Розроблено мультиагентну систему для надання дистанційних послуг в телемедицині за допомогою бездротового мобільного зв'язку. Одним з ключових компонентів системи є нейронна мережа, що застосовується для постановки попереднього діагнозу на основі обробки медико-реєстраційної інформації та зображень. Для іншого компонента, мобільного агента, реалізований фреймворк з метою віддаленого контролю за пацієнтом

Ключові слова: медична діагностика, нейромережева класифікація, віддалений моніторинг, організаційна мультиагентна система

Разработана мультиагентная система для предоставления дистанционных услуг в телемедицине с помощью беспроводной мобильной связи. Одним из ключевых компонентов системы является нейронная сеть, используемая для постановки предварительного диагноза на основе обработки медико-регистрационной информации и изображений. Для другого компонента, мобильного агента, реализован фреймворк с целью удаленного контроля за пациентом

Ключевые слова: медицинская диагностика, нейросетевая классификация, удаленный мониторинг, организационная мультиагентная система

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DEVELOPMENT OF MULTI-AGENT SYSTEM OF NEURAL NETWORK DIAGNOSTICS AND REMOTE MONITORING OF PATIENT

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1. Introduction

The role of the visual information is becoming increasingly important now. In everyday life we deal mostly with the high quality analysis of images.

In a number of cases, just a quality analysis of images is not enough and it is necessary to obtain quantitative information. This information is necessary, for example, for estimation of the state of a produced brick (Fig. 1), in the sports judging in artistic gymnastics (Fig. 2), while studying pathologic changes of skin diseases for diagnostic purposes (Fig. 3) as well as in many other areas.

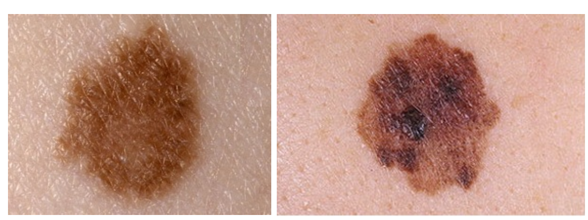
a *b* *c*

Fig. 1. Basic characteristics of a brick, based on visual defects after drying and firing: *a* – brick that meets standards; *b* – brick with cracks; *c* – underfired brick

In such situations, except for simple visual observation and comparison, the operations of calculation, measurement and statistical analysis of the obtained information become obligatory. Intelligent computer systems of the analysis of images can help here. But there are circumstances when the use of such a system is not efficient without the knowledge of an expert in a certain problem area.

a *b*

Fig. 2. During assessment of equilibria and leaps, it is necessary to consider legs swing (90° or 180°): *a* – in the air; *b* – reliance on one foot



a *b*

Fig. 3. Exterior view of birthmark and melanoma. Melanoma has uneven or irregular boundaries: *a* – birth mark; *b* – melanoma

The systems of analysis of images are applied in many scientific and technical and manufacturing sectors, where efficient procedures of processing visual data are necessary: in medicine, biology, industry, aerial photography, security systems, law and order protection, robot technology and others. In the diagnostic systems, the emphasis is either on the problem of prognostication or that of classification. This makes them rather limited in the field of specific diagnostics or applicable only for small subsets of populations. Development of new models, which can be used for the larger population, observation of an enormous amount of information for automatic identification of problems and safety threats (including models of optimal medical aid) becoming very relevant.

The use of neural networks (NN) for the images processing has advantages over traditional mathematical methods in three cases. Firstly, when the considered problem, because of certain features, defies adequate formalization since it contains elements of uncertainty, not to be formalized by traditional mathematical methods. Secondly, when the considered problem is formalizeable but there is no apparatus for its solution at present. Thirdly, when there is a correspondent mathematical apparatus for the considered, well formalizeable, problem, but the implementation of calculations with its help on the basis of the existing computing systems does not meet requirements of obtaining solutions by time, dimension, weight, energy consumption, etc.

The agent-oriented technology (AOT) is based on the use of intelligent program agents and makes it possible to increase functional capabilities of contemporary intelligent systems. One of the important directions of application of multi-agent systems (MAS) is the development of conceptual models of machine training, which allows combining information from the environment during data recognition, classification, forecasting, etc.

Thus, there appears the need for developing diagnostic/expert systems, in which it is possible to register remotedly the change in the state of objects based on the analysis of their images, taking into account special features of a certain subject area.

