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Hardware-software complex for psychological and professional diagnostics with the remote control function

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Розроблено апаратно-програмний комплекс для вивчення швидкості реакції людини на світлові, колірні, звукові і тактильні подразники, що є складовою частиною єдиної інформаційно-вимірювальної і керуючої системи прийняття рішень в предметної області, що досліджує професійну придатність і психофізіологічний стан людини. Представлена UML діаграма, що описує поведінку і функціональні можливості користувачів апаратно-програмного комплексу, їх ролі в системі. Описаний набір методик психофізіологічного тестування з принципами реалізації кожної з них. Визначені функціональні можливості комплексу відносно якісної і кількісної діагностики психофізіологічних показників психічного стану, емоційної регуляції або наявності розладів центральної нервової системи. Представлена структурна схема комплексу, в якій детально описані її складові: мікроконтролер, Wi-Fi модуль, програмне забезпечення, виконавчі пристрої та інші. Наведена спрощена архітектура комплексу при роботі з IoT сервісом ThingSpeak з описанням основних компонентів. Розроблене програмне забезпечення дозволяє вимірювати час простої сенсомоторної реакції на світло і звук, час складної сенсомоторної реакції на світло, критичну частоту злиття світлових мигтіння, реакцію вибору, розрізнення, теппінгометрію в різних модифікаціях. Розроблено базу даних експериментів для зберігання і обробки інформації, яка забезпечує зручність вибірки і порівняння отриманих результатів. Для збільшення функціональних можливостей комплексу в його склад введені компоненти, що забезпечують можливість віддаленої автономної роботи з використанням хмарних серверів. Наведена лабораторна модель апаратної частини комплексу. Сформульовані основні переваги реалізації даного комплексу: якісна дистанційна психодіагностика, можливість дистанційного керування пристроями комплексу, зберігання даних на хмарному сервері.

Ключові слова: *психофізіологічний стан, професіональна придатність, час реакції на подразники, апаратно-програмний комплекс, мікроконтролер, IoT, хмарний сервер.*

The software-hardware complex for studying the speed of human response to light, color, sound and tactile stimuli, which is an integral part of a unified information-measuring and control system of decision-making in the area of diagnosing the professional fitness and psychophysiological state of a person has been developed. The simplified system architecture for working with IoT service ThingSpeak is provided. The developed software allows measuring the time of a simple sensorimotor reaction to light and sound, the time of a complex sensorimotor reaction to light, the critical frequency of fusion of light flashing, the choice of reaction, differentiation, teppingmetry in various modifications. The structural scheme of the system, namely, microcontroller, Wi-Fi module, software, executive devices and others has been presented. The database for storing and processing experimental information has been developed. To increase the functionality of the complex the additional components that provide the possibility of remote autonomous work using the cloud server services have been introduced.

Key words: *psychophysiological state, professional availability, response time to stimuli, hardware-software complex, microcontroller, IoT, cloud server.*

The widespread introduction of robotics and digital technology management is the current mainstream of the society development. But there are the areas where modern IT technologies are not used efficiently: the professional selection, the re-certification of employees, the psycho-diagnostics of employees, as well as, the formation of psychological portraits of athletes, operators of complex machinery and military personnel, including those serving in combat areas.

The usage of a modern computer and a microprocessor technology provides the new opportunities in conducting psychological diagnostics of a person or a group of people on all stages. Thanks to computerizing the process of storing and analyzing the observations, the likelihood of errors is reduced significantly.

The obvious advantage of using the computer tools for psychological and professional diagnostics is the speed of receiving, analyzing and interpreting primary received data, that in turn, positively affects the employment of experts - relieves them from the labor-intensive routine operations and allows them to focus on solving much more important professional tasks. The operational change and the modification of applied psychophysiological and personality tests allows us to build more adequate models of the subject's state with physiological, psychological and behavioral characteristics necessary

for the task implementation: professional selection, re-certification, psycho-diagnostics, rehabilitation, etc.

The usage of modern hardware and software provides extensive opportunities for remote diagnostic systems. This function, added to a device or a system, increases their professional and commercial attractiveness.

The purpose of this work is to create the hardware-software complex (HSC) for conducting psychodiagnostic and social studies, in particular to study the rate of human response to light, color, sound and tactile stimuli. HSC is an integral part of a unified information-measuring and control system of decision-making in the area of diagnosing professional competence, psychophysiological state of a person and psychological compatibility of people in a group.

