Intelligent Analysis of Medical and Psychophysiological Data (invited paper)

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Abstract

The paper is dedicated to the application of Intelligent methods of data analysis on the examples of medical and psychophysiological tasks. Although there are pretty much research in this field, unified complex methodology of medical data analysis does not exist. In this paper we present the short overview of using various means of data analysis in medical applications: big data, machine learning, text mining, multi-agent systems. We present wo cases of intelligent data analysis performed by the researchers from Ufa State Aviation Technical University in collaboration with experts and researchers from the medical institutions in the city of Ufa. First case consist in analysis of weak-structured data about acute poisonings in the Republic of Bashkortostan. The second case was connected to analysis of the results of psychophysiological diagnostics of students in order to determine recommendations for their physical activity.

1 Introduction

In recent years several regulations was made in the sphere of medical data processing, e.g. [Ord11] and [Dec13]. According to these documents, a unified information system was introduced in medical organizations of Bashkortostan Republic. More than five years have passed since then, and a lot of medical data has been accumulated, in particular 4 million electronic patient records; 346 million cases of medical care; 370 thousand bills for the medical care; over 35 million medical images; 13 million referrals for laboratory research; 9 million electronic recipes. The accumulated dataset is a typical object of big data technology, containing a combination of unstructured and poorly structured knowledge about the processes and methods of treatment. This point of view allows us to consider the accumulated mass of information as a valuable resource for analytical work. In this regard, it is of interest to analyze related works in the field of medical big data.

Although there are pretty much research in this field, unified complex methodology of medical data analysis does not exist. In this paper we present a short overview of existing related works on medical data analysis (section 2), and an two cases of medical data analysis performed by researchers at the Faculty of Computer Science and Robotics, Ufa State Aviation Technical University.

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2 State of the Art

There are a lot of works in the field of big data in recent years. However, there are not so many publications in the open press on the application of this approach to the study of medical data. In this area, the following significant studies can be noted [Cve16,Il16,Eni18,TOM,Tha19,Ron14,Jak16]. In the works [Cve16,Il16], it is proposed to distinguish the following groups of practically significant tasks: quick identification of patients with various risks; increasing the effectiveness of medical interventions; making the best decisions; close monitoring; comparison of significant clinical data with the results of Big Data. Moreover, up to 90% of the data is unstructured. As a rule, data in different institutions are presented in various formats. Information comes from various sources and from various clinical systems. A 44-fold increase in data over the next decade is expected (one exabyte by 2020).

The use of data mining for the analysis of medical data has been the subject of many works, in particular, publications [Ugl17,Aks18,Sai18,Lin16,Muh15]. In these works, the use of the following analysis tools was studied: classification, modeling and forecasting methods based on the use of decision trees, artificial neural networks, genetic algorithms, evolutionary programming, associative memory, fuzzy logic. In [Sai18], an analysis of the used methods and technologies of data mining in the field of healthcare is presented. The authors of [Lin16] propose using data mining methods to solve public health management problems. The study [Muh15] is devoted to the tasks of data mining from a smartphone and wearable devices. An analysis of the studies showed that machine learning methods are usually used to improve the analysis of visual data and images, for example, in the works [Sha17,Zho17]. Paper [Cir12] is devoted to the application of deep learning for solving the task of classifying medical images. The following basic technologies are used in the considered papers: NoSQL (DBMS with non-relational data structure); Hadoop (the technological core of the project ecosystem for working with data); MapReduce (distributed computing model for parallel processing of large amounts of data; implemented in the Hadoop system); R language (programming language for statistical data processing and graphics); Python (a language for scientific computations with fine ecosystem of libraries, modules and applications).

The task of automatic analysis of medical unstructured texts is relatively new and relevant [Gal17,Men15,Tch10,Ros10], but there are no ready-made solutions in this area. Questions of automatic text analysis can be related to the construction of ontologies. There are tools for automatic ontology generation based on structured [Kur17] and unstructured material [Orb12,Moz11,Mas14,Kum16,Piv05]. The general questions of knowledge formalization are the subject of many works, in particular, [Gav03,Vas17,Nov18,Rai18,Sam09,Tra97,Yat82,Pop96,Mur07,Lop04]. However, the specificity of subject areas requires additional research and formalization of knowledge. There are some works on the formalization of knowledge in the field of medicine [Aba13,Kot05]. The authors of [Ber12] show that it is possible to present operational definitions of diseases using OWL and to successfully classify real cases of patients. A feature of the ontology developed in [Kha09] is the inclusion of temporality. The authors of [Ald17] suggest the need for additional research to identify bad practices and anomalies in the development of ontologies by computer scientists by the medical profession. Patients' data used belong to the category when it is necessary to save both the past and current state of the database, therefore, it is necessary to consider data temporality [Kos07,And98,Eli12,Kol09,Baz09,Koz10].