Efficient combination of AOT and machine training in the real medium predetermined the possibility of constructing multi-agent system of neural network medical diagnostics and remote monitoring of the state of health of a person. Thus, for instance, the timely detection of changes in the skin neoplasm will allow a doctor to diagnose skin cancer at the early stage, which will save a human life. Remote monitoring of health indicators is a successful method of medical support of the patients who need long-time medical observation. The users of the developed system may include patients with chronic diseases during dispensary examination, in the course of preparation for an operation, at the stage of recuperation and rehabilitation after acute states. Furthermore, the proposed system will make it possible for the patients to control independently the indicators of their health conditions. If necessary, a patient can distantly turn to the specialist for help or consultation.

2. Literature review and problem statement

The systems of support of clinical decision making and the neural networks were among the first successful applications of the artificial intelligence.

In the paper [1], the attention is concentrated on the intensive therapy. For this purpose, the system of support of clinical decision making was developed for patients with sharp chest pain. Here, the physiological data, recorded in reanimation departments, are used.

In the article [2], the emphasis is on the development of the system of computerized entering of orders for a hospital (medicines, as well as preparations for laboratory analyses and procedures). The model of logistic regression for predicting the duration of a stay in a hospital was built. Based on it, a decision making support system was created for improving control of the flow of patients in the pediatric intensive care unit of an urban children's hospital.

The assessment of risk of intrahospital diseases for patients is obtained by extraction of more than 10000 variables for each day of hospitalization [3]. In the work, the method of support vectors was used for obtaining the time series of the daily estimations of risk. The hidden Markov models were used for classification of the time series. They showed that the use of time information, which describes development of the state of health of each patient (consequently, the risk of infection), in the course of time leads to an improvement in the accuracy of classification. The forecasting model was built from the large population of patients in real time for notification and stratification of risk.

The method of intellectual data analysis, constructed on the basis of "question– answer", is used for detecting the anomalous template [4]. The IBM Watson system in partnership with the Memorial Sloan-Kettering oncologic center allows patients to undergo the test for diagnosis and treatment of different types of cancer. The peculiarity of the system is its capacity to process large volumes of unstructured text data (electronic medical records of patients, special literature, etc.) and to answer the requests in the natural language. The provision of probabilistic considerations helps doctors to make well-grounded decisions and to improve its efficiency by means of interaction with the user.

The system of intensive monitoring of vitally important functions of patients is described in [5]. Machine training is regarded as the base. The authors created the model of a specific patient, for whom the threshold of starting signaling k is calculated.

Very popular are also:

– systems for analysis of medical images (tumors, mammography, melanoma, ischemic disease of heart, etc.);

– neural networks for creating the classifiers of the state of a patient;

– systems that determine a physiological assessment rating point for premature newborns in the first three hours of life.

However, MAS with intelligent and autonomous agents are not widespread for mobile devices that allow using the necessary information remotedly.

In the medical systems of diagnostics and monitoring, the special features of medical and biological information play significant role. Their database often includes high-quality digital photographs and the video stream, used for formulation of preliminary diagnosis, dynamic observation of the current state of a patient, the assessment of the treatment efficiency. In many other cases, in the process of diagnostics, a change in the state of the tested object can be registered based on the analysis of its image.

The composition and interrelation of the components of the image processing systems depend on the nature of an input image (binary, half-tone, colored, etc.), as well as on the desired final result (localization of the objects of a class, information recognition, data generalization, etc.).

The review of the existing systems of computer analysis of geometric characteristics of the diagnostic images of blood vessels is given in the paper [6]. It was shown that the majority of such systems do not have the applicable software for measuring the complete set of diagnostic signs and diagnosis formulation. They contain only the tools of the images registration, keeping the records of diagnostic information about a patient and the tools for preliminary information processing, improving image quality and image tagging.

In [7], the problems connected with the analysis of objects on the images based on the example of solving problems on medical diagnostics were considered. The theoretical bases and the methods of image processing were described. The characteristics of medical objects in the problems on analysis and recognition were calculated. The applied systems were represented for the analysis and processing of medical images for histology, computer tomography and endoscopy.