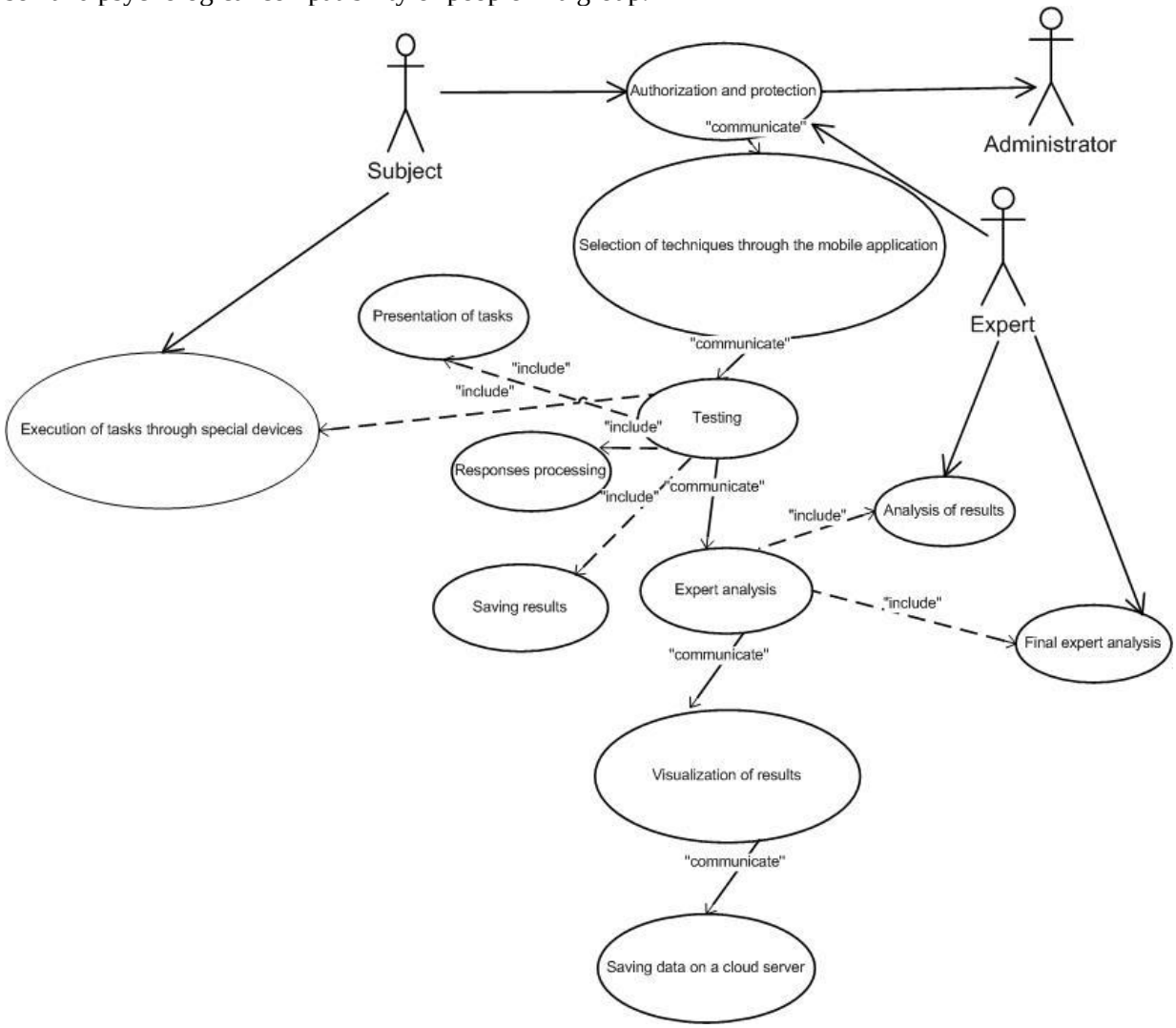

Fig. 1 Use Case Diagram of HSC

The UML diagram (use case diagram) describes the functionality and the behavior of the HSC at the conceptual level. (Fig.1)

1. The expert registered in the system is responsible for selecting, for each subject, the methods which are necessary and relevant to the purpose of the research, as well, as for analyzing of the results obtained during the study (primary expert analysis), producing the comprehensive conclusions using the results obtained through other methods (final expert analysis). Also, the expert has an access to all expert's analyzes stored in the system. The expert works through a mobile application developed by MIT AppInventor.

2. The subject registered in the system, applies selected methods by using the corresponding devices.

3. The administrator, which is responsible for authorization and protection of the network, has an access to all expert's analyzes stored in the system.

By using the system it is possible to measure the time of a simple sensorimotor reaction to light and sound, the time of complex sensomotor reaction to light, critical flicker-fusion frequency, choice reaction time, differentiation, typingomometry in various modifications.

