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The System For Managing The Training Of Medical Specialists On The Basis Of Simulation Centers

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Abstract

Various simulators and training equipment of various realisms levels are used to test the level of practical medical skills development in the conditions of a simulation center. The goal of the works described in the article is to create an information system that allows to automate the entire process of preparing and conducting simulation training as much as possible, as well as to create conditions for increasing the objectivity of assessing the actions of the student. Assessment of implementation of practical skills consists of the expert assessment and readings of the simulation equipment. Objectivity of assessment can be achieved through creation of vehicles and mechanisms of control with transparent numerical parameters. Besides, vehicles and mechanisms for the analysis of results must be provided in the system in order to achieve transparency of assessment, for which the readings of the simulation equipment and the expert's actions should be recorded in the course of training as detailed as possible, and the student's actions should be recorded on the video. All developed tools and systems make no sense without implementation of the simplest operations for registering trainees, managing resources and scheduling the simulation center in the system. Ultimately, the implementation of the developed system has led to a substantial increase in the objectivity of assessment, reduction in the workload on staff and experts of the simulation center, as well as their concentration on the process of study rather than on solving routine tasks and problems indirectly related to the training process. The developed system can be used as a platform for developing and testing assessment and training methods, as well as introducing new simulation technology.

Key words: checklist, checklist constructor, video recording, video grabbing, RTSP, REST API, medical simulator, C++, Qt, reverse Polish notation, error statistics, debriefing, simulation center.

INTRODUCTION

There are simulation centers for the practical training of medical professionals. These centers are clinics with medical simulators and standardized patients. The centers face the following challenges during training:

- discrepancy between the number of practicing experts and the number of students;
- ensuring objectivity of assessment by various experts in various conditions;
- arranging debriefing with participation of experts;
- accounting and planning of resources required for conducting classes.

An information system for managing the simulation center is created to solve these problems.

In medicine, like in many other branches, formation of practical skills and bringing their implementation to automatism is an important aspect of specialist training. Meanwhile, testing skills on real patients in the process of doctor and medical personnel training before they get a degree is unacceptable from the moral and ethical point of view and is banned at the legislative level in many countries. Many skills technically cannot be mastered in practice – for example, emergency assistance in a situation where there is a threat to the patient's life. In this case, the cost of error is too high, and it is impossible to admit the unprepared student to the patient on the verge of life and death. Objective control and evaluation of performance play the primary role in the process of mastering the skill.

The challenge of impossibility of training on real patients is solved thanks to technology that can replace a patient: medical simulators and standardized patients (the role of a patient is performed by an actor). With all the variety of medical simulators with various levels of realism, there remains a problem of the objectivity of assessment of the skill performed by a student on particular training equipment. This is due to the fact that no simulator is able to recognize and assess all student's actions, i.e. the simulator has some finite list of its states and manipulations that can be made with it, while the number of students potentially possible actions is not limited at all. This is why an expert necessarily takes part in the skill assessment, which indicates that it is impossible to exclude the human factor from the system of assessing the implementation of practical skills in the provision of medical assistance, which is why the question of objectivity of assessment is acute.

The human body is a very complex and not fully explored system, due to which the provision of medical assistance can hardly be standardized and controlled. The objective assessment of the professional level of medical specialists can be achieved by using numerical parameters for assessing the performance of appropriate actions in the process of modeling the clinical situation. A set of numerical parameters can be built on the basis of mechanical, electronic and computer models [1].

Reliability of assessment can be verified by testing the temporary stability of examination, i.e. by measuring the probability of the student receiving the same grade for several repeated examinations taken by the same student on the basis of the Pearson correlation [2]. The grade should also be stable when being given by various experts to the same student, which can be measured using Cohen's kappa [3]. Aside from the above criteria, the results of passing the examination by better trained students should exceed the results of less experienced students, which can be measured using Cronbach's α coefficient [4].

