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# Intelligent Expert System of Knowledge Examination of Medical Staff Regarding Infections Associated with the Provision of Medical Care

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**Abstract.** The use of intellectual recommender systems, based on the analysis of the questionnaire of medical workers, generates the rules for their education and detects gaps in knowledge, will allow to effectively solve the issues of prevention of IRMC, which will lead to a decrease in morbidity. The aim of the study is to create a software package that allows for an automated assessment of the knowledge of nursing staff on the prevention of hand hygiene in the performance of professional duties. With the help of the developed program complex, 817 paramedical medical personnel of medical institutions of the Kharkiv region were surveyed. Results are statistically processed. Dependencies of knowledge and skills of medical personnel have been established.

**Keywords:** expert system, knowledge assessment, infections related to medical care.

## 1 Introduction

Infections related to medical care (IRMC) cause negative health and social consequences and significant economic losses for patients and health systems around the world [1]. At the same time, good hand hygiene at the right time and in the right way can save the lives of many people [2]. Accurate compliance with the rules of hand hygiene is recommended for the prevention of all IRMC [3].

The management of health care institutions is responsible for ensuring the prevention and control of IRMC cases and the prevention of transmission of epidemiologically important pathogens [4]. Medical professionals who are directly involved in the provision of medical care to patients (for example, doctors and nurses), as well as support staff are responsible for the continued use of IRMC prevention and control practices, including hand hygiene [5].

Fulfillment of this rule is not without systematic training of hospital personnel, which may include lectures, practical exercises, and the use of training materials

available in paper or electronic form [6]. Training can help define guidelines for performing medical procedures in accordance with modern requirements, based on evidence-based medicine [7]. Classes with medical workers allow to determine the purpose of the program for the prevention and control of IRMC, increase staff compliance with the requirements of hand hygiene, dictates the need for its evaluation [8]. Providing feedback to department staff increases the effectiveness of IRMC prevention and control programs [9].

A high level of computerization of medical activity is the automation of health care management [10-11]. An automated management system is a means of collecting, processing, storing, storing and transmitting medical information, designed to automate both the management process itself and the professional activities of each medical worker [12]. The modern works of many scientists are devoted to the development of intellectual problem-oriented systems and their application to medical domain [13-16]. Quality computer aided systems with intelligent interaction with medical workers will solve a lot of problems in medical staff every day work [17].

The aim of this research is to create a software package that allows an automated assessment of the nursing staff's knowledge of hand hygiene prevention in the performance of professional duties.

## **2 Questionnaire Development**

In order to assess the quality of knowledge of nurses at several medical and preventive institutions on hand hygiene, as well as to study their knowledge on the rules for performing medical manipulations in the hospital and identifying the reasons that make it difficult for the nurses to follow the rules of hand hygiene. The questionnaire included questions characterizing respondents by sex, age and work experience, as well as questions reflecting the content of the current regulatory document: Order of the Ministry of Health of Ukraine of September 21, 2010 No. 798 "On Approval of the Surgical and Hygienic Handling Guidelines of Medical Personnel".

## **3 Expert System Development**

At present, computer equipment in solving operational problems, as a rule, is used only in the case when the algorithms for solving problems are strictly formalized [18]. In this case, the initial data for input into the computer is prepared by highly qualified specialists [19]. As a result, the optimal solution of problems cannot be fully implemented using simple and accurate algorithms, and therefore is automated without the creative participation of man. Such tasks are usually referred to as artificial intelligence (AI) [20].

One of the applied areas of AI is the creation of expert systems (ES), designed to reduce the intellectual burden on humans [21-22]. The ES is designed to solve problems in a specific problem area. In them, the source of knowledge is the experts who enable the programmer to develop appropriate strategies (programs) for solving specific problem tasks [23-24].

It is advisable to resort to the development of ES in cases where:

- the problem can not be strictly solved with a rigid (known) algorithm [25];
- to solve problems requires an intuitive approach [26];
- preparation of initial data requires encyclopedic knowledge and experience of highly qualified specialists [27];
- the necessary phased verification and correction of intermediate parameters [28];
- in the course of the decision change of circumstances (conditions) is possible [29];
- in the course of solving the problem, the level of knowledge and experience of the staff changes [30];
- time for performance of work changes [31].