The conceptual schemes of managing the processes in the system of image processing, which allow creating a graphic interface in accordance with the applied specific character of the solved problem, are proposed in the article [8]. The schemes make it possible to change and to boost the functionality of the system since they are built on the script-nucleus with the use of "intelligent" collaborative approach. This creates possibility to use objective and tested algorithms of image processing.

Thus, there is the need for updating and creation of new models of building up distributed systems to improve the operating quality of complex organizational structures. This is especially true for the systems that include a large number of users and many service providers (for example, the system of medical diagnostics and monitoring), and also for those providing the analysis and recognition of information. For developing such models, it is expedient to combine the agent-oriented approach and neural network technologies.

3. The aim and the tasks of the study

The aim of the work is to develop a system of medical diagnostics based on the medical and registration information and images, as well as the remote monitoring of human health in real time.

To achieve the set goal, the following tasks must be solved:

– to develop a generalized model of the process of neural network diagnostics and monitoring, its components and their interaction;

– to design organizational structure of the components of the developed model and to describe their interaction.

4. Generalized model of the multi-agent system of the neural network medical diagnostics and monitoring

The main actors in the system of distance diagnostics and monitoring are the patients and special services (sick-nurses, medical personnel, people engaged in monitoring, observers).

A patient is a person who is outside a hospital and whose physical state requires constant control, recommendations and, possibly, urgent aid. He must be registered at a medical organization for inclusion in the system. He has biosensors and measuring devices, which read the most important health indicators and are connected to the mobile device, which delivers the obtained data by means of the Internet to the main server.

Medical personnel are the qualified doctors, registered at a health-care organization, who control the state of health of a patient, write out prescriptions and perform required therapeutic manipulations.

The process of medical diagnostics and remote monitoring is described by the model, which includes: the block of intelligent methods, the agent block, the block of accumulation and analysis of experience, Web-interface, as well as the hardware block (Fig. 4).

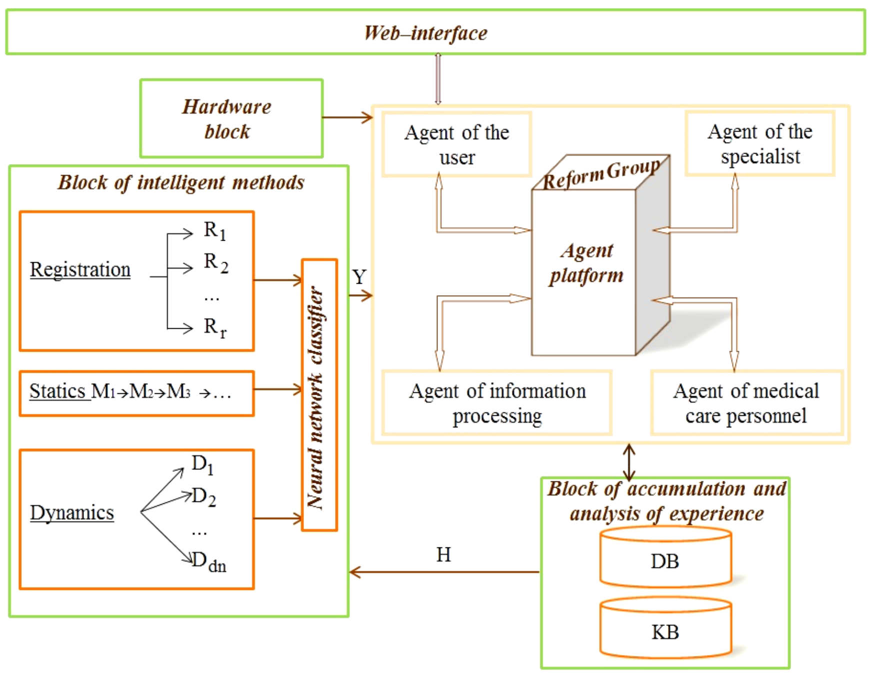


Fig. 4. Generalized model of multi-agent system of neural network of medical diagnostics and monitoring: R_i is the registration data; M_i are the tasks of processing the object images at rest; D_i are the tasks of processing the objects images in a state of motion; H is the matrix representation of the input data; Y is the set of classes; DB is the database, KB is the knowledge base

In a general form, the principle of MAS functioning for medical diagnostics and monitoring looks as follows.