Checklists are used in practice to achieve objectivity of the expert assessment. A checklist or an expert control sheet is a detailed list of actions that correspond to the skill execution algorithm. Objectivity of assessment depends on the detailed checklist: the more detailed the actions of the algorithm in the checklist, the higher the objectivity of the obtained assessment [5]. The detailed checklist allows not to distract practicing experts from their primary activities and to make an objective assessment of the correctness of the actions in the checklist by almost any specialist in the field. The checklist cannot be developed without the involvement of a practicing professional who provides assistance to real patients. The checklist is created based on the standards and algorithms for providing medical assistance for a certain skill.

Besides, the cases should be reviewed from time to time in order to improve objectivity and quality of assessment of professional skills and improve the student's level of training. The student can refer to the expert for clarifications about the grade received, which necessitates to review the examination process, analyze the completed checklist and the simulator readings. Besides, the analysis can be conducted by a team of experts to assess the actions of a particular student or an expert. Scenarios and recommendations for conducting analysis for various skills are discussed in detail in [6].

Major components of an objective assessment of the professional skills of medical specialists are expert assessment and simulator assessment. As such, there are four main tasks of the system under development:

1. interpretation of the readings of the simulation equipment in order to obtain a numerical estimate;
2. provision of tools for creation, verification and use of checklists resulting in the formation of a numerical estimate of skills
3. formation of the final assessment by combining estimates obtained on the basis of the simulator readings and the results of the checklist filled by the expert;
4. provision of technology and tools for debriefing.

Aside from the main tasks, the system should also solve the tasks of managing the training and assessment process: registration and accounting of the students and their results; accounting for consumables for classes; accounting for the workload of premises, simulators and personnel; scheduling.

These goals were achieved as a result of the development of the simulation center control system.

METHODS

To arrange efficient control of the simulation center and control of the implementation of practical medical skills, a simulation center control system was developed in the work, the architecture of which is presented in Figure 1.

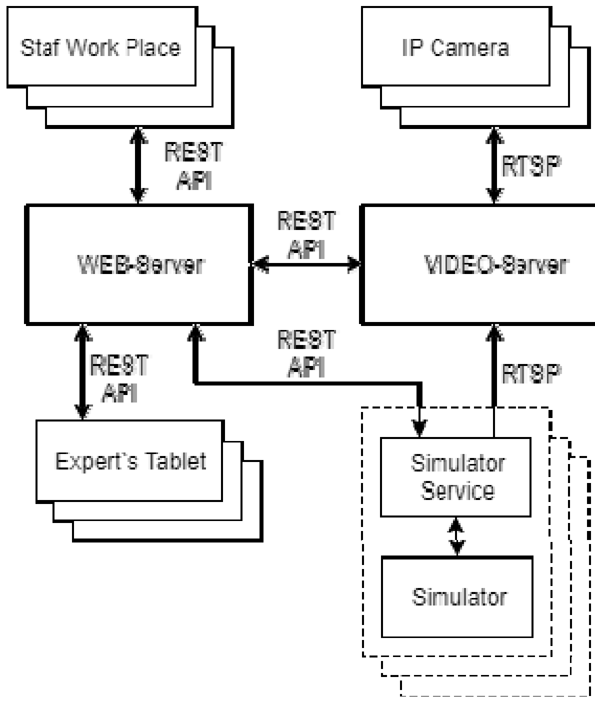

Figure 1 – Architecture of the simulation center control system

Interpretation of the readings of the simulation equipment in order to obtain a numerical estimate

To interpret the simulator results of training, they must first be obtained. Unfortunately, there are no unified protocols for data transfer from simulation equipment supported by manufacturers to date. Most medical simulators are a black box controlled by the simulator software. When developing a simulation center control system, this problem was solved for each simulator separately. For some simulators, it was sufficient to create a connection to its database (MySQL, SQLite, MS SQL Server, MS Access or PostgreSQL) and obtain data from it using SQL queries. Of course, it was required to study the structure of the database and enter the necessary queries in this case. Some simulators store data in the file system in the files of various text or binary formats. Obtaining these data necessitated the study of the file format and creation of a system for reading and writing data that did not interfere with the work of the simulator software.

