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Clinical Decision Support System for the Respiratory Diseases Diagnosis

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***Abstract*—The existing decision support systems used in healthcare for analyzing and processing medical data is considered in the article, their functionality is discussed. The solution for developing decision support systems to diagnose bronchopulmonary diseases, allowing to establish the patient's primary diagnosis treatments based on the integration of intelligent information processing, machine learning, pattern recognition, and extraction knowledge is proposed. The scheme of the proposed clinical decision support system for the diagnosis of respiratory diseases is discussed. Developing the clinical decision support system with the list of proposed capabilities will, on one hand, significantly improve the quality of medical care, since it reduces risks of human factors due to the use of computer-based information processing, and, on the other hand, increase the level of digitalization in medical institutions as well as their economic efficiency.**

Keywords—clinical decision support system, data processing, machine learning, pattern recognition

I. INTRODUCTION

Currently, many medical information processing systems have been already developed and continue being developed based on intelligent data processing technologies. Such systems are commonly known as clinical decision support systems (CDSS). CDSS is a type of decision support system (DSS) and focuses on interacting with useful information to obtain clinical guidelines based on a variety of factors related to patient data. Such systems provide the processing of advance information about the patient, provide support for clinical care solutions, and offer recommendations in treatment planning [1].

The analysis of the current state of the problem shows that clinical decision support system use allows to achieve significantly greater efficiency in the diagnosis and treatment of patients [2]. Garg AX. et. al. in the [3] cites the following figures: CDSS improved the work of the practitioner in 64% of studies and the results of patients in 13% of studies. The [4] indicates that decision support systems have significantly improved clinical practice in 68% of tests. Varghese J. et al. in the [5] cites data based on the results of 70 studies, which confirm that the use of the clinical decision support system in 23% of cases showed a significant positive effect, in 29% - an average positive effect, while in 29% of cases, the applied technologies showed none or little effect on the overall health of the patients. Market Research Future (MRFR) states that the market for clinical decision support systems will expand due to a steady compound annual growth rate (CAGR) during the period from 2018 to 2023 as the result of increasing demand for data management technologies [6]. However, there are also problems associated with the gap between the potential and actually used functionality of the CDSS, which makes them insufficiently profitable today [7].

Thus, we may conclude that the DSS use in the field of health is quite a promising direction, but the process of developing and implementing such systems should be carried out in close cooperation with medical professionals.

This article proposes the development of a system for supporting adoption of clinical guidelines for the diagnosis of respiratory diseases with the analysis of the entire set of patient data, including both structured and non-structured data, which will generally improve the efficiency of patient diagnosis and treatment.

II. STATE OF THE ART

In the course of the analysis of the current state of research and ready-made solutions in the field of clinical decision support system, the following most popular results were identified.

A software product developed by Cerner Corporation allows early detection of sepsis, as well as acute kidney damage, by reducing creatinine in human blood plasma. When assessing patient's symptoms, the algorithm calculates scores on the modified early warning system (MEWS), the national early warning system (NEWS), the pediatric early warning system (PEWS) based on the patient's age, and warns patients that they are potentially at risk. According to research, use of the product developed by the company made it possible to achieve a 17% reduction in the mortality rate from 2011 to 2014 [8].

McKesson Corporation has created the InterQual cloud service [9], which allows instant access to a medical record from both the patient and the medical institution. Due to machine learning, the service provides therapeutic services based on effective medical tests as well as patient complaints, and speeds up obtaining medical advice from the required specialist. Access to the system is carried out through a mobile application.

Epic Integrated Software (Epic Systems Corporation) combines the functions of clinical activities, access, revenue and analytics of an enterprise with a single patient-oriented database, and provides an open platform for building solutions on this basis. The system allows healthcare providers to communicate directly with patients and other

organizations in order to improve efficiency of medical care. Epic serves large and medium-sized groups of individuals affiliated with specific clinics, children's hospitals and educational institutions [10].

In February 2019, Zynx Health Incorporated made its debut at the HIMSS19 conference with a new clinical decision support system, which is designed to help medical organizations monitor patient care methods and costs. The developed system uses machine learning methods and provides an interactive retrospective analysis of medical services provided based on previously obtained empirical data that have proven their influence on the quality of treatment [11, 12].