The system allows:

• to determine the characteristics of the nervous system, stable characteristics of the mental state, individual style of activity, functional preparedness;

• to register the dynamics of changes in the mental state and efficiency in the process of performing functional loads;

• to establish the features of the mental state at a specific time: before the execution of the responsible task - the state of "combat readiness", premature "fever" or "apathy"; in the process of performing the task - adequate or excessive mobilization, manifestations of fatigue, mental supression;

• to quantitatively measure the psychomotor parameters of the processes of mental regulation, and based on that, to make a conclusion on the features of attention, volitional and emotional regulation;

• to qualitatively determine the presence of functional state disorder of the central nervous system.

The system is intended to use for scientific and practical research in such establishments as employment centers; educational establishments (including preschool); psychological centers; security, defence and law enforcement agencies; sport medicine.

The greatest diagnostic effect can be achieved with the dynamic monitoring of the same person for a long time. In this case, it is possible to compare the subject's current characteristics with their profile and timely identify the deviations. This is extremely important for testing employees of security, defence and law enforcement agencies and operators with a high degree of responsibility (dispatchers, drivers, etc.).

The working algorithms of the system are based on the following methods of psychophysiological testing [1, 2, 9]:

Simple visual reaction time

The method allows evaluating the functional state of the central nervous system. The functional level of the system, the stability of the reaction and the level of functionality reflect the excitability, lability and reactivity of the nervous system. The analysis of indexes makes possible to assess the stability of the central nervous system, the probability of errors, failures. Increase of the dispersion of physiological parameters, "instability" of physiological parameters in time is the earliest and most universal criterion of functional state disorder of the central nervous system.

Implementation of the method: The light signal is displayed at random intervals of the time. Subject is asked to respond as quickly as possible to its appearance by pressing the button. The interval of the time between the signal and the start of the response is the reaction time. The ratio of the reaction time to the signals of the excitatory (red) and the inhibitory (green) light reveals the balance of the nerve processes.

Choice Reaction Time.

An arbitrary sensorimotor choice reaction (or disjunctive reaction) is more complicated than a simple sensorimotor reaction and therefore is characterized by higher values of time. The complication of the reaction is connected, first of all, with the logical component - the decision making.

Implementation of the method: The subject is presented with several signals of different colors (it should be borne in mind that a potentially high concentration of attention models the psycho-emotional stress). The signal of each color needs to be reacted by pressing the corresponding color button. The time and accuracy of the performance of the sensorimotor selection reaction characterize stress tolerance and adaptation to changing environmental conditions.

Distinction Reaction Time

The method is intended for measuring of mobility of nervous processes in the central nervous system. A complex sensorimotor reaction, based on the differentiation of signals that are similar to the wave structure (for example, red and yellow). Increased mobilization of subject for rapid and accurate execution of the task provokes emotional tension. Therefore, good test results can serve as an indicator of tolerance to stress, indicating the balance of the processes of excitation and inhibition in the nervous system.

Implementation of the method: Two signals are presented to the subjects in random order in a short interval of time. In response to one signal, it is necessary to press the button quickly, and no action is necessary for the other signal. The dispersion, or variation, of the reaction time reflects the stability of the sensory-motor response.

Simple sound reaction time

This method is similar to the method of simple visual reaction time described above. The method also allows evaluating the functional state of the central nervous system.

Implementation of the technique: An audible signal is displayed at random intervals of time. It is suggested to respond as quickly as possible to its appearance by pressing the button. The interval between the signal and the start of the response is the reaction time.

The Finger-Tapping Test

It is used to evaluate the properties of the lability of the nervous system (the ability of the nerve cells to quickly move from the state of inhibition to breaking) and vice versa (to determine the speed capabilities of the motor analyzer). Test results can be used in assessing the strength of the nervous system, which is responsible for the working capacity of a person (according to E. I. Ilyin).

Implementation of the method: Subject is encouraged to press as many of the sensor key as possible during a given time interval.

Noise stability

It is the method of simple visual reaction time in the presence of dynamic obstacles. The level of noise stability testifies to the strength and balance of the nervous processes and serves as an integral indicator of the adaptive capacity of a person and his ability to resist the action of stimuli.

Implementation of the technique: The signal is presented to the subject on the computer monitor, against the background of signals of a different color, shape and size, which makes it difficult to quickly and accurately react to the given stimulus. Increasing the reaction time and the number of errors indicates the noise stability level.

