U_o \frac{T_m - T_a}{G}$
Heat transfer coefficient	$U_o = 10 \frac{W}{m^2 K}$
Useful heat	$P_T = q_m c_f \Delta T$
Current heat utilization	$\eta = \frac{P_T}{A_a \cdot G}$

The efficiency of the receiver is determined according to

$$\eta = \eta_s - a_1 (T_m - T_s) / G^* - a_2 (T_m - T_s)^2 / G^* \qquad (1)$$

Table 3: *Results of solar panel thermotechnical tests"*

No.	*(Tm-Ta)/G*	*η*
1	0,00	0,731
2	0,01	0,651
3	0,02	0,581
4	0,03	0,492
5	0,04	0,493
6	0,05	0,351
7	0,06	0,282
8	0,07	0,211
9	0,08	0,128

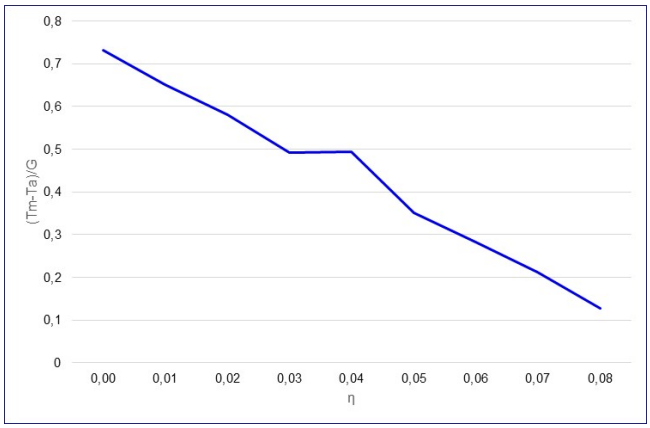


Fig. 4 *Diagram of the current heat utilization.*

5. Conclusion

Conducted hydraulic and thermotechnical measurements showed the following:

- Hydraulic and thermotechnical tests that have been performed on this panel showed high hydraulic and structural stability;
- The main disadvantage of the panel is selected electrochemical coating;
- Further development of the solar panel will be done in the future in order to improve some noticed disadvantages.

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IMPROVING THE EFFICIENCY OF THE FLAT PLATE SOLAR COLLECTOR SYSTEM WITH A NEW DESIGN

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Abstract: *Solar collectors are one of the most promising renewable technologies for energizing future systems. Solar collectors are used for a variety of heating systems such as domestic hot water systems and industrial application. Increasing the collector efficiency is an important factor in terms of unit cost. In this study is to increase efficiencies of flat plate solar collectors. For this purpose, various apparatus was place into collector tubes which increase the heat transfer between plate and fluid, thus it developed a new collector. In addition, a new collector hot water tank was designed. The changes in warehouse and collector were compared with the classical systems and the change in the usage water was calculated.*

Keywords: SOLAR SYSTEM, SOLAR COLLECTOR, ENERGY EFFICIENCY

1. Introduction

Technological advances and the increasing human population have increased in the last century energy needs. As a result of this increased use of fossil fuels is the main energy source. However, these sources are limited. Therefore, mankind has turned its attention to renewable energy sources. Renewable energy sources include solar energy is the most widely used source.

Solar energy has an important place among the renewable energy sources. Solar hot water supply in residential heating and cooling applications in the process industry in the provision of heat, agriculture irrigation, drying and cooking, electricity is an energy source that can be used in producing. In Turkey, a country with solar energy potential is very high. The annual average sunshine time is 2640 hours, the average annual solar radiation value 1311kwh / m^2 value [1].

Recently, detailed thermal applications related to energy storage and solar energy in the literature review studies [2]. Advances again saved the day in the heat system in the year have been revealed a study review [3]. The widespread use of solar energy in Turkey is to meet the housing needs of hot water. Solar collectors angle of for residential which should be established has been demonstrated studies [4, 5, 6].

The systems used in order to meet the hot water needs from solar energy works in two ways, on and off. The water circulating in the water collectors with open systems are the same as the system. Closed systems are the system with water is different of heating water. Water heated in the collector heat with the heat exchanger, it transferred the use of water.

The apparatus also relates to the use of copper tubing in the system, various studies have been made. Kumar [7], a rate of 18 to 70% of the bent strip for use in planar collector in the study was observed by increasing the heat transfer. The thermal performance was observed with increasing Reynolds number increases. Pipes, an increase in the pressure loss due to resistance by 87-132% create a flow of bent strip that is inserted into the rotary motion to the stream was observed. However, experimental work flow in the collector is arranged to circulate as in the coil from a single pipe collector. Kumar [7] this has been tried in the 5000-23000 range of the Reynolds number.

2. System Description and Methods

In the study, the effects on the system performance of using the apparatus inside the pipe in the natural circulation, closed system solar collectors were investigated experimentally.

Three different experimental setups have been established for this. For the normal collector, it is used with a natural circulating, closed system, a pressurized flat collector system storage. The plane collector is 2 pieces and each piece is 93 cm x 193 cm in size. Hot water storage of the system is 300 l capacity. There are 11 copper pipes with a diameter of 1.6 cm in each collector.

Two planar solar collectors, one 93 cm x 193 cm and one 186 cm x 193 cm, were designed in the scope of the study. Both collectors have 300 l of hot water storage. Pipes were prepared horizontally in plane collectors designed in the scope of the study. Copper pipes with a pipe diameter of 5 mm were placed at intervals of 3 cm and 52 horizontal pipes were used. The horizontal lengths of the pipes are 80 cm for the short collector system, 170 cm for the long collector system and 3 cm diameter half pipes are connected.

For both long and short collector systems in horizontal tubes, 52 pieces and 3 mm thick aluminum bars were bent. Bent aluminum rods are shown in Figure 1.



Fig. 1 *Aluminum Bars*

Flat plate collectors system schematic representation of the actual system and the external appearance are shown below in the Figure 2 and 3.

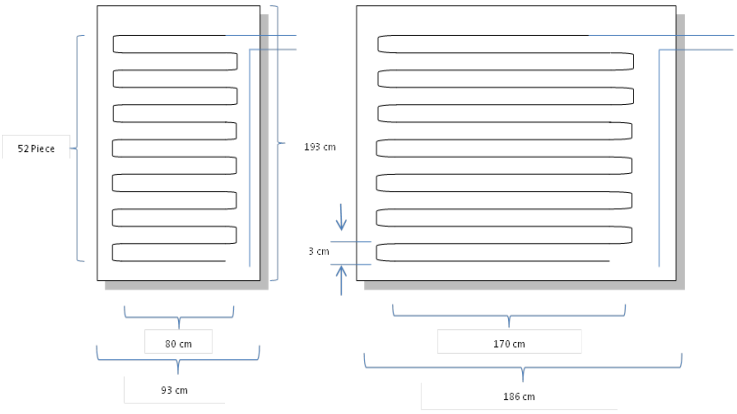


Fig. 2 *Collector dimensions*



Fig. 3 *Collector overview*

In order to compare the three systems in an objective way, these systems were run under the same operating conditions and the results were compared and examined in detail. Temperature measurements were made within the scope of the study. A temperature data logger is placed at the inlet and outlet of the collector to determine the temperature change in the collectors. By means of these data loggers, how much the fluid circulating in the collector has been measured. Measurements start at 8:00 in the morning and finish at 8:30 in the evening. The measurement range is set to 30 minutes.

Phase change material was used in the tank which was developed to extend the duration of hot water usage. In order to investigate the effect of the phase change material system developed for hot water storage, the system performance was examined by operating the hot water storage system in both a lean state and a phase change material system. The phase change system consists of a phase change material filled into copper pipes of different diameters. Paraffin wax, which is widely used in the literature and easy to fabricate, has been used as phase change material.

The general view of the collector hot water tank and heat exchanger is given in detail in figure 4, 5 and 6.

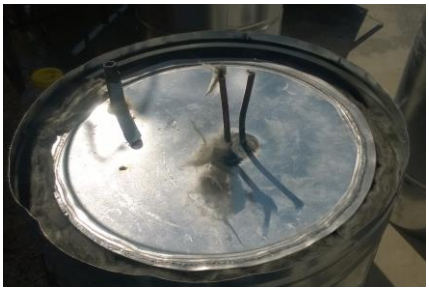


Fig. 4 *Tank overview*



Fig. 5 *Heat exchanger overview*



Fig. 6 *Heat exchanger in tank*

3. Results

Three solar collectors were used in the study. These collectors are designed and manufactured under study. Table 1 shows monthly changes in collectors temperatures. When the table 1 is examined it is seen that there is a difference of 3-4°C between the shorted collector and the long collector. The difference between the normal collector and the short type collector is 5-7°C. There is a temperature difference of 9-10°C between the normal collector and the long collector. The developed long collector has been increased by 21%. It was found that the long collector developed within the scope of the study was the most efficient.

Table 1. *Collector output temperatures averaged by monthly*

Months	April	May	June	July
Apparatus Collector	44,5	40,6	50,1	50,9
Apparatus Collector (long)	47,8	44,6	53	53,7
Normal Collector	38,3	35	43,8	45,4

One type of hot water storage was used in the study. The developed hot water storage has been used in apparatus long and short collectors. Table 2 shows monthly changes in hot water tank temperatures.

When the table 2 is examined it is seen that there is a difference of 5-6°C between the developed and normal hot water tank. The developed hot water storage has been increased by 15%. Especially in the summer months, the efficiency increase is higher.

Table 2. *Average temperature change according to hot water tank monthly*

Months	April	May	June	July
Normal Tank	32,83	35,34	35,5	35,5
Developed Tank	33,79	40,46	40,99	41,69

4. Conclusion

In this study, it was aimed to increase the efficiency of the solar collectors used to utilize solar energy from renewable energy sources. From here, the effect of the insertion of the planar solar collectors into the pipe is investigated. Depending on collector size, a temperature increase of 8-9°C compared to normal systems has been achieved. This temperature increase is not enough to increase the efficiency. However, because solar energy is the most important source of renewable energy resources, this efficiency increase will be a guide for future work.

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AN ALGORITHM FOR ISAR IMAGE CLASSIFICATION PROCEDURE

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Abstract: *This article offers a neural network architecture for automatic classification of Inverse Synthetic Aperture Radar objects represented in images with high level of optimization. A full explanation of the procedures of two-layer neural network architecture creating and training is described. The neural network is experimentally simulated in MATLAB environment.*

Keywords: NEURAL NETWORKS, ETALON MODEL, TRANSFER FUNCTION

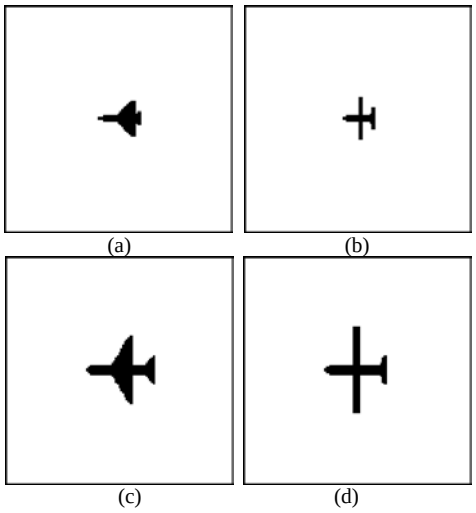
1. Introduction

In the time of globalization, many aircraft models are produced and thus the main ISAR (Inverse Synthetic Aperture Radar) systems task is more complicated because the planes are constructed with relatively small differences in product design for aircraft of a given class of different manufacturers. The neural networks technologies can be implemented in the classification and recognition process in different SAR and ISAR systems [1, 2, 3].

In this paper, a new procedure for ISAR objects classification in the recognition stage is proposed based on several main classes or sets of flying objects gained by the specifications in the structural models of the aircrafts. Different types of mobile objects can be easily distinguished by their size [4]. The algorithm in this paper can be used for a simple classification of the observed ISAR object to small, middle or big size.

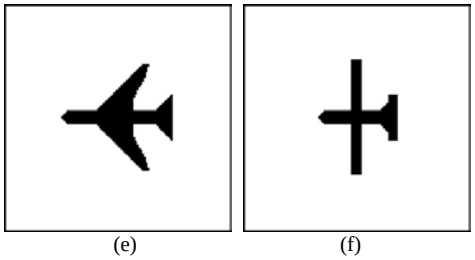
2. Preconditions

For the simulation environment is assumed that the process of obtaining a horizontal orientation of the observed object in a network of 256x256 pixels is completed with linear resolution at azimuth and distance, respectively $\Delta L = 0.5\,[m]$ and $\Delta R = 0.5\,[m]$. Procedures for filtering the resulting image and extraction of 128x128 pixels subarea containing the object‘s silhouette and image optimization are also preconditions for the binary matrix *S* with the aircraft object [6,7,8]. That object is to be compared with *L* etalon models representing the size classes “Small”, “Middle” and “Big”. The etalon models are designed to be binary matrices, whose elements are a numerical representation of graphically described dense models of sample airplanes of different sizes. Two models are used for each airplane size classes definition in relation with the most popular wing shapes for them. The exemplary graphically detailed dense aircraft models that form the model base in the numerical experiments are shown on figure 1. On Fig. 1 (a), (b) models of "Small" class are presented, on Fig. 1 (c), (d) - models of “Middle” class and on Fig. 1 (e), (f) -models of the "Big" class.



(a) (b)

(c) (d)



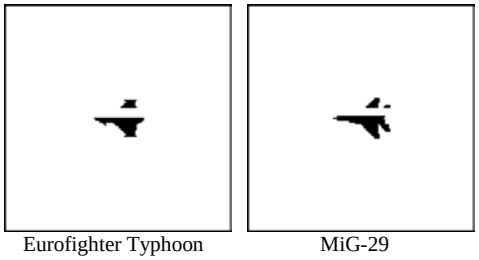
(e) (f)

Fig. 1 *Images of graphic dense reference models of classes "Small" (a, b), "Medium" (c, d) and "Big" (d, e).*

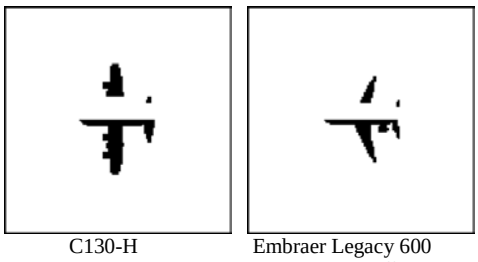
Dense object patterns are placed exactly in the middle of the frame, both horizontally and vertically. Model matrices with the size of 128x128 elements are formed as follows: If the pixel of the graphical dense model is part of the dense model, the value of 1 is assigned to the corresponding matrix element, otherwise the element is 0.

For the simulation experiment, sixteen airplane models are defined in a rectangular network of 128x128 pixels with network dimensions $\Delta X = \Delta Y = 0.5\,[m]$. Sixteen exemplary graphical dense models are used: Eurofighter Typhoon, Pilatus 9M, Rafale, Mirage 2000, MiG-29, Gripen, Falcon 2000, F-22, F-18, F-16, C-130 H, Bombardier Q400, Boeing-747, Boeing-737, Boeing-707 and Embraer Legacy 600. The reference models are created based on detailed graphical maps, accompanied by precise data on the geometric dimensions of objects in the three dimensions. Graphics cards and data are published on the FAS website (Federation of American Scientists). The models are designed to be scale copies of the actual planes. Exceptions are made to the Boeing 747 and Boeing 707, whose models are especially diminished geometrically, as they are much larger than the rest. The proportional reduction of the model is aimed to create difficult recognition conditions to assess the reliability of decisions taken by the classification system.