The General Electric Company introduces the Edison product, a GE Healthcare intellectual development consisting of applications and smart devices created using the Edison platform. Edison allows GE Healthcare to integrate and obtain data from disparate sources, as well as apply analytics and artificial intelligence in the field of data transformation in order to obtain effective results in the process of working with patients [13]. The developments of this company allow solving such tasks as processing of cardiograms, analyzing 2D and 3D images for qualitative or quantitative assessment of the anatomy of the heart and coronary artery vessels, visualization of the spine, graphical representation of the trajectories of blood cells, and others.

The Wolters Kluwer Health company has developed the UpToDate resource [14], the goal of which is to maximally support medical staff and provide them with up-to-date information, as well as help in making decisions in diagnosing and treating patients.

Athenahealth develops clinical decision support software [15] which provides verification of prescribed medical recommendations for efficacy and testing of prescribed medications for possible contraindications, provides recommendations for diagnosis and treatment. Software exists as an application for mobile devices.

Allscripts Healthcare Solutions Inc. dbMotion solution allows, through the use of intelligent processing technologies, to combine information from several medical records of a patient to create a single parameterized medical history [16].

Similar developments are carried out in Russia. For example, the Intellogic company has developed a product designed to analyze and recognize diagnostic images of CT, MRI, mammography and digital X-rays with the ability to assess the degree of tumor malignancy [17].

Galenos company offers a medical decision support system which utilizes the results of evidence-based medicine. The system includes a database of nosologies, a clinical module that monitors patient treatment and compliance, an analytical module that allows to calculate current and future demand for drug provision and generate reports on patients and their diseases [18].

Another Russian company, the Autoplan, helps to analyze medical images and form examination protocols. The program integrates with any DICOM standard equipment and storage systems. Additional functionality of the program provides physicians with the opportunity to build personalized 3D models for the purpose of planning surgical interventions and additional diagnostic imaging [19].

In summary, we can conclude that the field of clinical decision support systems is currently actively developing, but it lacks a universal clinical decision support system with the possibility of its application in any field of medicine. Developed clinical decision support systems, as a rule, are focused on a specific range of tasks with a specific specialization, and areas of health care that are responsible for diagnosing patients and issuing clinical guidelines are very extensive.

III. PROBLEM DEFINITION

Diseases of the respiratory system (RD) occupy the first place in the structure of morbidity and pain among the population of the whole world. In adults, respiratory diseases constitute 55% of the structure of general morbidity, in children - up to 70% [20]. RD are considered number one in the structure of morbidity with temporary disability. Diseases of the respiratory system steadily occupy places 3-4 in the structure for causes of death, and their growth is observed. By 2030, COPD (chronic obstructive pulmonary disease) can reach the 3rd place in the world in mortality, second only to coronary heart disease and stroke [21]. Also, respiratory diseases take places 3-5 in the list of causes of disability. According to expert estimates, pneumonia annually accounts for up to 1.5 million sufferers in the Russian Federation, the actual number of patients with chronic obstructive pulmonary disease may reach 22 million people, and 15 million people with bronchial asthma [22]. Socio-economic damage from diseases of respiratory organs is very high and amounts to 10% of the country's GDP in economic terms, which may be due to a significant decrease in the duration and quality of life [23]. Precise and timely diagnosis is one of the most important factors for the successful treatment of bronchopulmonary diseases and prevention of complications [24]. The use of CDSS is a sought-after solution, allowing to increase both the accuracy and speed of diagnosis, and the effectiveness of further treatment. But an analysis of the market for ready-made solutions in this area showed the absence of such products in the diagnosis of RD. Therefore, development of a support system for clinical recommendations in the diagnosis of respiratory diseases is an urgent problem, and its solution is a popular tool for both medical specialists to support decision making and to reduce the incidence of RD as a whole.

IV. PROPOSED SOLUTION

The key requirement for the system being developed is to obtain as much useful information as possible from unstructured data, i.e., texts, images, and audio files. Since much of the necessary information is contained in the form of images (X-ray and MRI images) and sound files (auscultation files of the lungs), recognition blocks for images and sounds are needed in the CDSS.