Aside from obtaining the results of the skill implementation from simulators, it was necessary to solve the problem of identifying these results and comparing them with a specific student. Comparison is required in order not to assign the results of one student to another. This problem is solved in various ways on different simulators. The simulators, the software of which supports the internal user system, receive list of students from the control system before training. The result is linked to a specific student already inside the simulator software. For a double check, the results are also bound to time and compared with the moment of passing the examination by the student. In the simulators that do not support the internal user system, the results are identified only in time. A single NTP time server is used to synchronize the time between simulators, system servers and expert equipment [13].

A service and a protocol for integrating the simulation equipment were developed to control the data flow between the control system and simulators [7].

Interpretation of the simulator assessment can also differ depending on the obtained data and is split into two levels:

1. At the level of the simulation equipment integration service;
2. At the server level of the simulation center control system.

Interpretation at the service level is required for serious mathematical processing of data flows. For example, the simulator delivers readings of its state throughout the class at a given sampling interval – for example, the depth of the chest compression. It is required to calculate the number of compressions using these data, as well as the average depth, frequency and number of compressions between interruptions for artificial lung ventilation. Raw data sets are processed in the system in order to obtain specific numerical values at the level of the integration service of the simulation equipment.

At the server level, the control system recalculates the readings received from the simulator into a single assessment system using custom mathematical formulas. Sometimes simple translation of the simulator results from its rating scale into the system assessment scale is sufficient. Results can be translated from the simulator scale to the system scale in the simplest case using the simple formula (1).

$$B = b * \frac{s}{S}, \quad (1)$$

where:

B is system assessment;

b is simulator assessment;

s is an upper bound of the simulator assessment scale;

S is an upper bound of the system assessment scale.

If the simulator does not provide final assessment but rather allows to get a certain set of parameters that allows to assess the influence of the student on the state of the simulator, it is required to estimate the degree of influence of each parameter on the total assessment. A system of weights and conditions is specified in order to take the influence of each parameter into account.

For example, the calculation of the assessment from the data obtained from the simulator for cardiopulmonary resuscitation consists of nine parameters: the number of adequate compressions in frequency, depth, relaxation and position of hands; air flow rate at artificial lung ventilation; duration of ventilation; total time without compression, and other parameters. At the same time, a threshold value can be imposed on each parameter, below which the result is not accepted and the examination is not passed.

All formulas are available for editing by the administrator of the control system. A reverse Polish notation (RPN) is used for the calculation of the formulas entered [8]. The Dijkstra's algorithm is used to translate formulas into RPN [9].

Initial weights for various parameters are selected by a practicing expert based on the importance of each parameter in order to achieve a positive effect from the provision of appropriate medical assistance. After obtaining a sufficient amount of statistical data, the weights can be refined by applying the methods for testing the assessment stability.

Provision of tools for creation, verification and use of checklists, which are filled out to form a numerical assessment of skills.

Paper checklists or spreadsheets can be used in the simplest case to check practical medical skills. The disadvantages of this approach are obvious:

1. Lack of a unified database of results, which causes difficulties in combining the results of video recording with the expert and simulator assessment;
2. Challenges of the debriefing as a consequence of the first clause;
3. High complexity in checking the checklists to achieve objectivity in assessment;
4. Problem of providing new versions of checklists to experts.

The system provides a checklist constructor and expert software that allows to automatically download checklists created in the constructor, depending on the tested skill, to solve these problems. The expert application also sends the results of filling out the checklist for a particular student of the control system server, from where they fall into a unified database of results.

The checklist constructor is implemented as an application created in the C++ programming language using the Qt 5 library. This application is compiled for the following operating systems: Windows, Linux, Mac Os X and Android. The constructor allows to create checklists in two formats:

- Tree-type checklist;
- Functional checklist.