The application of the multiagent approach in healthcare was considered, for example, in [Wit04]. The developed multi-agent system simulates the interaction of general practitioners, the chief physician of the clinic, specialists of the hospital, ambulance, medical university, managers of the Ministry of Health of the region, the territorial fund of compulsory medical insurance, an authorized pharmacological enterprise, and a patient of medical institutions. In [Dor15], a review of the use of multi-agent systems for various health problems is given. The authors identify the following areas of application of multi-agent systems: study of the effectiveness of different mechanisms of interaction of agents, different scheduling heuristics; operational planning of the treatment process; building simulation models of a specific hospital. Such a model reproduces with maximum accuracy the organizational structure of the hospital (or its parts), resources (wards, beds, equipment, staff), the interaction mechanism of the units and the real statistical characteristics of the patient flow. This model allows you to improve the organization of the healing process. In addition, the following areas of application of multi-agent systems in healthcare can be distinguished: decision support for managers, balancing and maximizing the use of available resources [Ben15]; DSS for managing hospital resources [Nes18].

The analysis of the related works has shown that work in the field of application of intelligent technologies for processing medical data is actively carried out in different countries and in different directions. However, the methodological basis for the formation of intelligent decision making for diagnosis, treatment and further support of the patient, combining a variety of intelligent technologies in a single methodology, is not sufficiently developed, therefore this problem is fundamental, and its solution is relevant and practically significant.

3 Research in Ufa

The scientists from the Faculty of Computer Science and Robotics at Ufa State Aviation Technical University made significant fundamental and practical research work in the field of medical data analysis in collaboration with experts from Bashkir State Medical University, Bashkortostan Kuvatov Republican Clinical Hospital number 21, Ufa City Clinical Hospital, and the chair of Physical Education at Ufa State Aviation technical University. In this article we describe two example cases of data analysis: exploration of the acute poisoning in the Republic Bashkortostan and decision support for improving the psychophysical readiness of students for successful professional activities.

Case 1: analysis of toxicologic data in Bashkortostan Republic

A group of scientists from Ufa State Aviation Technical University (lead by professors Nafisa Yusupova and Gouzel Shakhmametova) together with coleagues from Bashkortostan State Medical University (lead by professor Rustem Zulkarneev) has made a research [Yus18] on the toxicological data from the Republic of Bashkortostan for 2015-2016. The goal was to construct and apply a complex technique for the analysis of toxicological data including methods of mathematical statistics and data mining. The analysis of the data about the cases of poisoning could support decision making for treatment and prevention of toxicological diseases. These decisions are important not only from the medical, but also from the social point of view. This allow one to carry out the comprehensive analysis and to benefit from the largest possible amount of knowledge, interrelations and patterns.

The input of the data processing module included 6338 diversed records about the cases of poisoning in unstructured and semistructured form. The requested output include the following information: main reasons and structure of acute poisonings, structure of poisons, dependance on age and gender, definition of poisoning outcomes, etc. Use of data mining allowed discovering patterns among large volumes of data, which are objective and practically useful but invisible for statistical analysis. Parametric and non-parametric methods of statistical analysis were applied for processing quantitative data. Main results are presented in [Yus18] including some unexpected outcome about the structure of poisonings. E.g. main reasons of acute poisonings are the following: Alcohol (47,80%); Drugs (37,88%); Narcotic substances (5,99%); Carbon monoxide (5,43%); Mushrooms (2,15%); Snake bites (0,74%). Structure of the poisons which have caused acute poisonings is the following: Alcohol (28,9%); Carbon monoxide (49,2%); Narcotic substances (7,2%); Corroding substances (1,6%); Organic solvents and aromatic hydrocarbons (0,2%); Drugs (1,8%); Pesticides(0,001%); Other unspecified substances(11,1%). Exploration of poisoning dependence on age and gender showed the following results. For the children (age 015) no specific difference in poisoning was found. Adult men are poisoned more often than adult women: for the age 1630 67% of poisoned people are men. For the age 3145 this rate is 72%, for the age 4660 75%, and for the age 6175 70%. 60% of poisoned old people (age more the 75) are women; this may be explained by the fact that for this age total number of women is much more than total number of men. This case show that intelligent data analysis provide results, which are interesting from the theoretical point of view and may support decision making in the health-care management institutions.