A patient, who wants to consult a doctor and needs the services of a nurse (nurse's aid), etc., after registration on the medical Web-resource, receives a unique identifier and a special application is installed on his mobile device.

The sensors of the hardware block (measuring devices, cameras of video monitoring, photo cameras, etc.) perform monitoring of the state of a patient and transmit the information via Bluetooth to the mobile device. This device sends the received data to the "Agent of the user" A_{user}, which, in its turn, aggregates and converts indications from the devices to the form, suitable for further processing.

"Agent of information processing" A_{data} determines which tasks D_H, D_{Hr}, D_{Hst} and/or D_{Hdn} will be carried out in the block of intelligent methods, transmits/receives the information to the block of accumulation and analysis of information.

In the block of intelligent methods, the following tasks are solved:

– registration of the medical diagnostic information D_{Hr};

– processing of the images of objects at rest D_{Hst};

– processing of the images of objects in the state of motion D_{Hst};

– neural network classifier formulates a preliminary diagnosis and transmits the information to "Agent of specialist" A_{doctor}.

«Agent of specialist» A_{doctor} collects the information from «Agent of user» A_{user}, «Agent of medical care personnel» A_{nurse}, «Agent of data processing» A_{data}, administers treatment to a patient and gives instructions to «Agent of medical care personnel» A_{nurse}.

«Agent of medical care personnel» A_{nurse} exchanges information with «Agent of specialist» A_{doctor}, «Agent of data processing» A_{data} and sends orders to the patient, a nurse, a nurse's aid and relatives.

4. 1. Web-interface

For the generation of interaction between the users and the medical personnel by means of the Web-interface, the model of adaptation of the Internet-service was developed [9]. This model considers preferences of the users and makes it possible to automatically tune the content of the medical portal depending on the state of the environment or individual preferences of the user.

4. 2. The block of intelligent methods

The block of intelligent methods makes it possible to classify the medical-diagnostic information, received from the indications of biosensors, and based on the images of the examined object. An object can be both in motion and at rest [10].

The composition and the interrelation of the components of the block of intelligent methods Ξ is expressed as the conversion of the input values H to the output values Y:

$$\Xi \subset H \times Y, \qquad (1)$$

where H(i)is the matrix representation of the input data:

– medical-diagnostic information of measuring devices,

– the images, whose values of brightness of the elements are designated as h_{kj}, ($h_{kj}=\overline{0,255}$, $k=\overline{1,m}$, $j=\overline{1,n}$, $i=\overline{1,\tau}$) [11]; $Y=\{Y_1, Y_2, ..., Y_Q\}$, $(\gamma \subset Y)$ are the sets of classes.

Thus, the space (universum) $E = H \times Y$ includes $\Xi \subset (H \times \gamma)$, this means that there is the subset $H=\{H(1), H(2), ..., H(\tau)\}$, $H \subset H$ and the ratios between them, on which we built the model Ξ $(\Xi \subset \Sigma)$.

The flow of the input data, which consists of the set $H=\{H(1), H(2), ..., H(\tau)\}$, is classified due to the model Ξ with the assigned number of standard images N, to which the estimated object belongs.

For the output values Y, we built many tasks, the solution of which belongs to the set $D_H=\{D_{Hr}, D_{Hst}, D_{Hdn}\}$, where $D_{Hr}=\{R_1, R_2, ..., R_r\}$ is the problem of registering medical-diagnostic information (temperature, arterial pressure, pulse, etc.), $D_{Hst}=\{M_1, M_2, ..., M_{st}\}$ is the task of processing the objects images at rest (M_1 is the isolation of the area of interest, M_2 is the binarization, M_3 is the skeletonization, etc), $D_{Hdn}=\{D_1, D_2, ..., D_{dn}\}$ is the task of processing images of the objects in the state of motion (rectilinear, rotatory, progressive, uniformly accelerated and other forms). Reflection $\underline{T}: H \to Y$ allows finding for each $H(i)$ of such $Y_j \in Y$ ($j=\overline{1,Q}$, Q is the number of classes), which is the solution to the problem D_H.

The values $Y_j \in Y$ are used to form the final diagnosis with the help of the neural network classifier and determining the further tactics of behavior [12].