Attention test

On the basis of the visual-motor reaction to the signal in the presence of the static obstacle, the concentration and stability of attention are determined. Human's attention is very sensitive to functional fatiguability and overwork. Using the bimanual version of the response to the light stimulus (by pressing two buttons with both hands simultaneously), we can obtain data on the predominance and working capacity of the right and left hemisphere.

Implementation of the technique: The signal is presented to subject on the computer monitor, against the background of external light stimuli. It is proposed to respond as quickly as possible to the appearance of a signal by pressing the buttons of the visual-motor analyzer.

Evaluation of Critical Flicker-Fusion Frequency

The method is widely used for diagnostics of pathological processes of the visual system, for determining the degree of fatiguability of the eyes, as well as for conducting a medical and social examination of the visually impaired. This technique describes the functional state of the cortical department of the visual analyzer and the central nervous system (CNS), as well as the degree of inertness of mental processes. This is a very important integral indicator in the assessment of psycho-emotional stress, which, in turn, is a factor in psycho-physiological disadaptation.

Implementation of the method: Depending on the objectives and tasks of the diagnosis, a flashing light signal is presented to subject, differentiated on the right and left eye, using a tube, or simultaneously on both eyes, using a visual-motor analyzer. Stimulus may be red, green or other colors. The flicker frequency increases and decreases. The moments of continuous luminescence and the appearance of flickering are fixed by the subject by pressing on the corresponding button.

Dynamometer test

The test is used to assess static muscular endurance, which is a vital part of any muscular activity. Depending on the purpose it can determine the maximum muscle strength of the hands, motor asymmetry, muscular endurance with the estimation of vegetative changes.

Implementation of the method: The subject is supposed to squeeze the spring of the dynamometer as strong as possible and to hold a given muscular effort within a certain time interval, which is calculated as a percentage of the maximum. The quality of the test task and the feedback results are precisely determined by the method. The implementation of the method includes the visual and acoustic control of the task execution.

There are some other methods of psychophysiological testing which are to be implemented further.

Fig. 2 shows the structural scheme of the system. The central part of the system is the powerful 32-bit microcontroller of the STM32F4 series with ARM Cortex-M4F core from STMicroelectronics, which controls the hardware part of the system - the wide range of sensors and actuating devices. To the controller are connected a keyboard, alphanumeric or graphic indicator and actuating electronic devices,

namely LEDs of different colors, speakers, relay tactile stimuli. Other devices are planned to be included in the future. The software consists of a microcontroller program, a data exchange driver, a database, a user interface. The expert system and other software solutions are expected to be developed later.

Reaction time data are fed to the computer complex (PC) through one of the interfaces, USB or WiFi, where they are processed by general and special software (Software).

The structure of the HSC includes a miniature WiFi module based on ESP8266 chipset with built-in TCP / IP protocol stack and AT command control. The ESP8266 chip is a versatile and costly solution for organizing a Wi-Fi network node that is responsible for handling all of the network's data exchange functions in embedded applications. ESP8266 has good built-in capabilities for pre-processing data and I / O ports connecting it to APCs that require network data sharing.

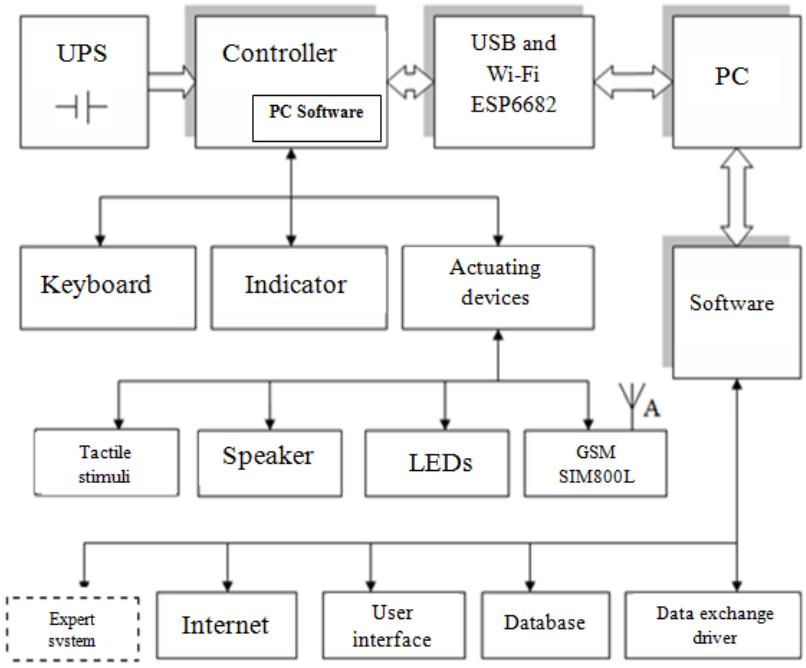

Fig.2 The block diagram of the system.