Case 2: Data Mining to support decisions on improving the psychophysical readiness of students for successful professional activities

Researchers from Ufa State Aviation Technical University (group from the department of Computational Mathematics and Cybernetics lead by professor Nafisa Yusupova and professor Olga Smetanina and expert Tatyana Naumova from the department of Sports Education) has explored the data about psychophysical conditions of students from the Faculty of Computer Science and Robotics [Yus19]. Human-machine interoperability plays an important role in the Industry 4.0 concept. To implement this concept, employees, including particular programmers, will require psychophysical readiness. Purposeful psychophysical training of specialists is possible using a special model (professiogram), which includes a detailed description of the conditions and specifics of work [Ego05a]. Professions with increased requirements for psychophysical readiness require a mathematical model that takes into account the relationship of qualifications, professionally important qualities and their mutual influence [Ego05b]. The author of [Ego05b] also notes that mathematical modeling of higher mental functions allows one to purposefully choose means of physical education and sports in order to form the psychological readiness of future specialists for extreme working conditions. Sharopin [Sha07] has developed an information system for assessing students' psychophysical readiness for professional activity, which allows one to obtain an integrated assessment of professional applied physical readiness. Sharopin also indicated that a quantitative

determination of the level of psychophysical readiness is necessary [Sha11]. Pichurin [Pic14] describes the role of physical education in the development of psychological and psychophysical preparation of students for professional work. The analysis of the related works allowed us to conclude that it is possible to apply data mining and use the results to support decisions in this area.

Methods for assessing professionally important physical qualities and mental properties are considered in [Sme16, Sme18]. Special tests, such as the Schulte test and the Rissou test, allow one to evaluate professional characteristics. For the development and improvement of professionally important physical qualities and mental properties, there is a certain composition of exercises. E.g., the following groups of physical exercises help to develop coordination abilities: exercises on the coordination of movements; exercises on the accuracy of movements; exercises in jumps and turns. Coordination exercises contribute to the development and improvement of psychological qualities such as attention, thinking and memory, so they must be developed together. As a rule, recommendations are given to a certain group of students with close values of indicators. Groups are defined by clustering.

The formal statement of the task is as follows: it is necessary to identify groups of students with close values of indicators (test results) in order to develop general recommendations for improving psychophysical properties. Our methodology includes four steps. The first step is aimed at preparing data for analysis. The preparation tools are data cleaning algorithms (detection of anomalies, filling in gaps, identifying duplicates and contradictions). At the second step, clustering by Kohonen neural network is applied to identify the similarity of objects. At the third stage, recommendations are made in the form of a set of exercises for each cluster. In addition to the results of clustering, it was proposed to use the knowledge of experts. At the final step, the formed production knowledge base is used. To implement the methodology, a comprehensive analytical platform Deductor Studio was used. The results are given in table 1. This results allow one to define recommendations for students.

Table 1: Defined clusters from [Yus19]

Cluster	Tapping test (characteristic of the nervous system)	"Hook" test (static strength endurance of the hand muscles)	Schulte test (characterization of volume, distribution and switching of attention)	"Running to numbered places" test (spatial orientation and memory)	Yarotsky test (general equilibrium)"
0	160..180	40..180	28..40	9,75..10,7	19..39
1	165..190	30..63	22..30	7,8..8,8	30..43
2	155..180	105..145	22..40	7..8,8	39..50
3	150..170	45..105	34..47	7,9..9,7	23..39

An analysis of the results shows that students who are in cluster 2 can perform the basic set of exercises. Students who make up cluster 1 should perform exercises on the static strength endurance of the muscles of the hands. For a small part (those with a Yarotsky test of less than 39), balance exercises are also added. Students included in cluster 0 are characterized by a complex similar to the previous cluster. In addition to this complex, exercises on spatial orientation and memory are necessary. Cluster 3 turned out to be the most difficult group. In this case, it is necessary to compose a complex of exercises that contributes to the improvement of all characteristics.

4 Conclusion

Research work in the field of intelligent technologies is being actively developed in such directions as big data, machine learning, text mining, multi-agent systems, etc. Different cases of applying these methods for the tasks of healthcare push their development and provide relevant results, which improve effectiveness of decision making in the field of healthcare. The researchers from Ufa State Aviation Technical University have long experience of scientific work in cooperation with researchers and practitioners from the field of healthcare. Achieved results can improve work conditions for medical workers and provide the institutions of healthcare with useful information. Considered cases of collaborative research show that medical data analysis include both classical (parametric and non-parametric statistical analysis) and intelligent methods for data clustering, classification, etc.. The second considered case demonstrate that means of intelligent data analysis allow one to define practical recommendations

on sports activity based on individual psychophysiological properties. Aquired experience is interesting from the scientific and practical points of view. It is also a promising starting point for further works.

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