The modeling is carried out under the following initial conditions. Objects are observed with ISAR, their movement is simulated in a rectilinear trajectory at constant speed and at constant altitude during observation. The object is modeled in its own two-dimensional coordinate system with network dimensions on both coordinates [2]. The all sixteen models of actual aircraft database are processed with added shading effect applied to parts of their structure (Fig.2).



Eurofighter Typhoon MiG-29



C130-H Embraer Legacy 600

Fig. 2. *Standard airplane models with added shading effect attached to parts of their structure.*

It is assumed that High resolution at a distance $\Delta R = 0.5\,[m]$ is realized in the Inverse Synthetic Aperture Radar by usage of impulses with linear frequency modulation. The geometry in modeling a 3D coordinate system of observation from the ISAR system and geometry of the 3D System of a flying object are shown on figure 3. The initial parameters of the flying object trajectory are defined in MATLAB environment as follows: $V = 600\,[m/s]$, $f = 10^{10}$ [Hz] is the carrier frequency, $\varepsilon = \arccos\left(\frac{R_{proj}}{R}\right)$, $\beta = \frac{\pi}{2}$, $\gamma = 0$, $H = 5000$ [m], $R = 50000$ [m], $T = 10^{-6}$ [s] is the duration of each impulse in the sequence [5].

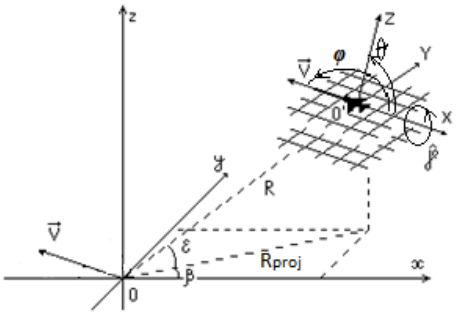


Fig. 3. *Geometry in modeling a 3D coordinate system of observation from the ISAR system and geometry of the coordinate system of a 3D model of a flying object[5].*

ISAR pulses are designed with linear frequency modulation of duration $T = 10^{-6}\,[s]$, repetition period $T_p = 10^{-5}\,[s]$, high frequency oscillation $f = 10^{10}\,[GHz]$, wavelength $\lambda = 0.03\,[m]$ and full frequency deviation $2\Delta F = 3.10^{8}[Hz]$.

3. Algorithm for the classification procedure

The processes for determining the parameters and the realization of the synthesized aperture in the modules of the automated system of ISAR are modeled. To the resulting complex matrix of the trajectory signal is added additive Gaussian noise, with the signal to noise ratio not exceeding 5 dB. The image is restored by applying spectral processing. The pixel intensities in the restored image are normalized in the range of 0 to 1. The image is additionally overwhelmed by additive Gaussian noise with constant zero mean and variance 0.01 and “salt and pepper” noise with density 0.015. It is assumed that the image has been preassigned through the autofocus and optimization procedures of the final image [6, 7, 8]. In this Algorithm for each reference model, the binary matrix of the original image S is multiplied by each of the matrices G_L, $(L = \overline{1,6})$ corresponding to the reference models from the size classes database:

$$S_m = SG_m \qquad (1)$$

where $m = \overline{1, L}$ is the number of the current comparison model. The resultant matrices are constructed with non-zero elements only at the positions in which both the S and G_m matrices have both non-zero elements. In this way, pixel address registration is performed by the matrices of a given reference model that match the pixels of the image of the object compared. The resulting L values are compared, and one of them that has the maximum value is chosen. Its number is related to the model number (model size) with which the compared object is processed with a maximum match between the non-zero positions of the matrices S and one of the G_m matrices.

4. Neural network classification procedure

The main idea in the proposed classification approach is concluded in the comparison of the intensity of the observed image pixels with a set of predefined reference models of different sized objects with a size-specific geometry. In the process of this approach realization, the task is put into conversion of the recognizable image into an input vector to be classified by a neural network as similar to one of the classes in the formed database.

During the second approach designing stage, the reference matrices with the pixel intensity values of the reference images are converted into vectors of 16384 elements by taking the corresponding column members. The resulting vectors form a common matrix „training“, named Training1. The matrix is designed to have dimension 16384x16 - 16 pillar, as is the number of objects in the database subject to the recognition procedure and 16384 lines as the number of pixels in one Image. At this stage, a matrix of the "desired result" named Target1 is also built, necessary for the neural network training process. The matrix is dimensioned 3x6 - 3 rows for the three types of objects, classified by their size and 6 columns, because for each size (small, medium and large) two sample models are applied. The location of the non-zero element in the main diagonal of each column is corresponded to the class number that associates the corresponding recognition result.

In the third stage of the design, a neural architecture consisting of two layers, which is built with the tools of the Matlab programming language (fig. 4) and modeled in the Simulink environment (fig.5), is constructed according to the assigned task.

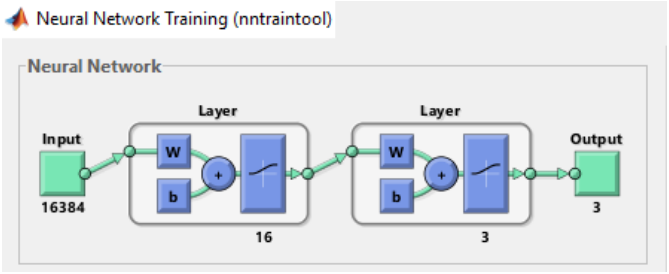


Fig. 4. *Block diagram of Neural Network I designed in MATLAB.*

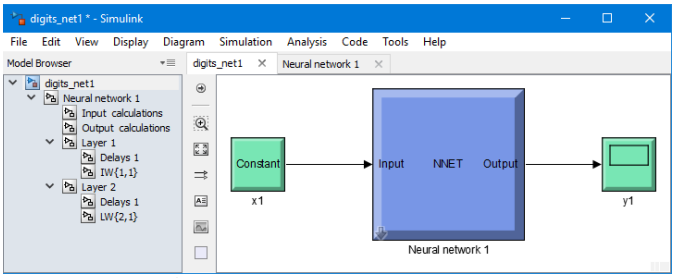


Fig. 5. *Schematic of Neural Network I, realized in Simulink.*

According to the algorithm, a neural network architecture of back propagation type with two layers is selected. Thus the associative memory functions in the presence of interference in the input Sequence are performed (Figure 6). In a theoretical aspect, the learning process for this type of neural network is proven to coincide, and therefore, over a sufficiently long period of self-learning, the weights of the neurons should be suitably adapted to solve the task of properly classifying the vectors from the trainee sample. The first layer of the neural network is "hidden" and is made up of 16 neurons with logarithmic-sigmoidal transfer function. the subclasses to which some of the input vectors are classified are formed by these neurons. The inner structure of this layer is depicted in figure 7.

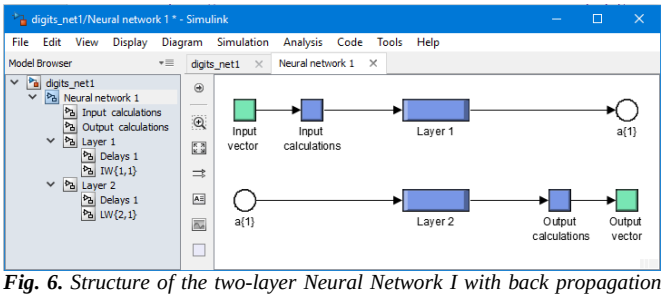


Fig. 6. *Structure of the two-layer Neural Network I with back propagation of the error.*

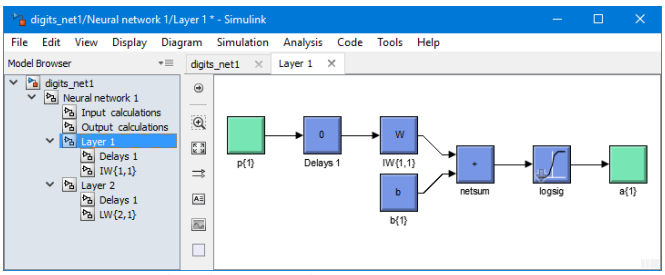


Fig. 7. *Structure of the first layer of Neural Network I built in Simulink.*

A delay line "Delays 1" is included in the layer structure for conversion of the input sequence elements into an input vector. The logarithmic-sigmoidal transfer function provides high sensitivity and high-resolution ability in the recognition process (Fig. 8).

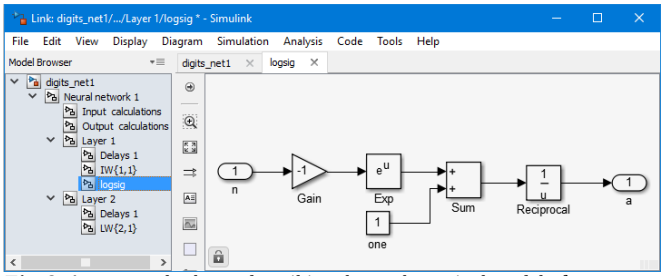


Fig. 8. *A structural scheme describing the mathematical model of Logarithmic-sigmoidal transmission function in Simulink.*

The structure of the mathematical model and the physical realization of the logarithmic-sigmoidal transfer function is presented - the structure of the neuron inputs in the layer where the weight matrix IW is formed from sixteen weighing vectors, the specific values of which are determined at the stage of learning of the neural network (Fig. 9).

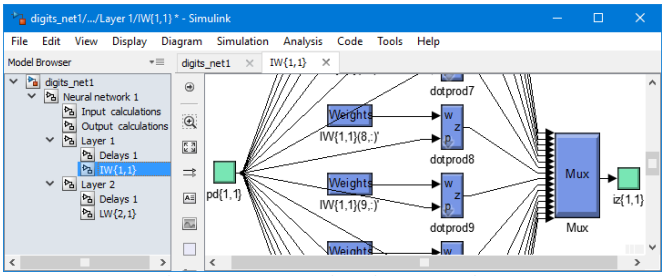


Fig. 9. *Structure of the input matrix of the first layer of Neural Network I.*

The second layer is made up of neurons again with a logarithmic sigmoidal activation function - the number of neurons in this layer is set according to the final number of desired classes, in this case the number is 3. The number of the neuron "winner" is corresponded to the class ("small", “medium” or “big”) to which the current input vector is associated. The role of this layer is designed to classify the results of the first layer and to summarize and reduce them to the user-defined number of classes. Its structure is analogous to the structure of the first layer with the indicated differences. The structure of the mathematical model and the physical realization of the logarithmic-sigmoidal type function is presented - the unfolded structure of the neuron inputs in the layer where the weight matrix LW consists of three weight weights, the specific values of which are determined at the stage of training of the neural network (Fig.10).

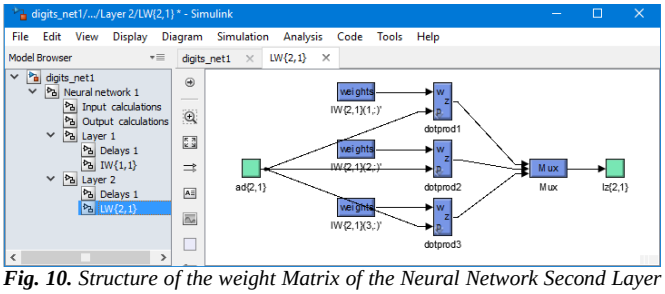
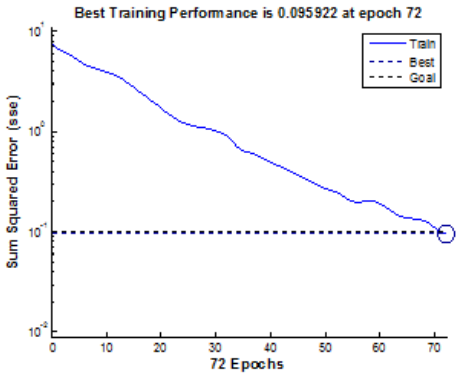
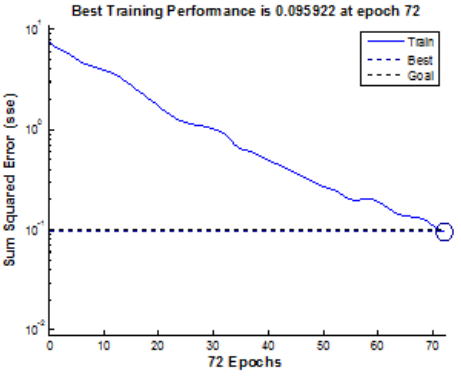


Fig. 10. *Structure of the weight Matrix of the Neural Network Second Layer Input.*

The fourth stage of the neural architecture is described as a neural network training process, which essentially consists of adjusting the coefficients of the weight matrices of the neurons of the two layers. Toolbox algorithms and procedures for automated self-learning of Matlab neural networks are used to facilitate this task. A method of training a neural network with a teacher is applied, following the next sequence of actions. Initial training of the neural network is processed without interference. At the input of the network, the "training" matrix Training1 is provided, containing the pixel intensity values obtained from the reference models. At the output of the network a desired result is produced, indicated by the Target1 matrix. The learning algorithm is backpropagation of the error. The goal for the possible error is selected to be 0.1 and the error calculating function is of the type sse (sum squared error - accumulated value of the square error). The training process is limited to 1000 epochs. The training results are shown on Figure 11 (a). The Network training is continued with higher requirements - the threshold for the level of permissible error is reduced ten times to 0.01. The learning outcomes are presented in Figure 11. (b). According to the graphs presented, the desired limit value is reached in two training cycles, where the training process is considered complete. Modeling the synthesis process of this neural architecture is executed In MATLAB environment.



(a)



(b)

Fig. 11. *Graphs describing the achievement of the desired permissible error of 0.1 (a) and 0.01 (b) in the no-noise training reached for 72 and 117 epochs respectively.*

The results of a numerical simulation experiment of observation of a model Falcon 2000 are presented on Figure 12. Figure 12 (a) shows the image of the object obtained from ISAR. The radar image

processed by the digital filtration and optimization-processing algorithms for quality improvement is shown in Figure 12 (b). The work of the Neural Network I is illustrated on Figure 12 (c) - the plane is classified as Middle.

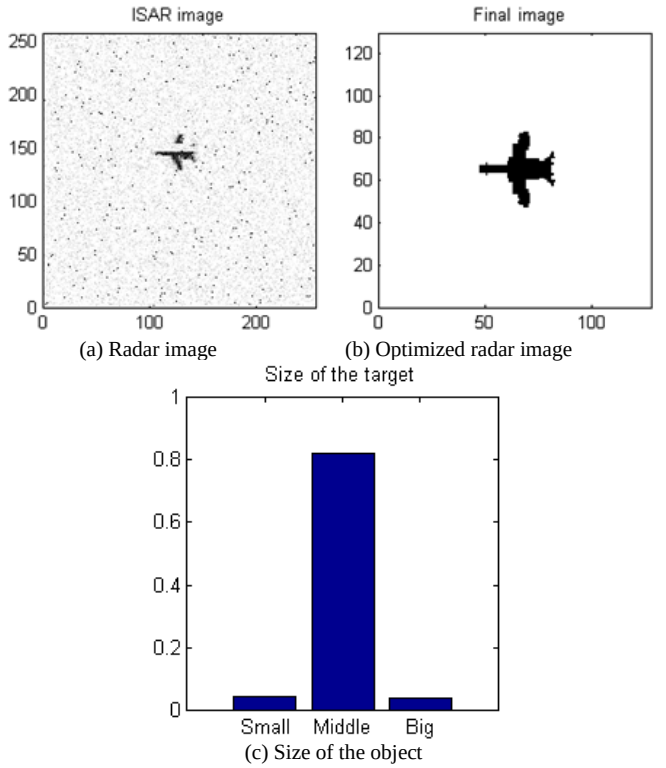


Fig. 12. *Observation (a), optimization (b) and neural network processing (c) for the model Falcon 2000.*

The results of a numerical simulation experiment of observation of a model Rafale are presented on Figure 13. Figure 13 (a) shows the image of the object obtained from ISAR. The radar image processed by the digital filtration and optimization-processing algorithms for quality improvement is shown in Figure 13 (b). The work of the Neural Network I is illustrated on Figure 13 (c) - the plane is classified as Small.