4. 3. The Agent block

The Agent block is represented by the following sets:

$$MAS = \{A, E, Org\}, \qquad (2)$$

where $A=\{A_{user}, A_{doctor}, A_{nurse}, A_{data}\}$ are the set of agents functioning in the medium E; E is the medium, which is a program platform for performing the agents and providing functionality for creating/deleting the agents, for applying intelligent methods and for receving/transmitting the messages.

Org is the Web-portal of the public health service, built on the basis of organizational model of the interaction of the agents [13, 14].

An organization consists of two aspects: structural and dynamic. The structural aspect of the organization includes groups and roles. The agents are organized into the interconnected groups, and the set of functions and their relations is determined for each role in the group. The dynamic aspect of the organization is connected to the established templates of interaction, determined by the roles.

For describing the structural part of the model, the three-level simulation Agent-Group-Role (AGR) is used, where the characteristic of the organization is at the upper level, the group characteristics are at the middle level, the role characteristics are at the lower level.

Fig. 5 presents the structure of the adaptive organizational model Org, which is intended to control the incident – detection and elimination of critical states of health of a patient.

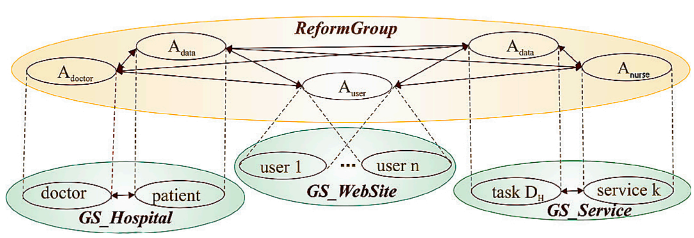


Fig. 5. Structure of adaptive organizational model of medical Internet-resource

The small ovals designate roles (Role), the large ovals designate groups (Group), the solid lines designate connections between the roles, and the dotted lines designate connections between the groups. The structure of the lower level depends on the specific area of application, in this case: *GS_Hospital* is the structural group of a medical organization, which consists of medical staff and patients; *GS_WebSite* is the structural group of users of the medical Web-site; *GS_Service* is the structural group that ensures implementation of intelligent methods and providing the services of a nurse, a sick-nurse, etc.

Another structure *ReformGroup* is the group of transformations (the upper level) that carries out adaptation of the organization and may be common for any type of application. The agents of this group perform adapting role, i. e., control the role, group and organizational characteristics.

In the case of managing an incident, the aspects will include: monitoring the state of health, formulation a diagnosis and medical aid. For the monitoring, the mechanism of "gradation" of the state of a patient is used, which defines ranges of the measured values, such as: cardiogram, blood pressure, the sugar level, the body temperature, etc., which are divided into the following levels of importance: critical (*Critical*), high (*Tall*), average (*Average*), low (*Lower*).

To describe the message exchange between the *agents*, we will use the following designations: A. send(B, m) – agent A sends a message m to agent B; roleIn(r, g) – role r is determined in group g; plays(A, r, g) – agent A plays role r in group g; GStruct(g, gs) – g is the group considered as an element of group structure gs; member(A, g) – agent A is a member of group g. The structural aspects of the model AGR are:

– every agent is a member of a group (at least one):

$$\forall A: Agent,\ \exists g: Group,\ \ member(A(i), g);$$

– every agent plays (at least one) role in the group:

$$\forall A: Agent,\ \forall g: Group \Rightarrow \exists r: Role,\ \ plays(A(i), r, g);$$

– agent is a member of the group, in which it performs a role:

$$\forall A: Agent,\ \forall g: Group,\ \forall r: Role,$$

$$plays(A(i), r, g) \Rightarrow member(A(i), g);$$

– a role is determined in the structure of the group:

$$\forall A: Agent,\ \forall g: Group,\ \forall r: Role,$$

$$plays(A(i), r, g) \Rightarrow \exists gs: GroupStructure \wedge$$
$$\wedge GStruct(g, GS) \wedge roleIn(r, GS).$$

For the expression of the correspondence between a patient of a medical organization and a user of the medical Web-site, we will use the expression:

$$role(patient, GS\_Hospital) \Rightarrow$$
$$\Rightarrow role(user, GS\_WebSite). \quad (3)$$

This constraint is determined as follows:

$$\forall A: Agent,\ \forall g: Group,$$

where groups $\exists g1, g2, g3: Group$ form

$$GroupStruct(g1, GS\_WebSite),$$

...