For stand-alone work, including remote operation of the equipment, the scheme includes the GSM module on the chip SIM800L, which allows conducting field studies where the only mobile communication is present. Data transfer, (to the cloud service ThingSpeak, for example) is carried out through the GSM module in the packet data mode.

Fig. 3 shows simplified architecture of the system, when working with the IoT ThingSpeak service, the main components of which are following:

• The Data and Local Control Controller, which pre-processes data from sensors and actuators, sends them to the Internet-server ThingSpeak.com Status Channel and accepts command-line commands for the ThingSpeak.com Actuator Channels;

• ThingSpeak services available on thingspeak.com include paid and free channels [8, 12]. The difference of free channels from paid ones is in the frequency of recording in the site database. For free channels, the recording period is limited to 15 seconds. Data collection is accompanied by a timestamp and coordinates. Visualization of data can be obtained using a variety of plug-ins and graphic resources provided by the embedded MatLab system;

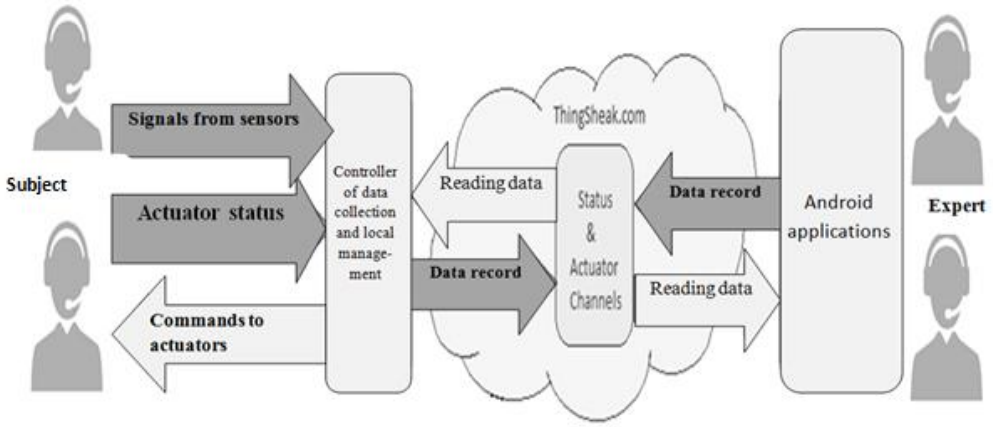

Fig.3 The architecture of the software platform of the system.

• The Android application or any other remote application requests data from the web server and displays them on the smartphone screen.

To create a local database, Microsoft Office Access product is used. It has been chosen because this database management system holds a strong position in the modern world of information technology and widely recognized as a simple and effective software solution. The version used (MS Access 2003) supports a variety of programming tools from traditional ODBC and SQL to the latest ActiveX Data Objects object protocols.

Based on the task, the database tables have been designed to provide for convenient sampling and comparing the obtained results. Moreover it provides for the possible increase in the amount of saved data, as well as, scaling the database itself.

The main menu has a simple and clear set of control elements. At the top, there is a list that prompts choosing the study to view or add data. In order to begin filling data, you must select the study to which these data will belong to. The user will be presented with the window to add the results of the experiment.

Fig.4 The hardware part of the laboratory model of the system

CONCLUSIONS

Modern information technologies and the elemental basis of programmable electronics provide new opportunities for the creation of hardware and software systems for psychophysical research. In this work, a structural model has been developed and an active laboratory model of HSC has been build. The distinctive feature of this model is that it gives the subjects and the experts the possibility of the remote and autonomous work. The new architecture of the complex corresponds to the concept of "Internet of Things". The UML usage diagram describes the business tasks and user interactions.

The structural scheme of the system presents the principles of interaction and operation of such components as the controller microcontroller STM32F4, the WiFi module based on the chip of the ESP8266, GSM module SIM800L, general and special software, database and other hardware-software components.

The advantages of this system are not only high-quality remote psychodiagnosis, but also the ability to control the external devices of the system remotely, as well as, cloud data storage by using one of the Web services.

Realized basic functions of the system allow making a qualitative and quantitative assessment of the subject's psychophysical parameters. For a better diagnostic effect, we have carefully selected and embedded the techniques of psychodiagnostics which allow determining the nervous system properties to study the features of the mental state and to detect disturbances of the functional state of the central nervous system.

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