The essence of the tree-type checklist consists in the tree-type structure of arrangement of checklist items, which allows to break items of knowledge and skill assessment into the stages of performing a professional skill with varying degrees of specification. An example of a tree-type checklist for assessing the skill of an intravenous injection is as shown in Figure 2.

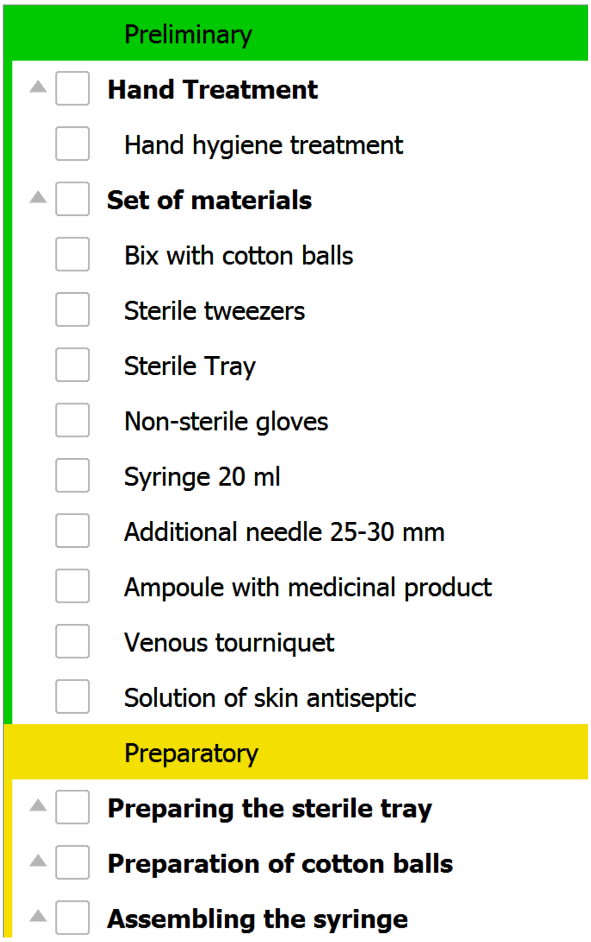

Figure 2 – Look of the tree-type checklist

Figure 3 – Look of the functional checklist

When a tree-type checklist is formed, each tree leaf (a descendant-free element is called a tree leaf) is assigned a penalty points, which are a non-negative integer. The penalty points are assigned to the student in case of failure or incorrect performance of the corresponding action. The tree-type structure also ensures the convenience and performance of the teacher dealing with knowledge assessment, because if all the actions of a stage are properly performed, it is sufficient to mark the successful completion of the entire stage. The same applies to the failure or incorrect performance of the entire stage – it is sufficient to mark the failure to perform the stage, after which the penalty points for all skills of this stage will be credited. This mechanism is necessary because detailed specification of the checklist is required to assess the correctness of the intravenous injection provided in the example, i.e. the number of the assessed actions exceeds 200.

The essence of the functional checklist consists in modeling the non-linear order of the skill performance. The nonlinearity of the performance order is determined by the presence of cycles and conditions. The structure of such a checklist consists of blocks of function buttons corresponding to certain points of knowledge and skills assessment. An example of a functional checklist for assessing the knowledge of the basics of cardiopulmonary resuscitation in the provision of first aid is shown in Figure 3.

The functional checklist includes 2 types of buttons: group buttons (of square shape in Figure 3) and indicators (of circular shape in Figure 3). The purpose of indicators is the same as that of tree leaves in a tree-type checklist, i.e. the indicator can be in two states: the action is performed correctly, the action is not performed or performed incorrectly. Indicators are also assigned penalty points. Assignment of the same group buttons is reduced to the fact that they are blocks of indicators, and when the group button is activated, all the indicators related to it are displayed in the program window with the checklist.