and `Group

$$GroupStruct(g3, GS\_Service)$$

are such, that

$$plays(A_{user}, user, g1) \Rightarrow plays(A_{data}, expert, g3) \vee$$
$$\vee plays(A_{doctor}, doctor, g2) \Rightarrow plays(A_{user}, patient, g2).$$

The agent of the Web-site consultant A(i) is activated when a consultant is a doctor in attendance at hospital:

$$role(consult, GS\_WebSite)$$

requires

$$role(doctor, GS\_Hospital) \vee role(expert, GS\_Service).$$

Its semantics is defined:

$$GStruct(g2, GS\_Hospital) \wedge GStruct(g3, GS\_Service),$$

$$plays(A_{doctor}, doctor, g2) \vee$$
$$\vee plays(A_{data}, expert, g3) \Rightarrow plays(A_{doctor}, consult, g1).$$

The agent of a user A_{user} turns for a medical service via sending a message to the agent of consultant A_{doctor}

$$\forall A_{user}, A_{doctor}: Agent,\ \ \forall m1: Message,$$

$$A_{user}.send(A_{doctor}, m1) \Rightarrow \exists g1: Group,$$

$$member(A_{user}, g1) \wedge member(A_{doctor}, g1).$$

The answer may be obtained in the form

$$\forall A_{user}, A_{doctor}, A_{data}: Agent,\ \ \forall m2, m3: Message,$$

$$A_{doctor}.send(A_{data}, m2) \Rightarrow \exists g2, g3: Group,$$

$$A_{data}.send(A_{user}, m3) \Rightarrow \exists g1, g3: Group,$$

$$member(A_{user}, g1) \wedge$$
$$\wedge member(A_{doctor}, g2) \wedge member(A_{data}, g3).$$

All the agents, which participate in the organization, perform the adapting role. The adaptability of the model lies in the flexibility of giving roles to the agents, but not in their changing.

4. 4. The block of information accumulation and analysis

The block of information accumulation and analysis includes the database (DB) of medical registration information and digital photographs, as well as the knowledge base (KB), which contains the output rules for formulation a diagnosis and the information, which is the result of accumulated experience. Besides performing operations of the same name, this block carries out back-up copying of data and their recovery. Prevention of ill-intended access is also implemented here.

5. Imitation simulation of a multi-agent system of neural network medical diagnostics and remote monitoring of a patient

For the simulation of the obtained theoretical results of the neural network diagnostics, the computer network Fast Ethernet with the physical topology "star" and the transmission speed of 100 Mbit was used, which consists of 10 four-nuclear processors Intel Core 2 Quad CPU Q8200 @2.33GHz with the videocard GeForce GTX 460. Multisequencing is performed with the help of the CUDA, OpenMP and MS MPI technologies in the programming language C++ in the operating system Microsoft Windows Compute Cluster Server 2003.

The initial data for conducting experimental studies were provided by the Institute of Dermatology and Venereology of the Academy of Sciences of Ukraine within the framework of the Agreement on Scientific and Technical Collaboration. The subject of the Agreement is the development of the system of differential diagnostics of skin diseases based on clinical criteria, clinical blood analysis and the data of humoral immunity.

A specific problem statement was implemented of the primary diagnostics of skin melanoma based on the data of questioning a patient and photographs of the sections of the skin lesions, with the following limitations:

– diagnosis of a patient may include not more than one disease (a patient is sick with one disease or is healthy). In the work, the subject area is skin diseases, namely, melanoma, nevus and lintigo;

– a patient is examined by a doctor from the moment of suspicion of the occurrence of the disease;

– to simplify the algorithm, the subtask of the search for the reason of disease is not considered.

In the process of consultation, a patient (possibly, remotedly) answers the questions, asked by a doctor. Based on the answers, the vector of questioning is formed, which, together with the result of the image processing, enters the input of the neural network for making a preliminary diagnosis. The mobile agent with the assigned periodicity sends messages, which contain reminder about the repeated photographing or the use of therapeutic and prophylactic preparations, about a control visit to a doctor, etc.

In the course of the experiments, the doctor at first was proposed to make a diagnosis independently, then with the use of the developed system (Table 1).