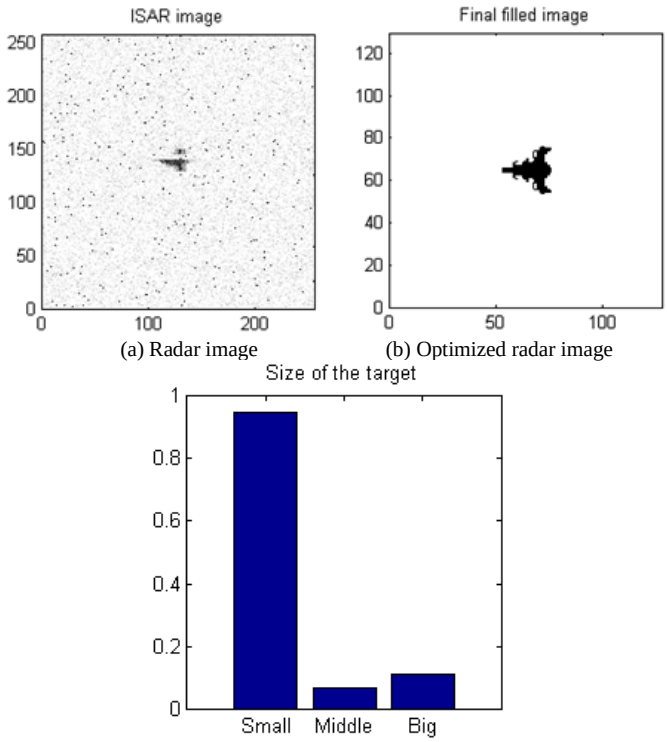


Fig. 12. *Observation (a), optimization (b) and neural network processing (c) for the model Rafale.*

4. Conclusions

As a result of the analysis and the carried out experiments the following conclusions can be made.

The chosen decision making algorithm is logical and accurate for the class belonging of the observed object.

The described neural network operates like an associative memory and makes correct classification of the ISAR objects in high level of noise environment as well as if the objects are not full or heavy damaged.

The used number of neurons in the first layer is smaller than in other networks because it depends of the chosen models in contrast to the image pixel number.

ISAR image classification procedures with similar algorithms can be implemented together for some specific aircraft analysis, leading to ISAR object's fast and complete recognition.

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ANALYSIS OF THE STEGANOGRAPHY IN IMAGE WHIT MOBILE COMPUTING

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АНАЛИЗ НА СТЕГАНОГРАФИЯТА В ИЗОБРАЖЕНИЯ С ПОМОЩТА НА МОБИЛЕН КОМПЮТИНГ

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Abstract: *The report examines the use of steganography as a method of hiding text, images or sound recordings in file-carrier for mobile devices, which may give the opportunity to keep the correspondence without awaking any suspicion. The information file is hidden in the file-carrier by the method Least significant bit (LSB) through various algorithms of coding. The experimental part compares mobile applications, which are using Steganography methods and compares their advantages. The experimental results show that the Ultra Mobile Steganography is realizing with fast pace, the applications have common static characteristics of the cypher image and are easy to use.*

Keywords: STEGANOGRAPHY, LSB, MSE, PSNR

1. Introduction.

The development of modern technology in our daily lives is evidenced by the wide distribution of the well-known smartphones. The statistics shows that the total number of smartphones users worldwide for 2016 already reached 2.1 billion users and also expects that by 2019 will exceed more than 2.71 billion users [1]. The high rates of users, which develop and use social networks, facilitate the dissemination of media files by sharing them to a wide range of people. Despite the convenience to share free images, audio and video files, the steganography transmission of messages through social networks is hampered by the policy of the most networks to compress the files, which are shared. With the reducing the size of the file, the embed message becomes destroyed. In that case the secret conversation becomes unavailable, due to lack of opportunity for discovering the secret message.

Mobile technologies have already entered our lives seriously and have become an integral part of it. Through them various types of activity can be carried out. From playing different types of games to managing your personal finances.

“Statista“ Figure 1 shows that from 173.5 million units in 2009, Smartphone sales to end-users have reached 1,432.9 billion units in 2016, which means sales have increased more than 8 times, expected in 2019. Sales to be over 1,862.3 billion. Total sales over the 10-year period will exceed 11.2 billion(see Fig.1).

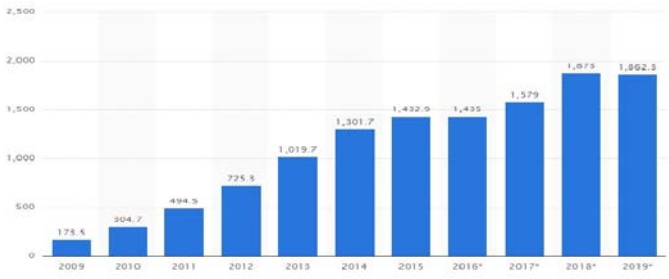
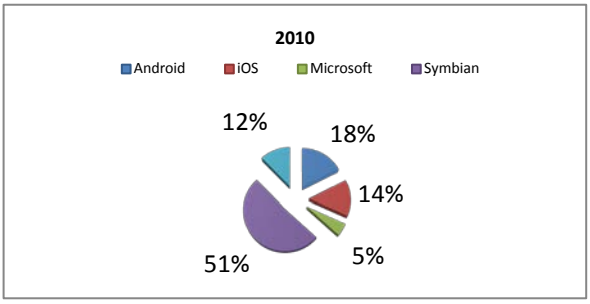
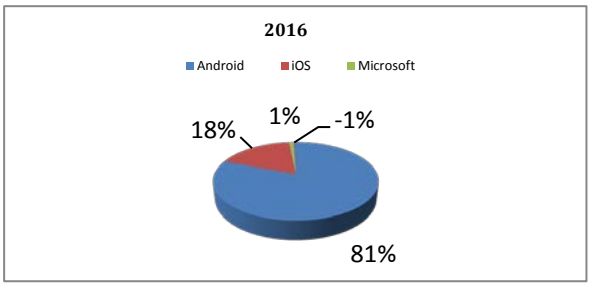


Fig. 1. *Sales of smartphones [1]*

With the increase in production, the market shares of smartphone operating systems sharply change (see Fig. 2a and 2b). In 2010 Android-17.2%, iOS-14.1%, Microsoft-4.9%, Symbian - 50.2% and others - 12%, while in 2016 Android OS reached a record 80.7% ,iOS-17.7%, Microsoft-1.1% and other OSs - 0.5%, and Symbian is not even produced.



a)



b)

Fig. 2. *Market Share in a) 2010[2] and b) in 2016 [2].*

With this impressive development, the involvement of the technologies in our lives also arises with the issue of the security and protection of the personal data of the mobile user. When it comes to security issues, smartphone users scamperly believe that the phone is safer than the computer.

According to Martin Hack, vice president of the NCP, who says that if you have access to some information on your smartphone, the hackers will have it too.

There are many of definitions for the Steganography as science, which describe it like a hidden method or art, which is used

for hiding a secret information in unsuspicious file-carriers [3], [5], [6]. Steganography as part of the science Steganology, which includes both Steganography and Steganalysis, is divided into two main types. Conventionally speaking, the first type we call classical steganography, which was established with the sole purpose to summarize the set of historically evolved methods, systems, techniques and applications, and the other type - high-tech steganography**.** The high-tech steganography on the other hand can be divided into IT-steganography, biological-steganography and etc.

Object of our attention is the IT-steganography, which consists the computer steganography, linguistic steganography and network steganography in itself. The computer steganography has two main ways to hide the information. The first one is using the special properties of the computer formats, and the second one is using already converted into discrete form signals, which are having continuous analog nature (images, video, sound).

2. Steganography methods

2.1. Steganography in mobile computing

It is possible to counteract the compression process by using files of smaller sizes, which do not require interference with the compression algorithms from the site, in which the information is shared.

Due to the rapid pace with which the smartphones market is growing, the developers of software applications for mobile devices have developed numerous applications that can hide information and a certain portion of them are free [3]. Media files that are used by mobile applications for hiding the information, for the most of the part, are images, but there are a large number of applications that are using for a file-carrier audio or video files.

Examples of free Steganography applications are the applications: "Hide it in", "Acoustic Picture Transmitter Pro", "Stegais", "DaVinci Secret Image";

To be successful the transmission of hidden information prerequisite is the consumers who share it to use the same application on their mobile devices, because each application is coding in its own method of embedding the message in a carrier file and require the same application to decode this same file carrier.

2.2. Exploring the possibilities of the programs:

Stego-image 24-bit format file storage using *RGB* (Red, Green, Blue) color model [7] is a prerequisite for the presence of a large excess of information that can be used for the purpose of steganography. Steganography synthesized algorithm for embedding information in images uses up to three of the last significant bits in each color channel pixels

"Stegais" and "Da Vinci Secret Image", as mentioned above, are free mobile applications which services are for hiding information by steganography methods. The information that can be transmitted in Stegais can be text or sound, and in Da Vinci Secret Image is text only. There is a possibility for both of the applications the messages they transmit to be encoded by the method *AES* (Advanced Encryption Standard), which is one of the most widely used cryptographic algorithms, another possibility for the secret text is to be written in both Cyrillic and Latin, since both applications support standard *UTF-8* (Universal Transformation Format 8-bit.). The main advantage in both applications is the relatively simple and easy to use interface consisted of a few simple steps:

- Create a secret message;
- Select the image file from the library-media or create an image through the camera of the device;
- Select on / off option for encoding;
- Select the button "Hide" to use the algorithm to hide;
- Save the file carrier carrying a hidden message in the device memory or send it by an e-mail to the receiver;

As a major disadvantage can be noted the fact that in both applications the carrier-file that is used to transmit data can be only image file.

Another feature is that images that are used as files-carriers must be of format .jpg or .png, which are widely distributed and used by photographic and complex images or as stored images, that are created with the most of the types of smart phones.

For the experiment is used the base image for comparison - “monkey.bmp” (see Fig. 3), which is converted into formats .jpg and .png. To track the changes in the image and the embed hidden text, the carrier-images of Stegais and DaVinci Secret Image are compared sequentially by Mathlab software.



Fig.3. *Test imege, Monkey.bmp*

To obtain the most objective data for both applications, their images are tested in all possible cases of embedding text.

The tests consists in a study of the mean square error after changing the image - MSE (Mean Squared Error), study of the signal - noise -SNR (Signal-to-Noise Ratio), the peak of the signal - noise - PSNR (Peak Signal- to-Noise Ratio) and the entropy. The calculating of the MSE is a standard static method for objective measurement of the level of difference between two images. The low value of MSE means that the average level of difference between the images is low. In case of two equal images, the MSE value is zero. Unlike MSE, higher value of PSNR means that the quality of the image is higher. In case of two equal images the PSNR value is near infinity. The main idea of all of the steganography methods is to minimalize the MSE and maximize the PSNR

The studied characteristics are represented with the formulas (1) and (2), where *PSNR* is based on the values of *MSE*:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2, \quad (1)$$

where *m* and *n* are width and height of the image*; l (I, j)* and *K(I, j)* are respectively pixels with coordinates (I, j) in the original and the steganography-image**.**

$$PSNR = 10.\log_{10}(\frac{max^2}{MSE}) = 10.\log_{10}(\frac{max}{\sqrt{MSE}}), \quad (2)$$

where *max* = 255 for 8 bit images.

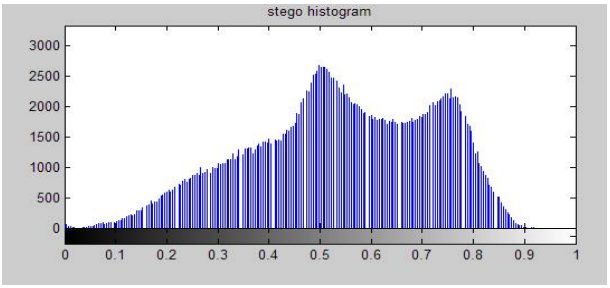
The degree of similarity of the images before and after the process of embedding of data, valued with *MSE* and *PSNR*, define the quality of the steganography image. When the similarity between the studied images is low, is accepted that the quality of the steganography image is also low [4].

3. Experimental results.

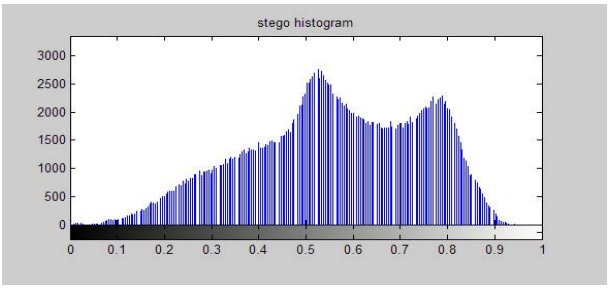
By implementing a programs for embedding/ extracting text messages many tests with different size messages and images have been carried out. The studied algorithm is based on the *LSB* method applied and tested on *BMP* image formats. Test results of the qualitative characteristics *MSE*, *SNR* and *PSNR* are analyzed. Visual analysis of the compared images shows lack of visual differences in visual control. Histogram analysis and the results of the qualitative

characteristics are obtained by MATLAB. Table 1 presents the results of the qualitative characteristics of embedded text files in English and Bulgarian with a size of 6 B to 15 B and cover digital image *Monkey.bmp* is used.

The results obtained from the study are filled in table 1, and the test histograms visualizing images are proposed in fig. 4.



a)



b)

fig. 4*. Histogram of stego-image, which has 15 kB of embedded information whit a) Stegais and b) Da Vinci Secret Image*

Table 1: *Qualitative characteristics of Monkey image in embedding a different size of the secret message*

Text	For mat type of the ima ge	Applic ation	Size of text [bit]	AES pass	MSE aver	SNR	PSNR
Cyrillic	.jpg	Stegais	15	-	10.9720	23.3884	28.7094
Cyrillic	.jpg	Stegais	15	+	10.9721	23.3884	28.7094
Latin	.jpg	Stegais	6	-	10.9717	23.3885	28.7094
Latin	.jpg	Stegais	6	+	10.9717	23.3884	28.7094
Cyrillic	.png	Da Vinci Secret Image	15	-	9.8509	22.8895	28.2105
Cyrillic	.png	Da Vinci Secret Image	15	+	9.8508	22.8895	28.2105
Latin	.png	Da Vinci Secret Image	6	-	9.8510	22.8895	28.2105
Latin	.png	Da Vinci Secret Image	6	+	9.8509	22.8895	28.2105

In Figure 5 can be seen histograms of original and stego-image obtained by embedding of 15 B information at base settings of the steganography algorithm whit Stegais, i.e. successively embedding in the three color components of pixels without using protection by stego-key in a pepper.bmp cover image

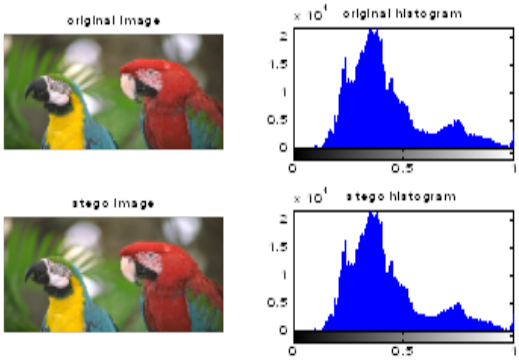


fig. 5. *Histogram of original and stego-image, which has 15 B of embedded information whit Stegais*

Difference in the histograms is hardly observed. This result can be attributed to the fact that the embedded message is not particularly large.