The scheme of the proposed clinical decision support system for the diagnosis of respiratory diseases is shown in Fig. 1.

Medical records, results of analyzes, epicrises, etc. in the form of scanned images come to the input of the text data recognition module. Using text recognition tools, they are converted into blocks of text, and then the necessary

information is extracted from them using text data analysis tools. The output of the module shows key indicators of the patient's condition. The list of indicators can be changed and/or set by a medical specialist (decision-maker).

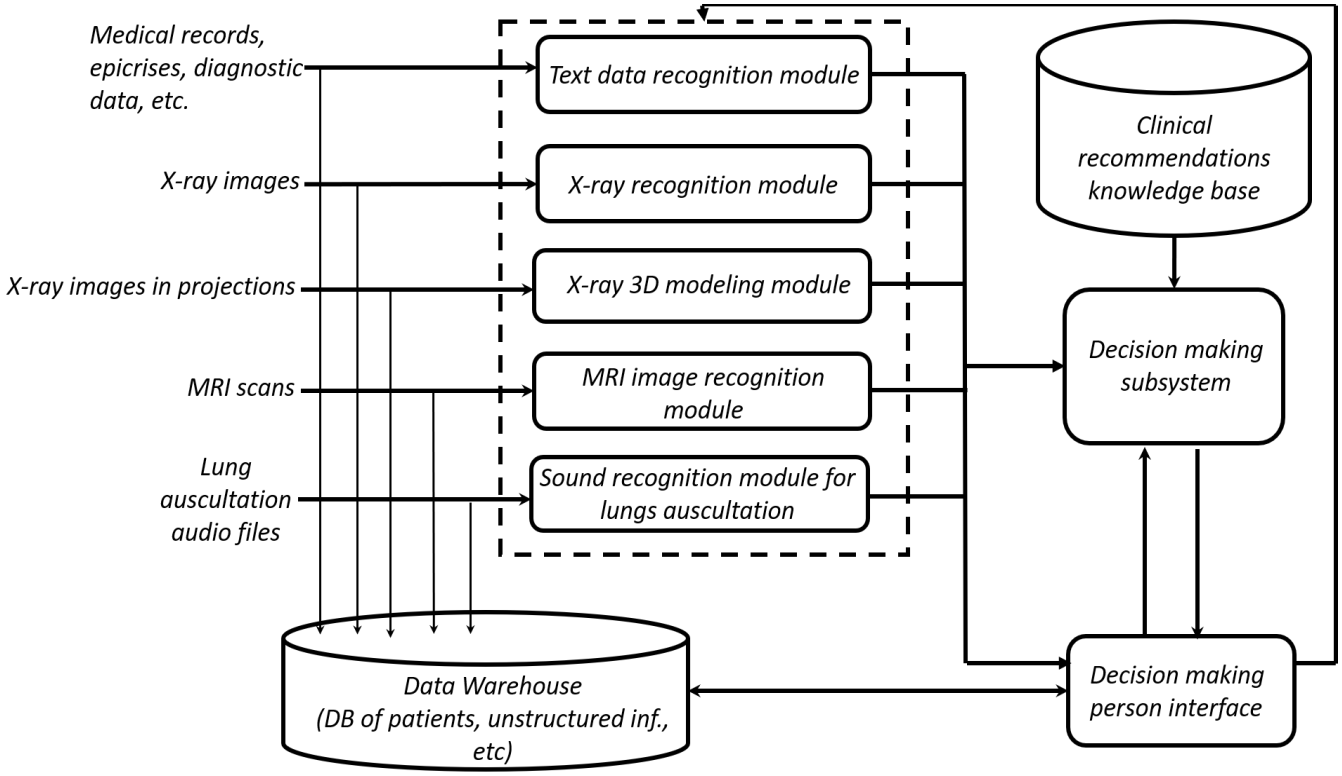

Figure 1. The Proposed Clinical Decision Support System Scheme

The second block is the X-ray recognition module. The inclusion of this module is due to the fact that about 80% of all bronchopulmonary diseases are detected on radiographs [25], since even minor manifestations of diseases such as inflammation of the bronchi, emphysema, tuberculosis, respiratory organs, rib fractures, pneumothorax, etc. can be identified on the basis of the picture. The input of the module receives x-ray images. Recognition is based on deep neural network and machine learning techniques. The output of the module would show the X-ray image classification according to the degree of decreasing reliability of the diagnosis.