The group buttons can also contain other group buttons in analogy with tree tops. Unlike the tree-type checklist, the final score in the functional checklist is calculated not by summing up all the penalty points scored by the student, but rather using the formulas set for the group buttons.

As such, the system allows to create and edit checklists from a single center, after which they will automatically be available to all experts for assessment through the expert software. The expert program is implemented in the C++ programming language using the Qt library and compiled for OS Windows and Android OS version 4.2 or higher. As such, the expert can use either a personal computer, laptop, or a tablet running OS Android or OS Windows to work with the checklist.

A formula for calculating scores must be specified in the constructor for each group button, which can include indicators related to this group button and other group buttons, time allotted for the performance of the action set corresponding to the group button, and the actual time spent by the student to perform the specified action set. The final score is defined as the sum of the calculated values of all the group buttons and the upper level indicators, i.e. the ones that do not belong to any group button. Besides, the number of execution cycles can be assigned for group buttons, i.e. the same indicators can be counted several times in the assessment of some repetitive actions during the test. For example, the correct position of hands when performing compression for cardiopulmonary resuscitation should be assessed for each compression cycle.

The estimated value of the group button is accumulated each time the action cycle is executed and is further taken into consideration when calculating the total number of penalty points in the absence of parent group buttons or in calculating the value of the parent group button.

Instead of text descriptions of actions in the functional checklist, icons can be used containing text or graphics that uniquely identify the corresponding action, which attributes another advantage to the functional checklist – that all indicators and group buttons can be placed within the scope of the screen, which eliminates the need to scroll through the electronic checklist to find an item corresponding to the action under assessment.

Formation of the final assessment by combining the estimates obtained on the basis of the simulator data and the results of the checklist filled out by the expert.

It is required to determine the degree of influence of both estimates on the final result in order to combine the expert assessment in the form of a filled-out checklist with the simulator estimate. It is necessary to determine the percentage of the final assessment contributed by the expert using a checklist and that of a simulator. For instance, when performing cardiopulmonary resuscitation, 60% of the assessment is contributed by the simulator, while 40% is contributed by the expert. In this case, both estimates must be in a unified system scale, and if it is not so, they must be brought to a unified scale according to formula (1). As a result, the final assessment of the cardiopulmonary resuscitation will be described by formula (2).

$O = O_s * 0.6 + O_e * 0.4$, (2)

where:

O is assessment of the skill performance;

O_S *is simulator assessment;*

O_E *is expert assessment.*

For different skills and simulators, the contribution of the simulator and expert assessment can vary greatly. For example, to assess the skills of laparoscopy, the role of the expert is only to check the presence of gloves, correctness of the tools holding and the absence of deliberately wrong actions (dropping the tool to the floor), but the expert assessment will play a big role in the final assessment of the skill performance, because they check critical points, in case of non-observance of which the operation cannot happen (hand treatment, putting on sterile gloves, etc.).

Providing technology and tools for debriefing

The review of the examination results is an integral part of training a medical specialist. The review pursues two main goals: to point out the mistakes the student has made with the aim of preventing them in the future; and to check the correctness of the expert assessment. A certain set of data is needed for a qualitative debriefing:

1. checklist filled out by the expert with the recorded time of marking each item relative to the beginning of the examination;
2. results obtained from the simulator;
3. simulator and expert assessment, as well as the final assessment;
4. time-synchronized video recordings of the examination process from one or more surveillance cameras, as well as the simulator screen (if technically possible);

The expert application and the integration service of the simulation equipment are connected to the control system server through the REST API interface, within which the protocol of data exchange with the simulation equipment and the protocol of data transfer between the expert application and the system server are implemented. The results of the simulator and the checklist filled out by the teacher are linked to the student and are stored in the control system database. The simulator assessment and the final assessment of the skill performance are calculated and stored in the system automatically as the data required for their calculation are received.