4. Conclusion

From the results it can be deduced that the applications do not establish substantial modification of the basic image by embedding text and that there is a minimal difference in the data as the presence of a key, and in his absence. But with -Low levels of entropy and noise that are expressed in the form of the hidden text in the image, the app that is distinguished is the Da Vinci Secret Image application.

Even the popular free distributed applications for steganography transmitting data are sufficiently reliable and secure to be able to send important information without raise suspicion at anyone.

- The used cryptographic algorithm ensures additional security during transmission and recovery of the stego-message.
- In embedding in the same image of equal length messages in Cyrillic and Latin, the stego-images obtained have approximately 0,0001 difference in the values of the parameters examined

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ANALYSIS OF DISTRIBUTED TECHNOLOGICAL COMPLEXES AS OBJECTS OF CONTROL AND MONITORING

АНАЛИЗ РАСПРЕДЕЛЕННЫХ ТЕХНОЛОГИЧЕСКИХ КОМПЛЕКСОВ КАК ОБЪЕКТОВ КОНТРОЛЯ И МОНИТОРИНГА

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Abstract: *The article analyzes the distributed technological complexes of the Republic of Kazakhstan as objects of control and monitoring. Examples of distributed technological complexes are the oil transportation system, the mega-cities heat supply system, high-voltage power transmission system. Two distributed technological complexes were analyzed. The aim of creation and application of control and monitoring system for each complex is substantiated. A structure has been developed for constructing a control and monitoring system for the heat supply system for megacities and a high-voltage power transmission system. The generalized functional diagram of the upper level of the monitoring and monitoring system was developed.*
KEYWORDS*: CONTROL, MONITORING, DISTRIBUTED TECHNOLOGICAL COMPLEXES.*

1. Introduction

Modern technological complexes perform the task of spreading the flows of technological resources (for example, oil, gas, electricity, heat energy, etc.). Examples of distributed technological complexes can be:

1 Oil transportation system.
2 Gas transportation system.
3 The system of heat supply of megacities.
4 High-voltage power transmission system.

We will analyse the system of heat supply of megacities and high-voltage power transmission system as objects of control and monitoring.

2. Problem discussion

Complex monitoring of the state of the equipment of distributed technological complexes is based on a system of software and hardware that provides continuous obtaining in real time information about the technical condition of the equipment and the adoption on the basis of this information of decisions on the necessary corrective organizational and technical measures.

The application of a system for control and monitoring technical condition is due to equipment with the following features:

- its destruction can lead to an incident, an accident and human casualties, significant material and environmental losses;
- access for the implementation of its periodic inspection and control by instrumental methods is absent or difficult;
- stopping it for another full-scale survey may result in a reduction in the life of the equipment itself and in violation of the operating mode of the technological complex as a whole;
- a significant amount of preparatory work and monitoring of equipment requires its partial or complete stop, the manufacture of special equipment for monitoring, leads to significant costs and reduces the efficiency of operation;
- its inclusion in the list of equipment to be monitored will allow to increase the time between routine stops for technical inspection and in the future to move to operation according to the technical state.

3. Analysis of systems as objects of control and monitoring

3.1 The system of heat supply of megacities.

Heat supply systems largely determine the viability of megacities in countries with a sharply continental climate such as in Kazakhstan. The structural complexity of heat-supplying complexes of megacities (H-SCM) in the first approximation is directly proportional to the number of population. Obviously, such complexes belong to the class of large distributed systems.

The main goal of H-SCM is the delivery and distribution of the coolant with the specified parameters (pressure and temperature) to the consumers, which are the municipal, industrial, administrative buildings and facilities of the metropolis [1].

The main elements of the H-SCM are: heat supply sources (HSS), main heat networks (MHN), pumping stations (PS), individual and central heating points (IandCHP).

Delivery of the coolant is carried out by pump units (PU). The amount of PU is determined by the size of the H-SCM, topographical and climatic characteristics of the H-SCM areas formalized in the geographic information system (GIS) database. Modern concepts of H-SCM are based on the use of frequency-controlled asynchronous electric drives of pump units at pumping stations in the forward and reverse lines of H-SCM. Existing (and gradually installed) adjustable valves in the nodes of the main heat network must have a two-position, and better regulated within the limits of the consumption characteristics of regulating bodies (RB), one and multi-turn actuators (O-MA) with electric drives. Modern O-MAs for the thermal power systems have a full set of monitoring facilities for their condition, local control from industrial logic controllers (PLCs), remote control of H-SCM adjusters in the locations of O-MA installation and automated control of dispatchers of the H-SCM system by means of SCADA systems [2].

The management of pump aggregates and monitoring of parameters on the PU, HSS, IandCHP, MHN nodes are possible with products with unified electrical signals equipped with means of interaction with local and global information networks.

It is doubtful that the automobile and engine manufacture could find the economic (and other) incentive necessary to develop alternatively fuelled products strictly on their own volition.

It is obvious that H-SCM is efficient, although many of them are ineffective and have large energy losses in virtually all technological parts. The main reason for such facts lies in the difficulty of managing the gigantic in their dimension of heat supply systems for megacities by traditional means, which were emphasized by the founders of the theory of heat supply for megacities.

Therefore, one of the main directions that allow to find solutions to the problem of ensuring quality heat supply is the creation of a monitoring and monitoring system for BM parameters. The aim of the system is to increase the level of H-SCM in formativeness.

The system for monitoring and monitoring parameters consists of 3 levels [3].

The lower level consists of a network of primary sensors that transmit data on the functioning of heat networks (temperature at control points, pressure, water flow, pump parameters) to the dispatching server, which is the upper level, which are analysed by the computer program complex.

The upper level includes a software package that automatically generates and solves large-scale systems of non-linear equations of operational and emergency thermal-hydraulic regimes of a variable technological structure. The tools of the software package make it possible to create an animation model of the complex, on which each element (pump, pipeline, gate valve, diaphragm, etc.) is reflected, its characteristics (pipe diameter, meter reading) and position at the moment (on or off, at the moment), which allows the dispatcher to visually see the work of the entire network and its components and control the mode directly from the monitor screen, adjust the results both by elements and globally across the entire model. In addition, the software complex, depending on the formulated task, can automatically maintain the present mode, reflecting its actions to control the operator, who is offered the optimal variant of achieving the result for the completion of the evaluation and decision making.

The middle level provides management of all process units: water treatment plants of CHP, district boiler houses, network pumping stations, control and distribution and central heat points, individual heat points of heat consumers and is represented by control stations and controllers connected by an industrial network with objects of upper and lower levels [3].

3.2 High-voltage power transmission system

The electrical network is a set of electrical installations for power transmission and distribution. It consists of a substation, switchgear, conductors, overhead and cable transmission lines, distributed over large areas, and refers to the distribution of technological complexes. Accidents on the high-voltage lines may be associated with insulation breakdown, breakage of current-carrying wires, supports of high-voltage power lines fall. They can lead to a lack of power supply of entire regions of the country. The present level of development of software and hardware automation makes it possible to create a system of control and monitoring elements of high-voltage power lines, with the transfer of information in the control room for the prevention and elimination of emergency situations. Developments in the field of distributed systems of information transfer along high-voltage lines are not available. Therefore, the creation of such a system is an urgent task that will ensure reduction of accidents and increase the reliability of power transmission on strategic high-voltage power lines [4].

Reliability of operation and the value of active power losses of transmission lines depends on the state of suspension insulators. Condition monitoring is carried out by suspension insulators periodic testing high voltage, resistance measurement, control voltage distribution on insulator structure, their visual inspection. The ineffectiveness of these methods is the complexity, high-risk and the need to disconnect the equipment from the power source. Such methods is not possible to detect the deterioration of the insulation or the insulators at an early stage of their operation. The main parameter characterizing the condition of the insulation are leakage currents. In the development of the automatic control system of the state of suspension insulators should be performed by measurements of leakage currents. Information about the state of insulators of high-voltage transmission line supports must be periodically transmitted to the control station [5].

Icing accident at the high-voltage lines are one of the most difficult and hard disposable due to off-road winter, frozen ground, and at the same time a large number of affected areas. Due to the icing deposits on the wire and ground wire appears broken wires, insulators mechanical destruction and deterioration of their properties. Timely removal of ice on the wires is an important task of power supply organizations [6].

Control and monitoring system consists of 4 levels.

The zero level of the complex allows using the control indicator sensors to monitor parameters: leakage currents of insulators, icing current wires, the positioning of the support of high-voltage power lines, the amplitude of the vibration supports.

The first level in each support of high-voltage power lines are transmitted telemetry data from the sensors to a local subsystem of collection and primary processing and preparation of the information collected for subsequent transfer it to the control station.

The second level of the system is realized the following tasks:

– the transfer of information from the supports (from the local collection and primary processing sub-systems) to the control station;

– systematic diagnosis telemetry communication channel.

The third level of the system is realized the following tasks:

– analysis of information on the reliability;
– restoration of lost or inaccurate information;
– construction of approximating functions of emergencies;
– construction of predictive models;
– diagnosis and localization of accidents occurring;
– notification of the dispatcher on the ensuing emergency;
– the formation of the current accounting log information;
– visualization of the received information;
– archiving and storage of incoming information;
– the formation of algorithms and mathematical models of information management with the support of the diagnosed portion of power lines [6].

4. Conclusion

Two distributed technological complexes were analyzed.

The aim of creation and application of control and monitoring system for each complex is substantiated.

A structure has been developed for constructing a control and monitoring system for the heat supply system for megacities and a high-voltage power transmission system.

The generalized functional diagram of the upper level of the monitoring and monitoring system was developed (Fig.1).

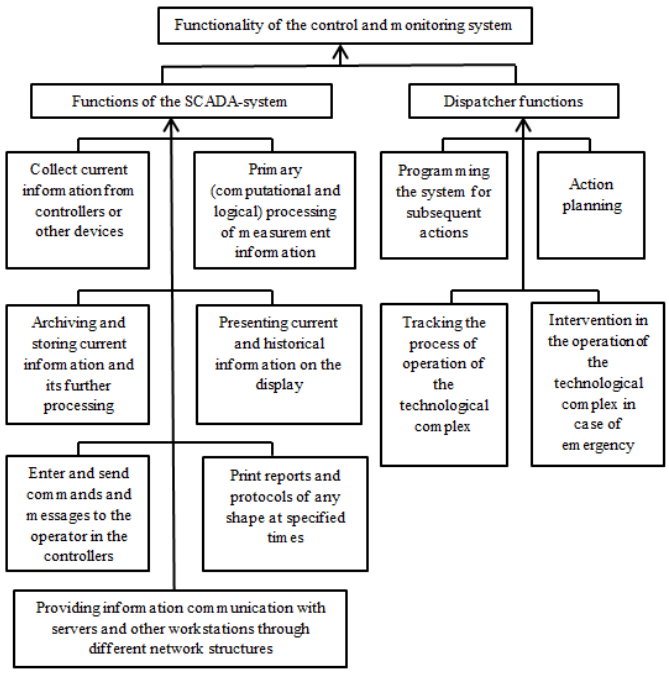


Figure 1: Functional diagram

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STRATEGY FOR THE DIAGNOSIS AND PREDICTION OF MACHINE FAILURES FOR DEVELOPING AVAILABILITY-ORIENTED BUSINESS MODELS IN CAPITAL GOODS

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Abstract: *Customers demand a guaranteed availability of machine components in capital goods industry. However, manufacturers are not willing to guarantee the demanded availability due to increasing costs based on high risks and uncertainties resulting from missing operational data, insufficient transparency of the machine condition as well as missing information of the customer behavior. In the following paper, a strategy to enable the development of availability-oriented Product-Service Systems (PSS) will be presented. Therefore, a use case focusing on the agricultural industry is regarded. Based on the use case, service-relevant parts will be identified and failure mechanisms of these parts will be determined. The subsequent development of condition monitoring strategies depend on the determined failure mechanisms. In a last step, the strategies will be assessed and the strategy with the highest added value will be chosen for an exemplary implementation, for which an electric motor and a conveyor belt of a potato harvester will be used.*

Keywords: INDUSTRY 4.0, CONDITION MONITORING, AVAILABILITY-ORIENTED BUSINESS MODELS, SMART PARTS

1. Introduction and research gap

In the capital goods industry customers demand a guaranteed availability of machine components. However, manufacturers are not willing to guarantee the demanded availability due to increasing costs based on high risks and uncertainties resulting from missing operational data, insufficient transparency of the machine condition as well as missing information of the customer behavior. Furthermore, the necessary data management to handle a vast amount of data is insufficient. However, to gain competitive advantages and provide availability-oriented services, the development of Product-Service Systems (PSS) in context of Industry 4.0 (PSS 4.0) is an essential approach to solve this issue. The integration of Industry 4.0 technologies [1], e.g. internet technology, smart sensors or business analytics, in PSS enable new forms of value creation, e.g. condition monitoring based on the connectivity of products and services. Implementing condition monitoring requires suitable smart service-relevant components. For identifying the service-relevant components, their failure mechanisms need to be analyzed. Afterwards, the developed sensors will be integrated into the service-relevant components. Based on the smart, communicating components, a smart system can be evolved. Within the smart system concept the sensor data will be saved on and analyzed by a cloud based platform. After analyzing the sensor data online, the gained information about the condition of the machine will be send to the operator of the capital good as well as to the service team. If a failure occurs, the operator and the service team can react on short notice and thus reduce down times.

Capital goods are subject to high requirements regarding availability and productivity [2]. To fulfill the requirements the product needs to be complemented by lifecycle-oriented services within an integrated solution. Those integrated solutions are called Product-Service Systems (PSS). The down time of a machine is related to high costs and service effort. Predictive maintenance can reduce down times and service efforts even before a machine failure occurs [3]. To realize predictive maintenance in times of big data and Internet of Things (IoT), the monitored components need to be smart, that means they are able to make a diagnosis of their own condition in real-time and are able to communicate. One of the objectives is the forecast of wear behavior to detect machine failures in advance. The implementation of such a system can increase the availability of the capital good, but also increases costs for development and realization. To reduce the costs to a minimum, only critical, service-relevant components have to be monitored.

In this contribution, the basis for the identification of service-relevant parts to realize predictive maintenance in an availability-oriented business model are in focus. First, critical, service-relevant components with a high impact on availability need to be identified. Then, concepts for condition monitoring of that components are developed. With the smart components, which additionally are able to communicate, the basis for failure prediction is set. By realizing predictive maintenance concepts, it is possible to offer availability by means of suitable availability-oriented business models.

2. State of the art

According to Mont, Product-Service Systems are defined as systems of products, services, networks of actors, and supporting infrastructure. The aim of a PSS is to increase the competitiveness of the PSS-provider and to satisfy customer needs. Furthermore, compared to traditional business models, PSS have a lower environmental impact [4]. A business model describes how companies generate, deliver and capture value [5]. There are different kinds of business models, which are enabled by PSS: function-oriented, availability-oriented and result-oriented business models. In availability-oriented business models, as only these are considered in the following, the PSS-provider guarantees the availability of a technical product. With this guarantee, the PSS-provider bears a part of the customers manufacturing risk [6]. To realize availability-oriented business models, suitable business model development concepts, smart components with the ability to communicate and a consistent information management are necessary.