Table 1

Results of testing the developed system of medical neural network diagnostics of skin diseases

Nominal class	Number of examples	Diagnostics results					
		without the use of the system			with the use of the system		
		set diagnosis			set diagnosis		
		lentigo	nevus	melanoma	lentigo	nevus	melanoma
lentigo	50	40	7	3	44	4	2
nevus	50	2	41	7	3	45	2
melanoma	50	0	10	40	0	5	45

The most labor-consuming subtasks while making a diagnosis are processing the images of large dimensionality and training the neural network. Therefore, for accelerating the solution of these problems, the technologies of the parallel and distributed programming were used.

NVIDIA NPP-library was used for the images processing in the block of intelligent methods. The results of comparison of the time period of the images processing are given in Fig. 6.

For the analysis of the procedure of the parallel and distributed training of neural network on the multiprocessor system, a number of experiments were carried out The time of training the NS in the high-performance environment for the solution of the problem of diagnostics of skin melanoma is given in Table 2.

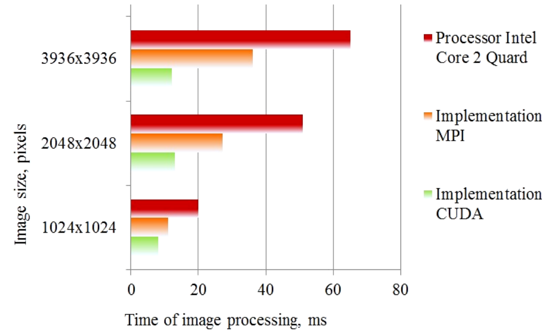


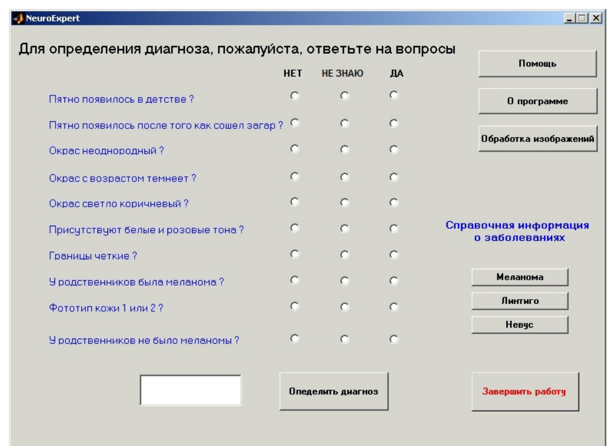
Fig. 6. Process of image processing based on sequential and parallel implementations

Table 2

Time of training of multilayer perceptron with different quantity of neurons of the input, hidden and output layers

Architecture of multilayer neural network	Quantity of processors MPI								Quantity of processors OpenMP		
	1	4	8	12	16	20	24	28	2	4	8
2500–120–28	923	279	202	149	130	120	123	130	504	280	183
4225–245–28	3613	1159	578	397	388	355	338	327	1959	1042	483
10000–455–28	5431	1025	508	377	353	337	322	310	2715	1180	705

The software for the mobile agent, carrying out remote monitring, is implemented on the platform .NET Framework with the use of language C# for the operating system Windows and Windows Mobile (Fig. 7).



a

b

Fig. 7. Screenshot of patients' interface for user: *a* — Windows 7; *b* — Windows Mobile

The personal digital software is installed on the personal digital device of a patient. It interacts with the sensors, attached to a patient, and receives the information from them for processing and subsequent sending to the central server.

6. Discussion of results of the imitation simulation

The clinical errors, connected with the variety of melanoma manifestations, in spite of the visual localization of a tumor, reach 25–40 % even with experienced dermatologists. With clinicians, who do not specialize in dermatology and oncology, the errors reach 50 %. Furthermore, almost 2/3 of doctors cannot diagnose dysplastic nevus, which is a melanoma predecessor that may be malignized (be regenerated in a malignant formation).

In the dermatological department of the Israeli hospital of Khadassa there is a laboratory of computer observation of birthmarks. When a patient applies there, the skin examination is carried out to detect the birthmarks, which are subject to observation. They are photographed with the help of a digital camera; the measurement of a diameter, area and color of a birthmark is also conducted. All these data are entered into computer database and saved there. The subsequent examinations are conducted once in half a year and their results are compared with the previous measurements. If necessary, biopsy is made.