The 3D-modeling module of X-ray images involves the reconstruction of a 3D model of the human thorax based on 2D projections from various angles obtained during X-ray procedure, which is especially important in the absence of MRI images. This opportunity will significantly expand the possibilities of diagnosing patients, and this reconstruction is especially needed in the absence of MRI images, which is important, for example, for medical institutions in remote areas. 3D reconstruction uses multilayer convolutional networks (CNN) and recursive neural networks (RvNN), which are trained together.

Magnetic resonance imaging image recognition module is designed to recognize and classify MRI images when available. MRI of the lungs and bronchi is recognized as the most highly informative, accurate and reliable procedure for the diagnosis of RD; it provides an opportunity to get a tomogram of the sample in three-dimensional image. This allows to identify the following diseases: pneumonia (bronchiectasis), bronchitis (acute or chronic), tumoral diseases, bronchial asthma, pulmonary emphysema, etc. [26]. The advantage for recognition over X-ray images is the fact that during MRI, the patient does not change his body position during the scanning procedure. Recognition is also based on the methods of deep neural networks and machine learning.

The sound recognition module during auscultation of the lungs is designed to recognize and classify sounds recorded in the process of listening to the patient's lungs using special equipment. On one hand, auscultation of the lungs is the most common and accessible method for the diagnosis of RD, on the other hand, it requires a highly qualified health care provider with considerable experience. The recognition unit for auscultation of the lungs is designed to provide the decision maker with additional information that will confirm or refute the conclusions obtained using other methods. At the input of the module are audio files with recordings of the patient's breathing sounds. At the output, there is a list of possible diagnoses in descending order of conformity. For recognition, CNN networks are used (TensorFlow, CUDA Toolkit 9.0, cuDNN 7.0).

The knowledge base of clinical recommendations is productional and contains knowledge in the form of the following rules:

1) to diagnose on the basis of available data and patient indicators;

2) to develop treatment recommendations based on the diagnoses and indicators (key indicators) of patients.

The data warehouse contains all data available and incoming to the clinical decision support system - structured, text, images, audio files, etc.

The decision making subsystem integrates the incoming structured data obtained by the recognition modules, and with the help of the clinical recommendations knowledge base, makes a decision about the most possible diagnosis and forms recommendations for further treatment of the patient. The outcome of the work of the clinical decision support system is the formation of a report that includes visual data on the diagnosis and the recommended method of treatment. It should be noted that the system is not fully automated: the decision-maker is involved in the stages of making a primary diagnosis and making treatment decisions. This will reduce the risk of misdiagnosis in case of borderline or complex diseases, as well as conduct additional training on the neural network mechanisms used in the system, which will gradually increase its effectiveness. Moreover, the work of the clinical decision support system provides for 2 modes:

1) using the knowledge base of clinical recommendations (BCR) and decision-making subsystem (DMS), preferably for a novice physician;

2) directly with blocks of recognition, bypassing the BCR and DMS, perhaps preferable for an experienced specialist.

In the course of the work of the clinical decision support system and the accumulation of new data, it is possible to additionally train constructed models of neural networks taking into account the incoming data. In the future, the addition of the clinical decision support system case block is considered (Case Based Reasoning) to identify the most typical cases, which will speed up the process of diagnosing and developing clinical guidelines.

V. CONCLUSIONS

Clinical decision support systems are currently a sought-after product and a means to increase the efficiency of patient diagnosis and treatment. Clinical decision support system, as a rule, is focused on a specific range of tasks with a specific specialization. The analysis of the existing clinical decision support system showed lack of ready-made solutions for the diagnosis and treatment of respiratory diseases. Such a system should provide for the collection and analysis of all patient data, including unstructured ones, as well as decision support in the initial diagnosis. Developing the clinical decision support system with the list of these capabilities will, on one hand, significantly improve the quality of medical care, since it reduces risks of human factors due to the use of computer-based information processing, and, on the other hand, increase the level of digitalization in medical institutions as well as their economic efficiency.

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