This article deals with the development of smart components. In the following, only the mechanical parts of the machine are focused. In the first step the electronics, the electronic components, the software and the sensor systems are not taken into account. In further steps, the method in this article can be analogically implemented in an adapted form on electronic components as well as on software applications.

In general, a machine consists of multiple components and assemblies fulfilling different functions. To structure the relationship between the components or the functions two perspectives can be differentiated. The first perspective is the functional structure of the machine and the second perspective is the product structure of the machine. The transformation of the functional structure into the product structure and the product architecture are shown in Fig. 1. [7]

The functional structure includes all functions of a machine. Those functions can be divided into main functions and auxiliary functions. The product structure contains all assemblies, sub-assemblies and components. Each component has a specific role for each assembly group and each sub-assembly group has a specific role for the complete assembly group or the entire machine. The functional perspective is analogical to the product structure. Each sub-function is of specific importance for the auxiliary functions,

main functions and the overall function. There are one or more linkages between assembly parts, assembly groups and functions. In case of a damaged assembly part or group, hence one or more functions are not properly fulfilled.

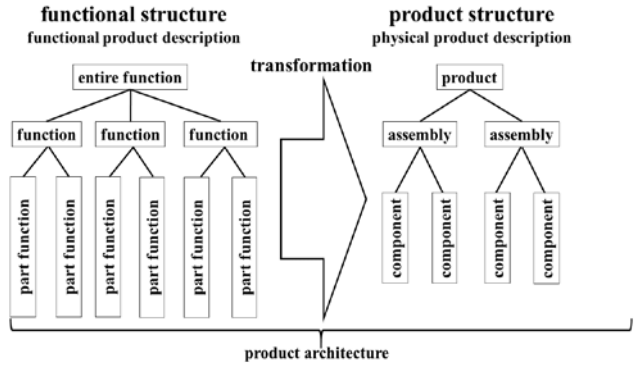


Fig. 1: Product architecture and transformation of function structure in product structure [7]

The availability of the machine will be reduced, if one or more functions are not fulfilled properly. In the context of this article the technical availability is defined as follows: "The availability describes the relative part of time, while a component or a system can fulfil its defined function as required (stipulated by contract main functions). The availability is the ratio of time, in which the systems is functional, to the total time" [8].The availability of the machine is reduced by the non-fulfilment of one or more functions. This implies that one or more failures occurred in the system. According to Eberlin/Hock, there are three categories of failures, early failures, incidental failures and wear failures [8]. Early failures cause machine down times due to failures in the early utilization phase of the machine. Those failures are caused by construction, manufacturing or operating errors. Random failures appear if an unexpected incident happens. Reasons therefore are environmental conditions or wrong operating. The third group of failures are wear failures. These failures generate machine down times due to the common machine wear. Fig. 2 shows the time progress of the sum of the error rate for.

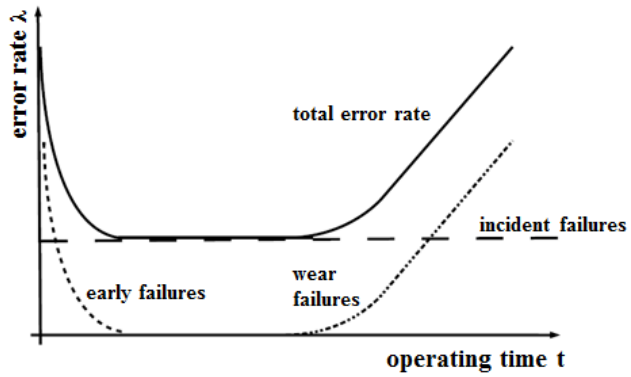


Fig. 2: Bathtub curve with sum of the error rate [8]

To increase the availability of a machine by condition monitoring, predictive maintenance, diagnostics and prognostics these three groups of failures need to be distinguished [9]. For this, the failure mechanisms and failure criteria need to be analyzed.

3. Identification of service-relevant components

In the context of this article, methods to identify the service-relevant components considering the three groups of failures are described. One failure implies one or more unsatisfied functions. The connection between the components and their related functions enables the identification of failures. The identification of service-relevant components can be realized by means of system analysis. Table 1 presents some methods for system analysis.

Table 1: Methods for identification of service-relevant components

	Name of the method
1	Failure tree analysis FTA DIN 25424-1 und DIN 25424-2
2	Event tree analysis DIN 25419
3	Failure Mode and Effects analysis- FMEA IEC 56/1579/CD:2014
4	Cause-effect-diagram
5	Intensity-Relation-Matrix

The fault tree analysis is a deductive method. The reasons for failures are identified based on unwanted incidents [10]. The event tree analysis is an inductive method, which identifies the possible impact of occurring failures. The Failure Mode and Effect Analysis (FMEA) is an analytical method for failure analysis. By application of this method, components, assemblies and subsystems can be analyzed and their possible failures, causes and effects can be determined. [11]

The cause-effect-diagram is used for the basic understanding of the constructive background and structure of the machine. The intensity-relation-matrix is a method for solving of complex problems. It is based on the method of linked thinking and network analysis. Effect intensities between different factors for complex machines or other systems can be estimated. [12]

By application of these methods, the critical components can be determined. The service-relevant components in this paper were chosen by application of the methods listed in Table 1 and of the software Visual-XSel® for calculation and visualization of the results. Based on these components, a machine diagnosis and prediction strategy can be developed.

To reduce the costs to a minimum, only critical, service-relevant components should be monitored and for these components, diagnosis and failure prediction strategies should be developed.

4. Strategies for machine diagnosis for availability-oriented business models

There are four strategies for machine diagnosis for availability-oriented business models. The strategies are shown and compared in Table 2.

Table 2: comparison of the strategies for diagnosis

	1	**2**	**3**	**4**
Strategy for monitoring of	Whole system	Compo-nents	Failure mecha-nisms	Combined
System complexity	low	middle	high	very high
Number of sensors	low	middle	middle	very high
New sensor development needed	no	no	yes	yes
Cost	low	middle	high	very high
Accuracy	low	middle	high	very high
Qualified for availability-oriented business models	no- not enough informa-tion about system condition	yes	yes	no- system complexity and cost to high

Strategy 1: Condition monitoring for prediction of machine failures for the whole system, for example electric motor, gearbox, conveyor belt. It is not possible to locate and monitor one service-relevant component. For this strategy, few sensors are needed. The complexity of the condition monitoring and failure prediction system is low, and the accuracy is low. It is not necessary to develop new sensors. For example, only the rotational speed of an E-motor or the vibration is monitored.

Strategy 2: Condition monitoring for prediction of failures of components, for example bearing, seal, gear, rotor, stator. It is possible to locate the component. It is not possible to determine the failure mechanism. For this strategy, more sensors are needed. The system complexity and accuracy of the failure monitoring are higher. The monitoring task can be solved with existing sensors. For example in an electric-motor the vibration of the bearings is monitored.

Strategy 3: Condition monitoring for prediction of failures based on the failure mechanisms. For example seal-leakage, bearing-vibration, bearing-temperature, bearing-currents, elongation of the conveyor belt. It is possible to locate the service-relevant component and to monitor its failure mechanism for accurate prediction of the failure. The system complexity is high. Many sensors are needed for every component and failure mechanism. The system accuracy is also high. For the monitoring of some failure mechanism new sensors have to be developed and the components have to be modified to be able to communicate, send and receive signals, and determine their own condition. Physical values typical for each failure mechanism need to be defined and monitored.

Strategy 4: Combination of the three strategies. For example monitoring of the whole system and detailed monitoring of service-relevant components and their failure mechanisms. This system has the highest complexity and costs and the best accuracy for condition monitoring and failure prediction.

Strategy two and three are qualified to be used for the development of availability-oriented business models.

5. Theoretical example

In this chapter, a theoretical example based on literature values is shown. The next example shows how the four strategies for condition monitoring can be used and how they work. Based on the literature, several components and their failure rates could be identified over a few years. In the following, the year 1999 will be analyzed. It was clearly determined that the main failure components of the electric motor are the rotor (1%), stator (2%), bearings (95%) and other parts (2%). Hence the service-relevant components are the bearings, based on the data of the year 1999. The information is shown in Table 3. [13]

Table 3: Failure components in electric motors [13]

Year	1985	1986	1995	1995-1997	1999
Stator	37%	36%	13%	9%	2%
Rotor	10%	9%	8%	6%	1%
Bearing	41%	41%	42%	75%	95%
Other	12%	14%	38%	10%	2%

Fig. 3 shows the failure mechanisms and main reasons for bearing failures in electric motors in general. Because of wrong and aged lubricant, grease missing or too much grease, vibration from motor or load machine, or bearing currents, failures occur. In [14], [15], [16], [17] and [18] examples for condition monitoring of bearings, based on vibration and temperature, are presented.

Based on the information in Table 3 and the Fig. 3, a theoretical FTA (DIN 2542-1 and DIN 25424-2) can be carried out. This is shown in Fig. 4. The Top-Event is the E-motor failure. This kind of failure occurs when the rotor, stator, bearings or other components are not working properly. The failure mechanisms of the bearings in E-motors are shown in Fig. 3. In this case there is information about the service-relevant components and their failure mechanisms.

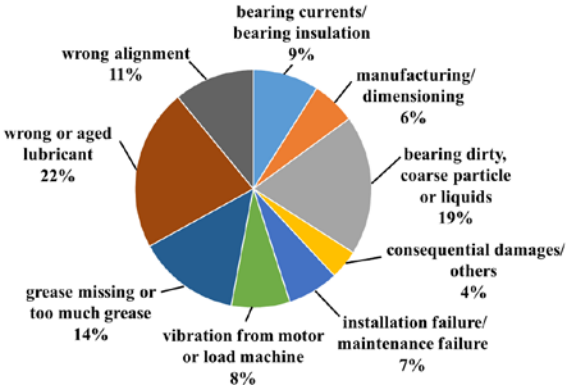


Fig. 3: Overview of mechanisms and reasons for failure of bearings in electric motors [19]

If there is no information about the service-relevant components and their failure mechanism by using of the FTA, FMEA, Cause-effect-diagram and Intensity-Relation-Matrix can be shown, which component and which failure mechanism have to be monitored.

Fig. 4 shows the four condition monitoring strategies based on a FTA structure. If the first strategy is chosen, only the E-motor as a complete assembly will be monitored.

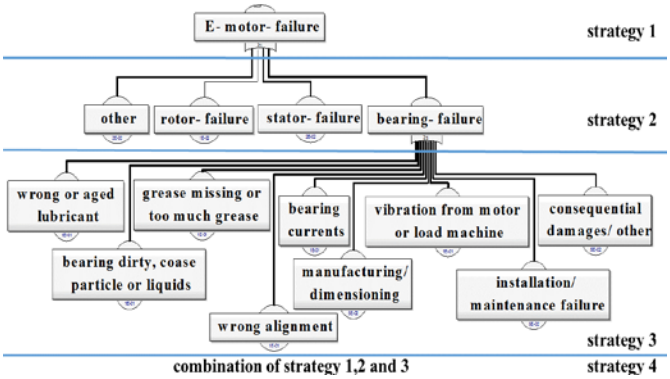


Fig. 4: Example of failure tree analysis with the four strategies

For the second strategy, it is necessary to monitor the bearings, because they represent the service-relevant components. Monitoring failure mechanisms, e.g. bearings failure, is essential for the third strategy. This process is highly complicated and expensive. It is necessary to define some significant physical values for instance temperature, acceleration, distance, length and to measuring them continuously. For the fourth strategy, it is necessary to monitor the main function of the relevant components (e.g. the rotation of an E-motor), the critical service-relevant components- and their failure mechanism characterization (e.g. bearings, their vibration and the physical values, which characterize the failure mechanism of the bearings).

To increase the availability of the machine in times of Industry 4.0, the service-relevant components have to be monitored, the data must be analyzed online and the manufacturer, service team and customer should have access to information about the machine condition. It is possible, that there are no existing sensors for some measurement tasks. Then it is necessary to develop new sensors for the specific tasks. In the following chapter an example of a newly developed sensor for a special measurement task will be presented.

6. Example from the agricultural industry

Focusing on the agricultural industry, the following use case analyzes a potato harvester. To harvest potatoes, there is a short span of time every year and there are rough environmental conditions under which the machines operate [20], [21]. Wear occurs and leads to failures when preventive service is lacking. It is very critical for the customer of the capital good and the manufactures, if a machine failure occurs during the harvest season. To increase the availability of the machine during the harvest

season and realize availability-oriented business models it was necessary in the first step to identify the service-relevant components and in the second step to develop a smart sensor concept to determine the condition of these components. By use of system analysis (failure-tree-analysis, cause-effect-diagram and intensity-relation-matrix) it was determined, that the conveyor belt of a potato harvester is the critical component.

After the identification of the critical component, the failure mechanisms of the conveyor belt were determined. After further analysis and experiments in test bench trials, the main failure mechanisms were defined. Results have shown that the elongation of the belt increased slowly according to the applied stress, and can be predicted. Investigations by the manufacturer of the conveyor belts identified the source of break-down as related to the elongation of the conveyor belts. It was possible to use the third strategy for machine diagnosis and condition monitoring for the development of an availability-oriented business model. [22]

The harvester uses conveyor belts to move the harvested potatoes through the machine and to separate them from the ground of the mounds, in which the potatoes are grown in, and other parts of the plant (Fig. 5). The conveyor belts consist of three belts made of hard rubber, which connect bars orthogonal to the conveying direction to build the conveying surface for the potatoes. The three belts are closed by locks. Both bars and locks are made of ferromagnetic metal. [22]



Fig. 5: AMR-Sensor (left [23]), conveyor belt (middle [24]), schematically (right)

The condition of the belts have to be monitored to trigger services just before a failure occurs in order to prevent failure of the conveyer belts in the harvester, avoid unnecessary maintenance and to increase the machine availability.

This was realized by developing of a robust sensor concept, robust signal processing concept, pre-processing concept and a model for signal interpretation. A magnetic measurement principle [25] was chosen to obtain a robust and reliable sensor signal. The AMR-Sensor from Fig. 5 was developed and tested. [22]

In the next steps the sensor will be implemented into the real machine and the condition monitoring strategy three will be tested. The sensor data will be stored in and analyzed by a cloud based platform. After analyzing the sensor data online, the gained information about the condition of the machine will be send to the operator of the capital good as well as to the service team. If a failure occurs, the operator and the service team can react on short notice and thus reduce down times.

7. Conclusion and outlook

In this paper a strategy for the development of availability-oriented business models based on diagnosis and prediction of machine failures is shown. In the first step service-relevant components need to be identified. Methods for this identification are described. After that the failure mechanisms of the components should be determined. When the failure mechanism is known, a strategy for the condition-monitoring of the components based on the failure mechanism as well as smart sensor concepts need to be developed. A theoretical example based on an electric motor and a practical example based on a potato harvester depicted this approach. In the next step, the smart-sensor-concept for the potato harvester will be tested in the machine under real conditions. Based on the smart, communicating components, a smart system can be developed. The sensor data will be analyzed by a cloud based platform. After analyzing the sensor data online, the information about the condition of the machine will be sent to the operator of the capital good as well as to the service team. In case a failure occurs, the operator and the service team could react on short notice and thus reduce down times.