When composing such programs, it is easiest to use heuristic methods (rules) that work according to the principle: “if condition A is set, then you should follow rule A” [32]. It is also possible to represent knowledge using semantic networks, as well as a frame [33].

To solve problems in a specific problem area, you can use the ES shell (skeleton and inference system) from another problem area, filling it with new necessary knowledge [34]. In such a shell, you can enter all the problems and ways to resolve them, both in the form of rules and in the form of complexly organized interacting structures. So, for example, when creating the ES, it is advisable to use a shell in the field of medical diagnostics to identify failed elements of the RTS [35].

The ES can significantly reduce the cost of manpower and resources, reduce the requirements for the qualifications of service personnel, as well as minimize the time spent on solving similar tasks [36]. At the same time, human activity will be reduced to the ability to work with computer programs and to collect the necessary initial data.

The first order logic language, the syntax and semantics of which we will define in the next section, is based on the concepts of objects and relations. It became extremely important for mathematics, philosophy and artificial intelligence precisely because these spheres of knowledge (and in fact the main part of everyday human existence) can be quite productively regarded as relating objects and relations between them [37]. The first-order logic also makes it possible to express facts about some or all of the objects in the Universe. This makes it possible to present general laws, or rules, such as the following statement: "In the squares adjacent to the square where the vampus is located, there is an unpleasant smell" [38].

The main difference between propositional logic and first-order logic is that each of these languages makes a different ontological contribution to the description of reality, that is, they represent the nature of reality in different ways [39]. For example, in propositional logic it is assumed that there are only facts that are or do not belong to this world. Each fact can be in one of two states: to be true or false. In the first order logic, broader assumptions are made, namely, that the world consists of objects between which there may or may not be some relationship [40]. Some variants of special-purpose logic allow for an even greater ontological contribution; for example, in temporal logic it is assumed that the facts take place at specific time intervals and these intervals (which can be considered infinitesimal or finite) are ordered [41].

Therefore, in variants of special-purpose logic, a first-class status is provided for some types of objects of a special kind (and axioms about these objects), and their definitions are not simply entered into the knowledge base. In the logic of high order, the objects themselves are treated as relations and functions, are considered in the logic of the first order. This allows you to formulate statements about all relationships, for example, if you need to determine exactly what the concept of a transitive relation means. Unlike most variants of special-purpose logic, high-order logic is strictly more expressive than first-order logic, in the sense that some statements of higher-order logic cannot be expressed using any finite number of statements of first-order logic.

Logic can characterize its epistemological contribution to cognition; this refers to the possible states of knowledge that it allows to express for each fact. And in propositional logic, and in logic of the first order, any statement is fact, and the agent either trusts with the statement that this expression is true, or trusts with the statement that it is false, or has no opinion on this matter. Therefore, in such variants of logic there are three possible states of knowledge relating to any utterance.

The main syntactic elements of first-order logic are symbols denoting objects, relations, and functions. Therefore, the symbols themselves are divided into three types: constant symbols denoting objects; into predicate symbols denoting relations, and functional symbols denoting functions.

Semantics must link sentences with models in order to be able to determine the truth. To solve such a problem, an interpretation is needed, which determines which particular objects, relations and functions certain constant, predicate and functional symbols refer to.

The truth of any utterance is determined with the help of some model and some interpretation of the symbols of this utterance. Therefore, the logical consequence, admissibility, and other properties of statements are defined in terms of all possible models and all possible interpretations. It is important to note that the number of elements of the problem area in each model can be unlimited, for example, the elements of the problem area can be integers or real numbers. Therefore, a limited number of possible models, as well as the number of interpretations.

After determining the logic that allows the use of objects, it becomes quite natural to create tools that allow you to express the properties of entire collections of objects, rather than sorting these objects by name. Quantifiers allow you to do this. The first-order logic includes two standard quantifiers, called quantifiers of universality and existence.