The proposed system differs from the Israeli system in that it helps a doctor to make a diagnosis owing to the remote automatic control of changes in the skin formations. The testing showed that the developed system of medical diagnostics of skin formations makes it possible to increase the diagnostics accuracy by 9.3 %. Thus, the development of the models of early clinical diagnostics of primary tumor may improve the results of treating the patients with skin melanoma.

For images processing, the set of images of the size from 1024x1024 to 3936x3936 was used. The time of images processing does not depend on the image content, but only on the number of pixels. With the parallel implementation using the CUDA architecture, a different quantity of physical flows from 1 to 112 was involved. The performed experiments showed that the application of a graphic processor with the use of 112 flows considerably accelerates the process of images processing.

The analysis of Table 2 demonstrated that the technology MPI makes it possible to accelerate the distributed training of NS with structures 2500–120–28, 4225–245–28, 10000–455–28 by 7, 11 and 17 times, respectively, for the "star" topology of data transmissions. However, at a notable increase in the number of processors, the time of data transmission between them grows in the system. Therefore, upon reaching a certain increase in the productivity, further increase in the number of processors in the system leads to the opposite effect – the productivity begins to decline. The OpenMP standard makes it possible to accelerate parallel training of NS by up to 7 times.

Accelerated data processing will allow using the system of medical diagnostics and remote monitoring of the state of health of a person in real time.

7. Conclusions

The system of diagnostics of skin melanoma was developed on the basis of the vector of questioning a patient by a doctor and the images of the examined skin section, which will help a doctor to make a diagnosis at an early stage. The proposed system has the possibility of distance control of the changes in the observed skin formations in real time due to high-performance computing.

This system is implemented due to the proposed generalized model of the process of the neural network diagnostics and monitoring, in which machine training and agent technologies are combined. This combination allowed using the results of remote monitoring for making a diagnosis. The application of the totality of methods and the tools of collection, storage, processing, analysis and transmission of the video stream or a separate image, described in the model, may be used not only in tele-medicine, but also in the systems, in which it is expedient to register remotedly a change in the state of objects based on the analysis of their images.

The interaction of the components of the proposed model was implemented due to the designed multi-agent organizational structure. The aggregative levels were formed for this purpose. Dynamic distribution of the roles among the agents of the organizational model of the medical Internet-resource made it possible to adapt for managing such incidents as monitoring the state of health (control of the change in the dimensions of skin formation), making a diagnosis (melanoma/nevus/lentigo) and medical aid (recommendations on taking medicines).

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INFORMATION SYNTHESIS OF ADAPTIVE SYSTEM FOR VISUAL DIAGNOSTICS OF EMOTIONAL AND MENTAL STATE OF A PERSON

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Розглянуто процес візуального визначення емоційно-психічного стану, що базується на оцінці подібності лівопівкульного та правопівкульного портретів людини. Запропоновано метод аналізу подібності таких портретів за модифікованою ентропійною мірою Шеннона в рамках інформаційно-екстремальної інтелектуальної технології. Доведено, що запропонований метод дозволив зменшити поріг чутливості системи психодіагностування до зміни емоційно-психічного стану через визначення в процесі навчання оптимальних в інформаційному розумінні співвідношень RGB-складових зображень обличчя

Ключові слова: оптимізація, інформаційно-екстремальна інтелектуальна технологія, інформаційний критерій, психодіагностування, навчання, критерій функціональної ефективності

Рассмотрен процесс визуального определения эмоционально-психического состояния, который базируется на оценке сходства левополушарного и правополушарного портретов человека. Предложен метод анализа сходства таких портретов с использованием модифицированной энтропийной меры Шеннона в рамках информационно-экстремальной интеллектуальной технологии. Доказано, что предложенный метод позволил уменьшить порог чувствительности системы психодиагностики к изменению эмоционально-психического состояния путем определения в процессе обучения оптимальных в информационном смысле соотношений RGB-составляющих изображений лица

Ключевые слова: оптимизация, информационно-экстремальная интеллектуальная технология, информационный критерий, психодиагностирование, обучение, критерий функциональной эффективности

1. Introduction

As technogenic catastrophes are significantly influenced by the human factor, the actual problem is the evaluation in a monitoring mode of psychological and emotional state of operators of potentially dangerous plants and production facilities with the aim of determining their current functional state and the ability to continue performing their functions.