8. Acknowledgements

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INTERACTIVE APPROACHES TO THE ORGANIZATION OF STAFF INTERACTION WITH AUTOMATED CONTROL SYSTEMS

ИНТЕРАКТИВНЫЕ ПОДХОДЫ К ОРГАНИЗАЦИИ ВЗАИМОДЕЙСТВИЯ ПЕРСОНАЛА С АВТОМАТИЗИРОВАННЫМИ СИСТЕМАМИ УПРАВЛЕНИЯ

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Abstract: *Until now, the majority of ergatic control systems in various technological areas are based on a functioning independent of the maintenance process. This approach reduces the efficiency of maintenance and the safety of the system. The report proposes an alternative model of the system's behavior, based on interactive interaction with both operational and technical staff.*

***KEYWORDS**:* CONTROL SYSTEM, INTERACTIVE INTERACTION, MAINTENANCE, OPERATIONAL PERSONNEL, TECHNICAL PERSONNEL

1. Introduction

Most automated process control systems are ergative systems. This means that there is a distribution of powers between the operator and the technical means [1].

At present, many approaches have been worked out to investigate and form an interactive interaction between the operator and the equipment. Thus, the principle of ergatics is provided, within the framework of which a comprehensive evaluation of the reliability, efficiency and safety of the functioning of the automated system is performed [2, 3].

However, little attention is paid to the interaction of technical means of the system with the servicing (technical) personnel, as well as the complex interaction of equipment, operational (operational) and technical personnel. In such conditions, the functioning of ergatic control systems becomes insufficiently explored, and approaches to rationing performance indicators do not take into account a variety of operational and technical factors. Particularly relevant is the problem for railway transport, information control systems which directly affect the safety of technological processes (train and shunting work).

Thus, a further study is aimed at taking into account the interactive interaction between all types of personnel and the technology of information control systems. This will allow to develop more reliable approaches to designing ergatic systems in industry, energy and transport.

2. Preconditions and means for resolving the problem

The technical staff of the automated control systems is currently ensuring the proper state of the performance indicators through the maintenance subsystem (Fig. 1). It includes a set of maintenance and repair works, regulatory documents and an organizational component [4].

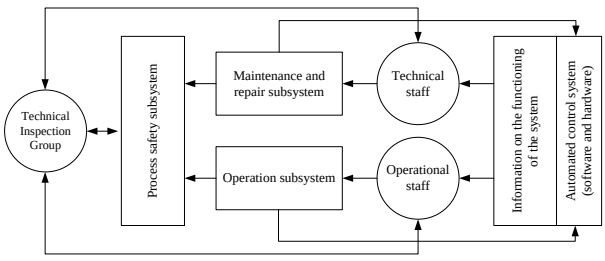


Fig.1. The existing scheme for ensuring the safety of automated control systems

The safety management scheme includes a set of maintenance and repair works, regulatory documents and an organizational component.

Technical personnel, guided by regulatory documents and visual information on the status of devices, carries out the necessary list of works. According to statistics, quite a significant number of security breaches in the implementation of technological processes occur due to errors of technical personnel: poor quality of work, violation of the deadline for their execution, use of non-normative materials and equipment, etc. In fact, the person and the control system in this situation operate in parallel and interact little . The system does not directly control the maintenance process, so this function has to be assigned to a separate headquarters, which checks the quality of maintenance and the operational safety. A similar situation is observed with the process of technical use of the management system, that is, with exploitation. Despite some progress in the algorithm of human-operator interaction, which can take place in modern microprocessor systems, the situation has not fundamentally changed. In fact, there are some developments in the interactive interaction of the system with the operator (the formation of warning dialog boxes with audible alarm in the event of damage, user authorization, confirmation of information, automatic provision of reference data on the analysis of the process at the facility, etc.).

Therefore, the operation of the operational staff is also controlled by individual staff, as shown in the diagram (Fig. 1). Over the past two decades, there has been a trend to strengthen this control system, but there have been no significant changes in the quality and safety of the maintenance and operation subsystems.

Consequently, there is a classic problem in the management system, which is called the watchman for the watchman. With this approach, the use of subjective control can have only one-off, short-term consequences and always reduces the effectiveness of the process. In this regard, it is proposed to change the system of interaction of the human operator with automated control systems. Unlike the existing method, the system will have built-in functions for operative monitoring of the safety of personnel actions, monitoring of operation and maintenance. In case of dangerous situations, the system will block the development of dangerous events by using intelligent subsystems: personnel diagnosis, identification and hazard localization (Fig. 2).

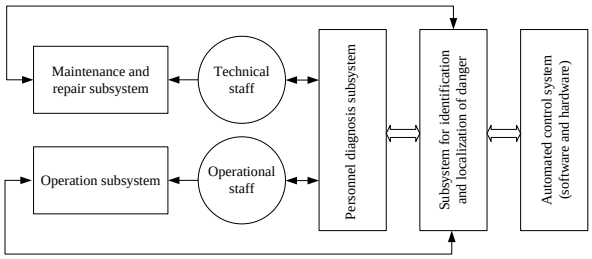


Fig.2. The scheme of safety on the basis of diagnosing the personnel

The subsystem of personnel diagnostics on the basis of programmed criteria determines the adequacy of the behavior of both operational and technical personnel in the current situation at the technological facility. If there are actions that do not correspond to the situation (for example, attempts to interfere with the operation of executive devices when performing their assigned functions), the subsystem issues a warning, and in case of its failure, by blocking the corresponding dangerous action with the help of the identification and danger localization subsystem. The control team enters the automated control system, including its hardware and software, only under condition of passage of the diagnostic control in both intellectual subsystems. The implementation of this approach can occur as software, or hardware or combined (software and hardware) tools.

3. Solution of the problem under consideration

3.1. Generalized formalization of interactive interaction

To implement the interactive scheme of interaction between personnel and technology (Fig. 2), an approach based on the formal-multiple establishment of the adequacy of the actions of personnel according to certain criteria is foreseen. It is based on the isomorphism of sets of states and actions, the definition of which is carried out using the apparatus of the theory of groups and relations. Each component of the scheme depicted in Fig. 2 is interpreted by an ordered set of objects, their states and properties. In the framework of a set, equivalence classes are formed according to a structural-functional feature. For each class, compliance is established at the level of the technical diagnostic subsystem, which is proved using the theorems on permutations of group elements [5].

At the same time, the criterion of inadequate actions of any personnel (operational or technical) is the violation of the established isomorphism detected by the diagnostic subsystem.

A separate stage establishes the adequacy of the complex interaction of all components associated with interactive interaction with the management system. For this, a pairwise comparison is performed with subsequent complex analysis using the graph-analytic method (Fig. 3) [6].

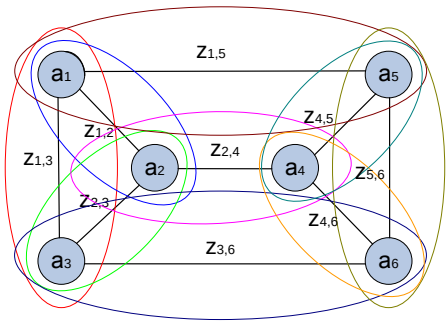


Fig. 3. Scheme of the complex definition of the adequacy of the interactive interaction of the ergatic control system

The correspondence of the vertices of the graph shown in Fig. 3, with the elements of the circuit in Fig. 2 is defined as follows: a1 – Maintenance and repair subsystem; a2 – Operation subsystem; a3 – Technical staff; a4 – Operational staff; a5 – Subsystem for identification and localization of danger; a6 – Software and hardware. The resulting correctness is determined on the basis of comparison of the actual ordered set of links $Z = \{z_{ij}\}$ with the reference one, which is laid in the subsystem of technical diagnostics.

3.2. Periodic monitoring of technical diagnosis

At the same time, there arises a single problem of controlling the reliability of the shadow diagnostics of an automated control system. At the same time, it should be borne in mind that the management systems for responsible technological processes are built on a multi-channel principle, which increases their safety. In such conditions, additional control of technical diagnostics can be carried out on the basis of information comparison in various control channels of controllers of executive devices (objects). An algorithm for such a control is shown in Fig. 4.

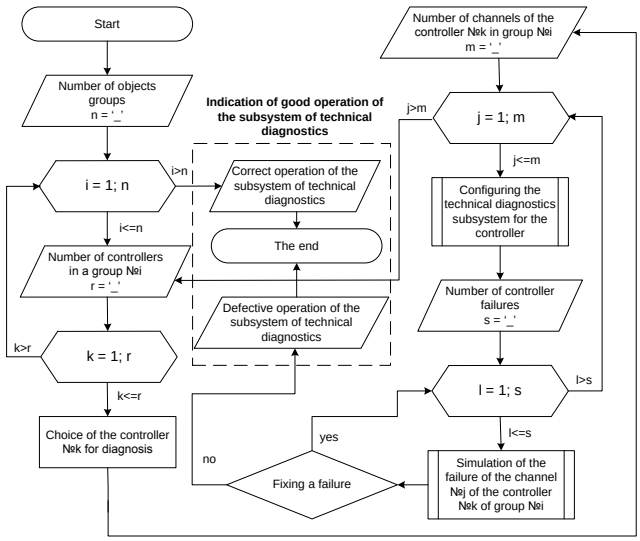


Fig. 4. Algorithm of periodic monitoring of the subsystem of technical diagnostics

The joint execution of the procedures depicted in Figures 3 and 4 gives the most complete picture of the functioning of the control system. Depending on the specific control system, these structures can be refined or detailed.

3.3. Intermodular interaction of functional components

However, the claimed procedure of the analysis requires clarification of the interaction between the functional components of the automated control system. Given the multi-level hierarchical construction of most such systems, as well as the client-server architecture of their construction, such interaction is displayed by the circuit depicted in Fig. 5 [7].

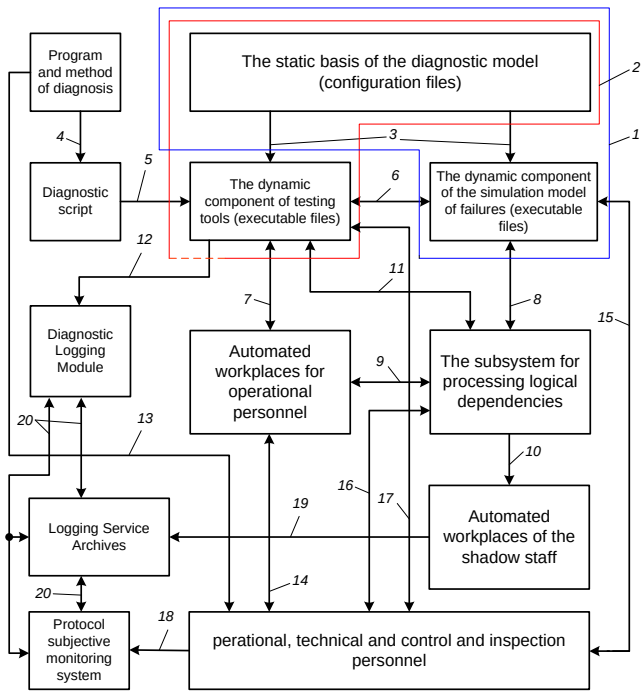


Fig. 5. Structure of intermodular interaction of components of the ergatic control system

The links and the elements indicated in Fig. 5, have the following meanings: 1 – Simulation model of sensors and actuators of the system; 2 – Software tool for automation of technical diagnostics; 3 – Process of synthesis (integration) of the simulation model and the means of automation of technical diagnostics; 4 – Process of forming a test script for technical diagnostics; 5 – The process of integrating the test script with the technical diagnostics automation tool; 6 – Process of initialization of states of sensors and actuators; 7 – Actions of operational personnel or their modeling (reproduction); 8, 9, 10, 11 – Monitoring the response of the subsystem for processing logical dependencies on test and diagnostic impacts, respectively, from the simulation model of sensors and actuators, automated workstations of operational and technical personnel, automation tools for technical diagnostics; 12 – Automatic registration of diagnostic results in an electronic protocol; 13 – Process of interaction of the control and inspection personnel with the program and the diagnostic technique in the non-automatic mode; 14 – Process of interactive interaction of operational personnel and the system or its modeling (reproduction); 15 – Process of changing the states of sensors and actuators of the system; 16 – Process of modeling the actions of destabilizing factors; 17 – Setting up an automated diagnostic tool; 18 – Manual (non-automatic) registration of the results of technical diagnostics by inspection personnel; 19 – Analysis of the results of the logging of the system during the technical diagnosis; 20 – Comparison of manual and electronic reporting on the results of technical diagnosis.

The initial component of the process of objective control of the interactive interaction of personnel and equipment is the simulation model of sensors and actuators 1, which is synthesized 3 on the basis of combining configuration and executable files. software system diagnostics automation is formed for the automation of technical diagnostics 2 synthesized similarly to the simulation model.

The initial position of the technical diagnostics is the program and methodology, on the basis of which 4 test (diagnostic) script is formed, which is laid 5 in the diagnostic automation tool. According to it, the automation tool establishes the initial, current and final states of the sensors and actuators (including simulating their failures and failures) 6 and reproduces the operator's work by simulating manipulations at the workstation's automated workplace under the respective conditions of the sensors and actuators 7.

The installed states of the sensors and actuators and the operator's commands are fed into the subsystem for processing logical dependencies, the reaction of which to them is perceived and controlled by the means of the simulation model, the automated workstations of the operative, technical personnel and the diagnostics automation media through channels 8, 9, 10, 11 . also, the channel means 11 sets the automation of technical diagnostics various states of logical dependencies processing subsystem channels (including ITPO destabilization in their work) and internal controls of their reaction to the impact of external factors. Fixed reaction 12 is automatically registered in the electronic record. In addition, the information is archived by the service logging of the control system, which can be read by means of automated workplaces of technical personnel (to which it comes via channel 10) or directly (decryption of protocols). Comparison of the system operation protocols with the electronic reports of the diagnostic automation tool 20 makes it possible to verify the correct functioning of the logging service as an integral part of the security of the control system.

If there is no automation of technical diagnostics or a combined approach in which only part of the technical diagnostics procedures are automated, the representative of the inspection personnel directly follows the provisions of the program and the technique of technical diagnostics, 13 simulating the work of the operator 14 in accordance with them, changing the states of the sensors and actuators 15 and destabilizing a work logical dependencies processing subsystem 16. With the help of the operator 14, the service persons interfaces Ala 10, adjustment and testing 15, 16 the reaction of various components of the complex's control system is analyzed, which is recorded in the protocol of technical diagnostics.

In the case of partial automation of the technical diagnostics process, the automation tool can be used to perform individual phases of the program and the diagnostic procedure, for which it is preconfigured before the diagnostic procedures begin, and start and stop 17 during interactive interaction. With the full automation of technical diagnostics, even if the adequacy of diagnostic imitation models has been confirmed, the expediency of additional verification of their results by control tests has been established.

At the end of each cycle of technical diagnostics, a comparative analysis of 20 electronic, manual protocols and archives of the logging subsystem of the logical dependency processing subsystem or only the manual protocol and logging archives (provided there is no automation), on the basis of which a report on the performance of technical diagnostics is prepared and processed Results using standard methods of the theory of experimental planning.

Thus, corresponding to the scheme shown in Fig. 5, the automated control system should simulate two interface lines of interaction with sensors and actuators – virtual and real (Fig. 6) [8].