## **4 Program Realization of Developed Expert System**

In order to assess the quality of knowledge of nurses at several medical and preventive institutions on hand hygiene, as well as to study their knowledge on the rules for performing medical manipulations in the hospital and identifying the reasons that make it difficult for the nurses to follow the rules of hand hygiene. The questionnaire consisted of questions characterizing respondents by sex, age and length of service,

and questions reflecting the content of the current document regulates: Order of the Ministry of Health of Ukraine of September 21, 2010 No. 798 "On Approval of the Surgical and Hygienic Handling Guidelines of Medical Personnel"

To automate the assessment of knowledge and data collection from medical staff, a web application has been developed, the platform for which .net core is chosen, since during development most of the necessary components of the application can be downloaded as separate modules through the package manager NuGet. This allows you to reduce the number of excess dependencies and the total size of the finished product. Also, a project based on .NET Core is fairly easy to transfer to the cloud. Microsoft Azure already supports hosting .NET Core projects in both Application Services and virtual machines. .NET Core allows small projects to take full advantage of the enterprise-level platform, while providing convenient and development tools, as well as low-cost infrastructure. Also a project based on .NET Core is best suited for computing and analytical tasks.

The developed web applications used technologies such as HTML, CSS, LESS, JavaScript, .NET CORE, Angular, Grunt, MS SQL, Material, the main advantage of which is the low threshold of entry and ease of use. Using the Angular framework reduces development time. Also Angular allows you to create one-page applications. According to the logic of their work, they reduce the load on the server and can provide a much richer interface for the end user. There are opportunities to use these technologies to create hybrid mobile applications.

Grunt was chosen to compile the project, because it can be used to easily compile Less, compress the CSS and minify JavaScript in order to keep the files as small as possible.

MS SQL is the generic name for Microsoft SQL Server 2005/2008/2012/2014/2016 Express Edition. It is a reliable server with excellent features, high speed and maximum security. MS SQL is installed on the central server, and all other computers are connected to this server. Well suited for storing test results for further analysis, as MS SQL is a high-end SQL server, it takes care of managing the database, its security and stability. MS SQL guarantees a high level of data protection and virtually no problems.

This web application is implemented in the form of a web page on which the user is asked to answer the question of the developed questionnaire. The result of the program are recommendations based on the analysis of the received answers of the user of the system in the process of questioning. Recommendations are the result of an expert system developed in a web application.

The expert system is the direction of research in the field of artificial intelligence to create computing systems that can make decisions similar to the decisions of experts in a given subject area. Expert systems have one big difference from other artificial intelligence systems: they are not designed for solving some universal tasks, such as neural networks or genetic algorithms. Expert systems are designed for high-quality problem solving in a specific area of developers, in rare cases - areas.

The expert system incorporates two main blocks:

- knowledge base;

- machine logical inference.

The knowledge base contains the user's answers in the questionnaire process, the correct answers to the questionnaire questions and recommendations are based on expert opinion. The logical inference machine determines the correct answers of the user and, based on the logic of second-order predicates, determines the recommendations for the system user.

## 5 Results

A survey of 817 paramedical medical workers of medical institutions was conducted. Before the survey, the respondents were explained the purpose of the survey and the rules for filling out the questionnaire. The survey was conducted on a voluntary basis. Respondents chose the answer option on their own. The results of the study were processed statistically.

An analysis of the data obtained during the survey was conducted. The results were tested for validity. Validity characterizes the suitability of the test to measure a certain amount. It should be noted that it is impossible to talk about the validity of the test without specifying the conditions for its use. Also, validity means the test's suitability to measure the property for which it is intended to determine. This test is aimed at assessing the level of knowledge of nursing staff regarding the prevention of hand hygiene in the performance of professional duties. The measured property in this case is the level of knowledge of medical personnel. During the test, the level of knowledge has not changed.

The "position" criterion does not affect the passing of the test, only the level of knowledge of nursing staff influenced, and is a measurable property. It can be argued that this test is valid, and subsequent analysis of the data obtained will carry a qualitative and believable assessment of the knowledge of nursing staff.

The questionnaire was divided into two sets of questions: "Skill" and "Knowledge".

The "Skill" block was formed to reveal the level of practical skills of medical personnel. For example: How often do you follow hand hygiene before and after contacting a patient?