Video recording of the examination is performed by a separate video recording server that receives streaming video through the RTSP protocol [10] and saves it to MPEG-4 files [11]. IP cameras of any models and manufacturers that support the RTSP protocol are sources of the video stream. Besides, a video capture service is used to capture video from the simulator screens, which is a RTSP server that streams video from the simulator screen. The task of mapping an examination video to a specific student is solved at the system server level in the following way: the system database contains information about network addresses of IP cameras and simulators, as well as the location of cameras in specific premises of the center. During the examination planning, a list of involved premises and location of simulators and experts in the premises are determined. At the beginning of examination for a particular student, the system server receives a signal from the expert application and automatically detects premises, simulator and cameras involved in the examination of a particular student. As such, the video recording server obtains information about which video sources are involved in the examination through the REST API interface and records video from them. To achieve synchronicity of video recordings from different sources, recording starts simultaneously once the connection with all video devices is established. If any of the devices cannot connect, the video from it is not recorded. At the end of the exam, the video recording server sends the control system server the paths to the obtained video files in the general video archive through the REST API interface.

It is sufficient to find the results of the particular student among the examination results by searching in order to access the results obtained. The system allows to view assessments, results obtained from the simulator, completed checklist and video recording of the process of the skill performance.

RESULTS

As a result of the work, the simulation center control system was created. This system was successfully introduced into the educational and virtual complex Mentor Medicus of the Sechenov First Moscow Medical University. The following results were obtained during the development and introduction of the system:

1. The technology of integration of the simulation equipment and methods of interpretation of the results obtained from simulators was created;
2. The checklist constructor and expert software to fill them out were created;
3. The mechanism for combining the results of the simulation equipment and the expert to form a final assessment of the skill performance was developed and implemented;
4. Tools that allow to review the results from video recordings, expert assessments and results from simulation equipment were implemented;

The developed system also allows to manage the resources and the process of training and assessment: a subsystem of submission and approval of applications for training; a subsystem for accounting resources of the simulation center; a subsystem of maintaining the schedule of the center operation; and a reporting subsystem are implemented. The developed subsystems are quite simple and do not need a detailed description, but a full control of the simulation center is impossible without them.

DISCUSSION

The results obtained during the creation of the simulation center control system allowed to achieve a high level of the assessment objectivity and ensure its transparency. The system revealed its efficiency during real operation in the simulation center Mentor Medicus of the Sechenov University. The time for preparing and conducting examination has been significantly reduced due to the efficient management of the center resources, automatic scheduling and transfer of information about students to the simulation equipment. Training programs and checklists have been improved thanks to the emergence of new tools for collecting results and their statistical analysis. The time for debriefing has decreased tens of times, because a huge amount of time was previously spent searching for the completed checklist, results in the simulator software and video from the general video surveillance system.

Besides, as a result of the system introduction, it was possible to reduce the burden on practicing experts due to the detailed study of checklists, which allowed to verify the skill performance by any specialists from the field. Besides, reduction in the time spent preparing and conducting the examination due to reduced non-production costs (routine operations automated by the developed system) led to an increase in the satisfaction of the employees of the simulation center by their work.

The system created is not unique in its kind. To date, there are simulation center control systems. The most famous are Learning Space and SimulationIQ. The difference of the developed system is that it has flexible mechanisms for creating checklists and interpreting the results of the simulation equipment to obtain the final assessment. In other words, the system fully takes on the task of assessing the skill performance. Besides, the created system supports any IP cameras supporting the RTSP streaming video protocol, while the systems under consideration are supplied with cameras of specific models and manufacturers. The developed system also has advantages in the depth of integration with the simulation equipment, as it allows not only to capture video from screens and obtain numerical data but also to send information about the students to the simulator software. Besides, the provided solutions are very expensive and almost unaffordable in the Russian market. So far, the Learning Space system is installed only in one simulation center of Russia.