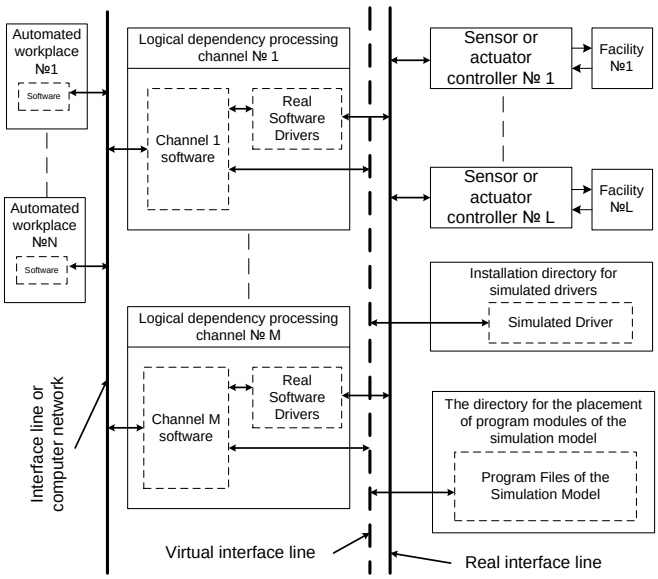


Fig. 6. Structural-functional diagram of the automated control system in conditions of interactive interaction with personnel

The interaction of the system with real sensors and actuators (or their object controllers) is performed on a real interface line. At the same time, the test actions of the technical diagnostics subsystem using the simulation model are implemented on the virtual interface line. The application software of the subsystem for processing logical dependencies does not distinguish between the corresponding lines (virtual and real). Thus, the simulation of failures in the process of technical diagnostics is performed identically to their actual manifestation for the system.

A more detailed scheme for organizing a virtual interface line is shown in Fig. 7.

Each interface module provides access to files and folders. The implementation of the virtual interface line is based on the complete identity of the structure of temporary files of real and virtual interfaces of drivers.

Use of the given simulation model is possible only after confirmation of its adequacy. Otherwise, it is impossible to achieve reliable results of technical diagnostics in the process of interactive interaction of personnel and equipment. Therefore, the adequacy of the model is proved by testing with subsequent comparison of the reference and actual results of its functioning. Only their complete coincidence guarantees the adequacy of simulation modeling.

The adequacy criterion is established both for a discrete automaton. At the same time, it is necessary to reproduce the fullness of the states of the sensors and actuators of the control system, as well as all associated technological situations [9].

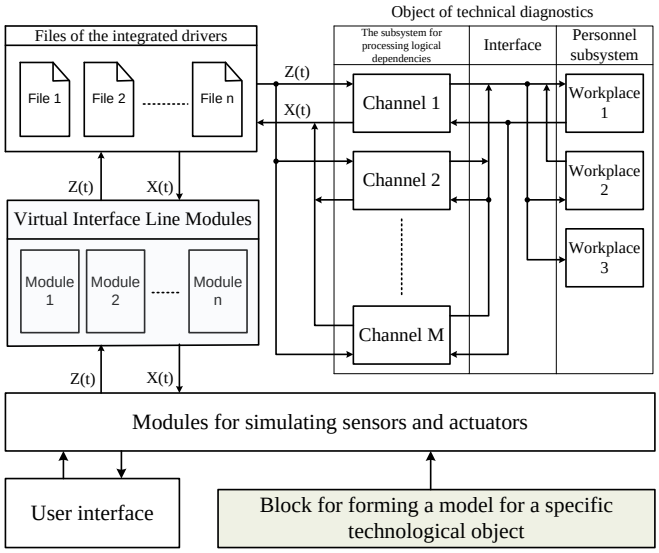


Fig. 7. The scheme for organizing a virtual interface line

In such conditions, it is possible to achieve the greatest safety of operation, taking into account the influence of the human factor both in the aspect of operation, and in the aspect of maintenance and repair.

4. Practical implementation

The proposed approach to the interactive interaction of operational, technical personnel with machinery, as well as control of the reliability of technical diagnostics, is experimentally introduced in the systems of microprocessor control of pointers and signals at a number of railway stations in Ukraine (Fig. 8) [10].


Fig. 8. Cabinet of the subsystem for processing logical dependencies of microprocessor interlocking of pointers and signals

For such systems, especially high requirements for functional safety and reliability are characteristic. This is connected both with the regulation of the passenger traffic, and with the transport of dangerous (including radioactive) cargo.

Therefore, the subsystem of processing the logical dependencies of microprocessor centralization is based on the majority reservation principle, within the framework of which the character of multichannel has not only hardware, but also software. This means that software development for each channel of the logical dependency processing subsystem is performed by different development teams under a single technical assignment.

Interactive interaction of the system with the operative and technical personnel is carried out by means of automated workplaces, tuning monitors and specialized maintenance stands.

At the same time, the technical means of diagnostics and its control are implemented programmatically – on the basis of the level of processing of logically dependent systems. Monitoring of the functioning of such an approach is carried out on the basis of an analysis of archival information, which is formed by the subsystem of recording the system's actions. After the end of the pilot operation, possible shortcomings and comments will be taken into account, after which the approach will be implemented on an ongoing basis.

5. Conclusion

Thus, new approaches to the interactive interaction of man and technology in automated control systems for responsible technological processes are proposed. Unlike the known, they assume an objective control not only of the operational factor, but also the maintenance and repair factor, as well as the control of the reliability of technical diagnostics. The introduction of approaches will significantly enhance the functional safety of the control systems used.

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METHODICAL SYSTEMS OF LEARNING INTEGRAL EQUATIONS, USING MODERN COMPUTER MATHEMATICS SYSTEMS

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Abstract: *We consider methodological aspects of teaching integral equations in terms of introduction of information technologies in the higher education system, which gives an opportunity to students of mathematics to improve their mental and creative skills, develop their thinking and logic, and get the basics of professional competences.*
KEYWORDS**:** *INFORMATION TECHNOLOGY, LEARNING INTEGRAL EQUATIONS, SYSTEM OF COMPUTER MATHEMATICS MAPLE, BACHELOR OF MATHEMATICS.*

Introduction

Harmonious combination of fundamental principles of the traditional education and modern information technology offers great opportunities of qualitative reorganization of principles and methods of teaching classical mathematical disciplines. Analysis of traditional forms, methods and means of organization and carrying out of lessons determines necessity of development new approaches to learning that are characterized by qualitative changes of the education content and structure, and the introduction of information and communication technologies (ICT) in the educational process. To do this it is necessary to create new methodical systems of training future bachelors of the natural - scientific field, focused on the development of student's intellectual potential, on the formation of abilities independently to acquire knowledge and to carry out various types of research activities.

Today it is impossible to realize what was possible in the traditional university system. Classroom load is reduced, not only based on the increase of teaching efficiency, but also in connection with a reduction in the level of perception the information by the separately taken channel. Light version of universal higher education, overcoming language barriers, is extended synchronously with the information infrastructure. A deep special training or will be available to units of gifted students, or move to the post-graduate level.

Development of modern technologies in education should be carried out, taking the following principles into account (N.A. Usnovich, 2005; V.I. Bel'ko, V.V. Dainiak and O.M. Kondrat'eva, 2008):

- integrity of the technology, which represents the didactic system;
- reproducibility of technology in a particular pedagogical environment to achieve goals;
- prioritize of factors, affecting on the mechanisms of self-relevant pedagogical systems;
- adaptations of the learning process to the student's personality and its cognitive abilities;
- potential redundancy of educational information, which creates optimal conditions for the formation of generalized knowledge.

The significant contribution to the basis of development of the conceptual theory and methodology of information technologies use in teaching has been made by J.K. Babanskii, A.P. Yershov, A.A. Kuznetsov, M.P. Lapchik, N.V. Makarova, I.V. Robert and others.

Fundamental research of N.V. Talyzyna, V.M. Monakhov, A.A. Kuznetsov, A.V. Pankov, V.P. Kulikov, G.A. Kruchinina and others are devoted to the psycho-pedagogical problems of the design and use of information technologies in education.

By analyzing the content, features and capabilities of computer mathematical systems, we found that effective methodological approaches are implemented with adaptation of specially designed in Maple educational software products and textbooks, developed by university teachers in accordance with the thematic plans of taught disciplines, as well as views on the methodology of their teaching. Advent of computer mathematics systems (CMS) essentially and ambiguously impacts on the process of teaching mathematics in high schools, and has been a subject of many studies. For example, issues about use of CMS were studied by (V.P. Dyakonov, 2003; A.V. Matrosov, 2001; M.N. Kirsanov, 2007; O.V. Manturov, 2001; B.M. Manzon, 1997; A. Gray, 1991; Y.N. Burkhanova, 2013) and others.

Results and discusion

CMS Maple has already taken a strong position in higher education and it is an indispensable tool with which teachers can qualitatively change teaching methods and organize new forms of learning process, improve level of the studied material, better develop the individual characteristics of students, organize independent work.

Maple is an integrated system, i.e. it combines a powerful programming language, editor for preparation and editing of documents and programs, mathematically oriented user input language and programming language, multi-user interface with ability to work in a dialogue mode, the core of algorithms and rules for the conversion of mathematical expressions, program numerical and symbolic processors with a diagnostic system, the most powerful library of built-in and optional functions, packages of extension and application of the system and a huge, very easy to use help system. To all of these tools there is a complete access directly from the system.

The mathematical graphics of system allows us to obtain images of plane and space curves and surfaces, moreover, by all possible ways to modify them and combine. It is possible to build two- and three-dimensional graphics only by the selected expression (Smartplot option) without use of commands and reference of ranges for variables.

In the computing mode of Maple it is possible to interleave bursts of programs - one-liners, for which there is a fairly simple and intuitive command language. Moreover, the system has a large number of tools, devoted namely to the students, that largely explains the popularity of the system. Interface of Maple is convenient; there are push-button panels to input mathematical formulas.

Nowadays CMS Maple is widely known in universities of leading scientific research centers and companies. Hundreds of books are published, describing Maple and its numerous applications in research and for teaching natural science disciplines. Having an intuitive interface, easy work rules and broad functionality, the system has gained popularity among students, studied in the specialty "Mathematics" of natural - scientific direction.

The main concept of Maple that has been used as a basis more than 20 years ago is stored in the main despite the numerous upgrades and expansion. Maple is a system to solve mathematical problems. Now there are all reasons to bring it to use of the largest possible number of users. The last projects of Waterloo Maple Company allow us to suggest that in the near future its main efforts will be aimed at promoting the Maple as an interactive learning system. Even a special center dedicated to the popularization of Maple among students, is created.

Currently, CMS are gaining in popularity, and are increasingly used in training. A technique of using CMS Maple, MathCAD during the lectures is developed to demonstrate various graphs and

make mathematical calculations in technical universities (E.B. Klimenko, 1999). Theory and methods of using CMS Mathematica have been studied: for laboratory works during the learning of Higher Mathematics it has been studied in (S.A. D'yachenko, 2000), in the teaching of the Differential Geometry in (T.V. Kapustina, 2001), for Differential Equations in (R.M. Aslanov and A.S. Bezruchko, 2011), during the mathematical preparation of economic profile specialists in (E.A. Daher, 2004).

Development of a laboratory practice with CMS MathCAD in teaching mathematics students of pedagogical universities and methods of use of the CMS MathCAD software in the course "Numerical Methods" in the training of pedagogical high school students are considered in (I.B. Belenkova, 2004; U.V. Plyasunova, 2004).

Some authors (M.P. Lapchik, M.I. Ragulina and E.K. Henner, 2002) suggest to use CMS (MathCAD, Maple, Derive, Mathematica, MathLAB) for their theoretical development and formation of experience in these programs during the course "Information technology in Mathematics".

Recently, it is necessary to introduce these computer systems and programs into the learning process of integral equations that give an opportunity to students to develop their intellectual and creative abilities, develop thinking and logic, get basics of professional competences and determine the course of his future career. By using the CMS, future bachelors of mathematics have possibilities:

1) to compute and analyze all kinds of calculations, both numerical and analytical, or character;

2) to visualize analytical data, graphically process the results of experiments, build charts and bar graphs, build arbitrary images, using graphics primitives

3) to formalize and store electronic files, where it is possible to alternate text fragments, computing and graphics;

3) to create high-quality animations of graphics and, even analytical images;

4) to create a database and knowledge base;

5) to program, using the specific programming language of ultra-high-level for SCM, moreover, to program not only mathematical problems, but any combinations of actions, which are available in the system;

6) due to openness of CMS, user can input new features in the use, designing them on the base of the available system functions and by the method of conversion rules;

7) to create high quality educational software products in the environment, including computer textbooks and workshops with a branched structure, using hypertext.

For several years at K.A. Yasawi International kazakh-turkish university (Turkestan, Kazakhstan) research on introduction of ICT into the educational process is conducted, which includes the use of Maple CMS in the educational process of learning integral equations of the future bachelors - mathematics. As a result of the ICT introduction into the educational process database (Knowledge Bank) on integral equations is created, which includes computer textbooks, manuals, problem books, collections of tests, electronic dictionaries, reference books, encyclopedias, numeric data, computer training materials.

Let us consider some examples on Maple CMS application to study graphs of functions which are exact solutions of integral equations.

Example 1. Solve the Fredholm integral equation:

$$u(t) = t^3 + \int_0^1 (2+ts)u(s)ds.$$

Solution: Write an integral member of the equation in the following form:

$$\int_0^1 (2+ts)u(s)ds = 2\int_0^1 u(s)ds + t\int_0^1 su(s)ds.$$

Denote

$$Q_1 = \int_0^1 u(s)ds,\ Q_2 = \int_0^1 su(s)ds.$$

The original equation can be represented as the following algebraic equation:

$$u(t) = t^3 + 2Q_1 + Q_2 t.$$

Calculate Q_1 and Q_2:

$$Q_1 = \int_0^1 u(s)ds = \int_0^1 \left[s^3 + 2Q_1 + Q_2 s \right] ds =$$

$$= \left[\frac{1}{4}s^4 + 2Q_1 s + \frac{1}{2}Q_2 s^2 \right]\Big|_0^1 = \frac{1}{4} + 2Q_1 + \frac{1}{2}Q_2,$$

or

$$-Q_1 - \frac{1}{2}Q_2 = \frac{1}{4},$$

$$Q_2 = \int_0^1 su(s)ds = \int_0^1 s(s^3 + 2Q_1 + Q_2 s)ds =$$

$$= \left[\frac{1}{5}s^5 + Q_1 s^2 + \frac{1}{3}Q_2 s^3 \right]\Big|_0^1 = \frac{1}{5} + Q_1 + \frac{1}{3}Q_2,$$

or

$$-Q_1 - \frac{2}{3}Q_2 = \frac{1}{5}.$$

Consider the system of linear algebraic equations concerning to Q_1 and Q_2:

$$\begin{cases} -Q_1 - \frac{1}{2}Q_2 = \frac{1}{4}, \\ -Q_1 - \frac{2}{3}Q_2 = \frac{1}{5}. \end{cases}$$

Using the Cramer formula, we find Q_1 and Q_2:

$$Q_1 = \frac{D_1}{D}, \quad Q_2 = \frac{D_2}{D},$$

where

$$D = \begin{vmatrix} -1 & -\frac{1}{2} \\ -1 & -\frac{2}{3} \end{vmatrix} = \frac{1}{6} \neq 0,\ D_1 = \begin{vmatrix} \frac{1}{4} & -\frac{1}{2} \\ \frac{1}{5} & -\frac{2}{3} \end{vmatrix} = -\frac{1}{6} + \frac{1}{10} = -\frac{1}{15},$$

$$D_2 = \begin{vmatrix} -1 & \frac{1}{4} \\ -1 & \frac{1}{5} \end{vmatrix} = -\frac{1}{5} + \frac{1}{4} = \frac{1}{20}.$$