The block "Knowledge" was formed to test the level of knowledge of medical personnel. For example: What are the stages of surgical treatment of hands?

One of the goals of the work was to determine the relationship between these two blocks. For further analysis, all the results of the survey were recoded accordingly. The answers to the first block of questions were grouped into two categories: "The skill level is above average" and "The skill level is less than average." The answers to the second block of questions were grouped into categories: "Correct" and "Incorrect". The obtained data was processed in the R language in the RStudio software environment. RStudio is available in open source versions and has useful features for both beginners and experienced R developers, including code completion, source execution, search history, and support for developing Sweave documents. The result was a data set consisting of the average values of each group for each block of ques-

tions. It was found that, on average, 791 people answered the first block of questions (at the level above the average), at the level below the average — 26 people. 492 people answered the questions of the second block correctly, 326 people incorrectly. A total of 817 people were interviewed.

Since all data are presented on a categorical scale, the analysis was performed using the Pearson Chi-square test. As a result,  $p\text{-value} = 1$  was obtained (since  $p\text{-value} > 0.05$ ), so it can be argued that there is no direct connection between the first block of questions and the second.

It was revealed that the older the employee, the more experienced he is and his level of knowledge about the prevention of hand hygiene does not depend on such two signs as “age” and “experience”. Both signs are represented by a categorical scale, the Pearson Chi-Square test was used to determine the significance of differences. This is a non-parametric method that allows assessing the significance of differences between the actual (identified as a result of the study) number of cases or qualitative characteristics of the sample falling into each category, and the theoretical amount that can be expected in the studied groups with the validity of the null hypothesis. As a result, it was found that  $p\text{-value} < 2.2e-16$  (no difference).

It was also found that medical staff adhere to the rules governing the requirements for handling hands, only if these rules are available. It was also calculated that  $p\text{-value} < 2.2e-16$  (there is a connection), so it can be argued that medical staff wear medical gloves if necessary and follow the rules of hand hygiene after they are removed. It can be argued that most medical personnel adhere to hand hygiene before and after contact with the patient and the surfaces of objects and equipment, since the dependence was confirmed by the Pearson Chi-Square criterion ( $p\text{-value} < 2.2e-16$ ). It can be argued that medical personnel are aware of the rules established at the medical institution and based on the questionnaire, it is possible to identify the reasons for non-compliance with the established rules and give an individual assessment for each interviewed employee, general statistics and recommendations of the medical institution administration to resolve the problems.

The results showed that the level of knowledge of medical personnel is insufficient.

## 6 Conclusions

A software package has been developed that allows for automated interviewing of health workers and greatly simplifying its analysis. It has been established that in medical institutions where the study was conducted there are clearly developed rules for the treatment of hands based on current regulatory documents. In-patient workshops are held on hand hygiene. Most respondents know the algorithms of washing and hygienic antiseptics of hands, less than half know the sequence of actions in the surgical treatment of hands.

A statistical analysis was carried out which allows conclusions to be drawn regarding hand hygiene in medical institutions. It has been established that in medical institutions where questionnaires were conducted there are clearly developed rules for the



treatment of hands, based on current regulatory documents. It is known that in-patient training seminars on hand hygiene are held. Among the respondents, the majority knows the algorithms of washing and hygienic antiseptics of hands, less than half know and can list the sequence of actions during surgical treatment of hands.

The results of the survey of nursing staff showed that when conducting training seminars for health workers, hand hygiene rules should be given special attention to the prevention of CB, including providing health workers with moisturizing protective creams, focusing on the correct implementation of all stages of hygienic and surgical treatment of hands; it is necessary to strengthen the control over the uninterrupted provision of hospital departments with alcohol antiseptics and liquid soap, and to revise the load standards for nurses to ensure the quality of medical care for patients.

The results of the survey were tested for validity and it was found that the data obtained are valid. In the future, based on these results, it is possible to develop a software package, in the form of a web application, which will be aimed at individual assessment of each respondent, general statistics and recommendations for the administration of the medical institution to eliminate insufficient knowledge and possible factors that interfere with hand hygiene.

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