To date, the system supports integration with the following list of simulation equipment:

- Tele-Mentor (tele-mentor.ru),
- Resusci Anne (laerdal.com/us/products/simulation-training/resuscitation-training/resusci-anne-qcpr/),
- BT-CPEA (btinc.co.kr/eng/sub/sub02_02.php?cat_no=2&idx=2&pageMode=view);
- Lap Mentor (simbionix.com/simulators/lap-mentor);
- Lap X (http://www.medical-x.com/products/lap_x/);
- Lap Sim (http://sim-era.com/product_details/531);
- CAE iStan (https://caehealthcare.com/patient-simulation/istan);
- CAE Lucina (https://caehealthcare.com/patient-simulation/lucina);
- CAE PediaSIM (https://caehealthcare.com/patient-simulation/pediasim);
- CAE BabySIM (https://caehealthcare.com/patient-simulation/babysim).

As the system is introduced into various simulation centers, it is planned to integrate new simulators for various purposes into the control system in the future. Besides, it is planned to further develop the capacity of the system to reduce the burden on experts and teachers. To do so, it is planned to add the functions of automatic control over the actions of the student in the skill performance to the system. Some actions can be checked by the system automatically using speech recognition and computer vision algorithms. The research is already underway.

CONCLUSION

As a result of the work, the task to increase the degree of automating the formation and control of practical skills in the training of medical professionals on the basis of simulation centers has been solved. Tools and prerequisites have been created to continuously improve the objectivity of assessing the implementation of practical skills and improving teaching methods.

The developed system can be a platform for testing both technical and methodical solutions in the field of simulation training.

The urgency of the performed work is determined by the absence of a domestic simulation training control system in Russia that would cover the control of all the processes of the simulation center, while the purchase and introduction of foreign analogues are inexpedient due to the limited range of tasks solved and high costs.

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REFERENCES

[1] Gorshkov M.D., Andreenko A.A., Ershov E.N., Lakhin R.E., Makarenko E.P. and Schegolev A.V. (2016). Obyektivnaya otsenka urovnya professionalnogo masterstva. Spetsialist meditsinskogo simulyatsionnogo obucheniya [Objective assessment of the level of professional skills. Specialist in the medical simulation training]. Moscow: ROSOMED, pp. 154-192.

[2] Pearson K. (20 June 1895) "Notes on regression and inheritance in the case of two parents," Proceedings of the Royal Society of London, 58: 240–242.

[3] Cohen, Jacob (1960). "A coefficient of agreement for nominal scales". Educational and Psychological Measurement. 20 (1): 37–46.

[4] Lee J. C. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16, 297-334

[5] Morgan, P. J., Cleave-Hogg, D., DeSousa, S. and Tarshis, J. (2004). High-®delity patient simulation: validation of performance checklists. British Journal of Anaesthesia 92 (3): 388-92

[6] Howard, Z., Siegelman, J., Guterman, E., Hayden, E. M. and Gordon, J.A. (2011). SIMULATION CASEBOOK. Cambridge: Harvard Medical School

[7] Svistunov, A. A., Gribkov, D. M., Smirnov, S. S., Sytnik, D. A. and Kolysh, A. L. (2016) Integration of Medical Simulation Equipment into Unified Data System. Journal of Theoretical and Applied Information Technology, 92(1): 81-89.

[8] Pratt, T. W. and Zelkowitz, M. V. (2002). Programming Languages: Design and Implementation. 4 ed. St. Petersburg: Piter, pp. 688.

[9] Dijkstra E. W. (1959). A note on two problems in connexion with graphs. Numer. Math — Springer Science+Business Media, 1(1): 269–271.

[10] Real Time Streaming Protocol (RTSP). (n. d.). https://tools.ietf.org/html/rfc2326 (access date: 14.07.2017).

[11] MPEG-4. Moving Picture Experts Group.(n. d.). http://mpeg.chiariglione.org/standards/mpeg-4 (access date: 14.07.2017).

[12] NTP: The Network Time Protocol. http://www.ntp.org (access date: 03.07.2017).