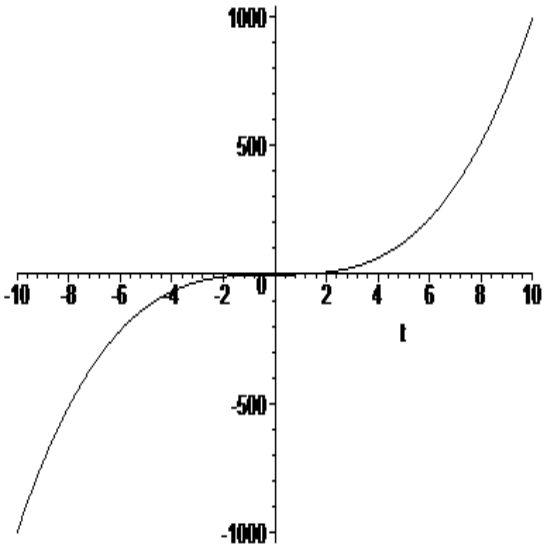
$$Q_1 = \frac{D_1}{D} = -\frac{2}{5}, \quad Q_2 = \frac{D_2}{D} = \frac{3}{10}.$$

Putting the values of Q_1 and Q_2 into the algebraic equation, we find the exact solution of the integral equation:

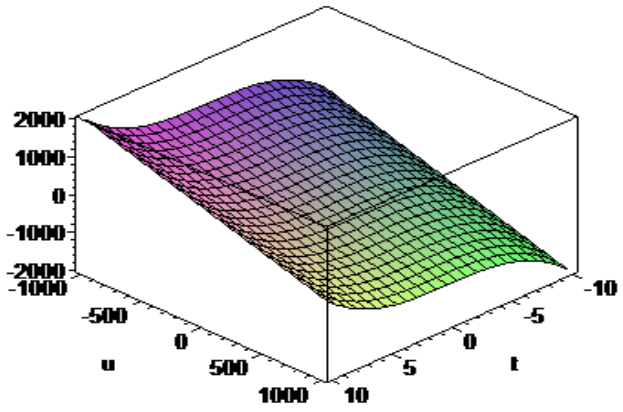
$$u(t) = t^3 + \frac{3}{10}t - \frac{4}{5}.$$

To study the behavior of the solution we will use the computer program system Maple.

```
> restart;
> u:=t->t^3+3*t/10-4/5:
> u(t):
> plot(u(t),t=-10..10,color=black);
```




```
> restart;
> f:=(t,u)->t^3-3*t/10-4/5-u:
> f(t,u):
> a:=-10..10;b:=-1000..1000:
> plot3d(f(t,u),t=a,u=b,axes=boxed);
```



>

Conclusion

As a result, we can conclude that the mathematical computer systems can and should be used as a means of ICT in learning. The most effective application of computer mathematical systems for educational purposes can achieve when software of educational purposes and computerized textbooks, problem books, collections of tests, electronic dictionaries, reference books, encyclopedias, numeric data, computer training materials are developed in their environments.

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CREATIVE LEARNING IN ICT-PROFESSORS' TRAINING PROGRAM

КРЕАТИВНОЕ ОБУЧЕНИЕ В ПРОГРАММе ПОВЫШЕНИЯ КВАЛИФИКАЦИИ иКТ-ПРЕПОДАВАТЕЛЕЙ

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Abstract: *The main issues are considered in this article: urgency creative learning in the system for retraining and improving of pedagogical staffs' professional skills in the Republic of Uzbekistan, specificity of ICT-professor's activities, pedagogical conditions and content of ICT-professors' creative learning, pedagogical model and stages of organization classroom for ICT-professors' creative learning.*
KEYWORDS: *CREATIVE LEARNING, INFORMATION and COMMUNICATION TECHNOLOGies, higher education, system for retraining and improving of pedagogical staffs' professional skills, pedagogical model, curriculum, innovative TRAINING technologies.*

"Imagination is more important than knowledge"

A. Einstein

1. Introduction

In modern conditions of innovative education, creativity is considered as one of the main professional qualities of a teacher, since in a dynamically changing world the success of teacher's professional self-realization depends on his ability to find and make effective original decisions in a timely manner, be well orientated in the new context of education.

Effective forms, methods and means, on which possible to develop the creative potential of the teacher, in practically, the teacher of the Higher education (hereafter reoffered to as "a professor") is definition of the problem.

It should be noted that this problem is defined not only as socio-economic and socio-cultural changes in the society, but as well as the methodological problems. With a great interest of researchers to the concept of "the professor's creativity" there is still no clear mechanism for his development.

Each person has creative abilities and this idea is important for pedagogy.

In our opinion, any teacher is creative, moreover, the professor, who works in the field of information and communication technologies (hereafter reoffered to as "ICT-professor") is more creative, due to the innovative nature of information and communication technologies (hereafter reoffered to as "ICT") itself.

The purpose of the article is to examine the content and methods of developing the creativity of ICT-professors in the context of the system for retraining and improving of pedagogical staffs' professional skills in the Republic of Uzbekistan.

2. Preconditions and means for resolving the problem

2.1. Legal basis for the system of professional development of academic staffs in the Republic of Uzbekistan

The Law "On Education" and "On National Training Program", adopted in 1997, became an important factor in creating a national model for the training of personnel in the Republic of Uzbekistan.

In these basic documents, the system for retraining and improving of pedagogical staffs' professional skills is an independent type in the system of lifelong education, it that demonstrates the importance of this field in Uzbekistan.

The advanced training and retraining of pedagogical staff of the Higher educational institutions is carried out by *the Head Scientific and Methodological Center for professional development for academic and executive staff in Higher education*, as well as 16 branch centers for various fields of training programs in Tashkent and regional centers in the regions of our country.

The decree of the First President of the Republic of Uzbekistan No.91 from June 2, 2005 "*On improvement of the system of training in the field of ICT*" [1], *Tashkent University of Information Technologies* has been determined as a responsible university for a preparation of ICTs' specialists. Five branches of the university in the cities Nukus, Karshi, Samarkand, Urgench and Fergana provide training for ICTs' specialists in the regions of the country. In Mart 2017, Tashkent University of Information Technologies was named after Muhammad al-Khorazmi [2].

The decree of the First President of the Republic of Uzbekistan No.4732 from June 12, 2015 "*On measures to further improve the system of retraining and improving of pedagogical staff's professional skills of the Higher education*" [3] sets out the goals and tasks, as well as the structure of this system.

The main task of these branch centers for the system for retraining and improving of pedagogical staffs' professional skills is to disclosure of the creative potential of each academic staff, based on innovative and modern teaching technologies.

Achieving this goal is possible only with the use of adequate, purposeful, content and teaching technologies that involve each person in an active creative information and communication process, allow creating conditions for the awareness and effective application of acquired knowledge.

It is important to understand that techniques and skills of creative activity do not fit the traditional model of teaching and learning.

2.2. ICT-professors' training program

Changing the goal of learning primarily leads to change a content and a curriculum of the system for retraining and improving of pedagogical staffs' professional skills.

The new curriculum was developed for the system for retraining and improving of ICT-professors' professional skills, which includ the following training modules:

1) The legal and regulatory framework for Higher education,
2) Innovative training technologies and creativity,
3) ICT in education,
4) Practical English language,
5) Fundamentals of system analysis and decision making,
6) ICT-subjects,
7) Practice,
8) Attestation.

The percentage of these training modules in the curriculum is shown in the diagram (Fig. 1).

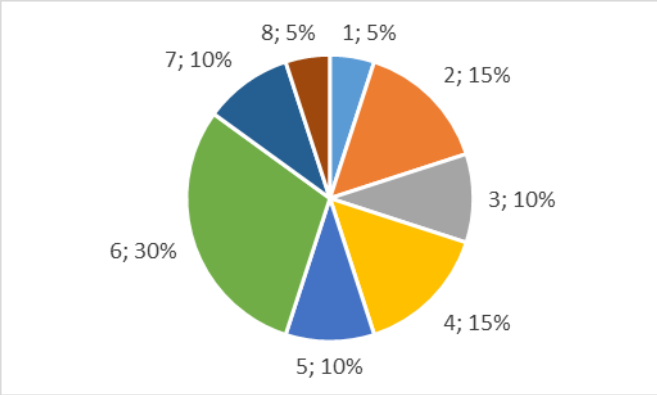


Fig. 1. *The curriculum of ICT-professors' training program*

Creativity has become one of two interrelated components in the program of the system for retraining and improving of ICT-professors' professional skills:

1) an independent training module;

2) a creative learning: "A form of education that develops people's potential for original ideas and actions" [4].

3. Problem-solving

3.1. A creativity as a training module

As an independent educational module, a creativity is presented the theoretical and practical point of view in the program of the system for retraining and improving of ICT-professors' professional skills.

The core of the module "Innovative training technologies and creativity" is consists of a familiarization and practical application with the basic approaches for development of creativity, as a necessary condition for the emergence of a creative personality, ability to go beyond the available knowledge, views, opinions and create a new one.

The module assumes the development of the creative potential of ICT-professors by reducing the share of reproductive activity and increasing the share of productive and creative activity.

In the classroom, ICT-professors solve situational tasks on methodological problems on the basis of methods of creativity development [5]:

- "10 discoveries",
- "Disney's Creative Strategy",
- "Plus. Minus. Interesting",
- "Novelty. Attractiveness. Exercise",
- "Simply. Complicated. Unrealistic", etc.

Additionally practical skills help to disclose the specific of the professional activity of ICT-professors, spastically, to use modern ICTs not only as an object of study, but also by means of innovative forms, methods and tools teaching and learning.

ICT-professors pioneer in introducing in innovative technologies into the educational process – an electronic learning systems, distance learning technologies, interactive electronic boards, 2.0/3.0 web-technologies, SMART-rooms, etc.

On the other hand, modern ICTs make possible to reveal the creative potential of the person [6].

3.2. The model of ICT-professors' creative leaning

The creative teaching is the creative education-research activity where both professors and listeners create the atmosphere where new innovative products are born.

Pedagogical conditions was developed for the effective development of ICT-professors' creativity:

1. Use a motivation of ICT-professors for scientific and innovational pedagogical activity.

2. Orient on a specific product in forms of a new pedagogical ideas, sites, blogs etc.

3. Competent-oriented work with the real pedagogical projects.

4. Use interactive forms, methods and tools for developing ICT-professors' creativity.

5. Use pedagogical innovations and results.

Since we are dealing with practicing ICT-professors, we need to make maximum use of their experience and innovative knowledge in the field of information and educational technologies, for we created the model of ICT-professors' creative leaning for the system for retraining and improving of pedagogical staffs' professional skills (Fig. 2).

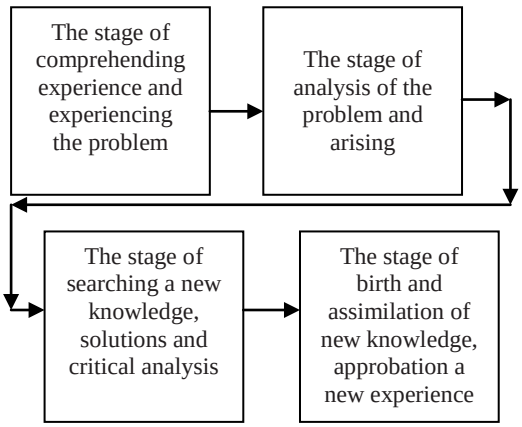


Fig. 2. The m*odel of ICT-professors' creative leaning*

In such creative teaching environment the main place is occupied by a group of interacting ICT-professors who, while discussing issues of interest and participating in discussions, stimulate and activate each other in statements and actions.

In order to implement creative ideas, ICT-professors, working in the group, carry out pedagogical projects, presenting their methodical products in the form of presentations (PowerPoint, Ispring, etc.), mental maps in MindMap, videos, blogs, educational and methodological software products, etc.

4. Results and discussion

The experiment was conducted at the branch Center for retraining and improving of ICT-professors' professional skills of Tashkent University of Information Technologies in November 2016, and also in January 2017.

In total, 103 participants of the system for retraining and improving of ICT-professors' professional skills (Table 1) in the areas:

- "Informatics and Information Technology" (IIT),
- "Computer Engineering" (CE),
- "Software Engineering" (PE).

Table 1. *General data*

№	Category	IIT	KE	PE	TOTAL
1	Without a scientific degree	48	14	22	**84**
2	Candidate of Science	8	3	5	**16**
3	Doctor of Science	2	1	0	**3**
4	Total**:**	**58**	**18**	**27**	**103**
5	Of them: -men; - women.	**40** **18**	**13** **5**	**24** **3**	**77** **26**

At the beginning of the experiment, a survey was conducted to determine the basic concepts of creativity development technologies.

The main questions and answers are reflected in the diagram (Fig. 3).

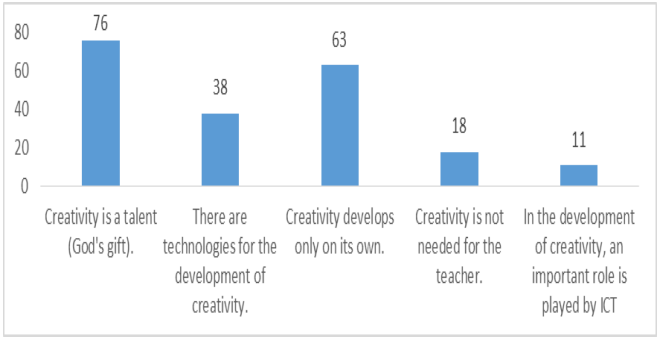


Fig.3. *The scheme of the analysis of the phenomenon of the ICT-professors' creativity*

The data of the questionnaire do not require comments and, in our opinion, reflect the insufficient awareness of the problem in question.

At the beginning of the study module "Innovative training technologies and creativity", testing was conducted to reveal the level of creativity according to the method of E.Torrance [7].

The analysis revealed that (Tabl. 2):

1.The factor of the flexibility is 56%;

2. The factor of the fluency is 31%;

3. The factor of the accuracy is 24%;

4. The factor of the originality is 23%.

Table 2. *Data of Torrance's testing*

№	Category	IIT	KE	PE
1	The factor of the flexibility (%) Of them: -men; - women.	55 54 56	51 49 53	62 61 63
2	The factor of the fluency (%) Of them: -men; - women.	31 29 35	29 26 32	34 33 35
3	The factor of the accuracy (%) Of them: -men; - women.	22 23 21	24 24 24	27 28 26
4	The factor of the originality (%) Of them: -men; - women.	25 27 22	21 22 20	22 25 19

The data of the testing are consistent with the fact that ICT-professors are creative by their nature and by the rapid development of modern ICTs.

It was also noted that female ICT-professors (and about 25% among ICT-professors) have a higher level of fluency and flexibility; however, they possess relatively lower originality; whereas the ICT-professors of the male gender have opposite characteristics.

This is consistent with the fact that women are more plodding and solve problems by existing methods, and men are trying to use non-traditional methods in order to do quickly.

After going through the training courses, ICT-professors noted that the followings were new for them:

- Creative abilities are widely used in pedagogical practice;
- Creativity manifests itself not only in individual activities, but also in collective activity;
- Creativity is developed through practice: participating in the processes of creative production thought: create programs for computer, computer diagrams and figures, sites, and so on;
- New technologies provide new opportunities for creative thinking, as well as new forms of access to ideas, information and people;
- Creative is not the subject of a curriculum; it is the general functions of education.

5. Conclusion

In conclusion, this article reveals the model of ICT-professors' creative leaning in the system for retraining and improving of pedagogical staffs' professional skills and its specificity.

The creative leaning is a main condition for the maximum development of ICT-professor's professional abilities that will enable to see, find, effectively solve and correctly evaluate solutions to creative problems in his activities. The model of ICT-professors' creative leaning consist of the four interrelated stages: comprehending experience and experiencing the problem, analysis of the problem, searching a new knowledge, solutions and critical analysis, birth and assimilation of new knowledge, approbation a new experience. This model corresponds with models of creative leaning by A.Osbrn [8] and K. Rossman [9].

The data of the experiment show that ICT-professor is a creative person, whose professional activity relat to ICT's innovation and ICT-professors' creativity able to be developed.

6. Literature

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