Cloud-Based Platform For Drug Therapy Planing

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Abstract

The article describes development of a decision support system for drag therapy planning based on a specialized medical platform. The use software of the platform allows you to prescribe a personalized treatment in various fields of medicine. The software of the platform is based on the ontological approach, in accordance with which all information resources - knowledge and data bases are formed on the basis of ontologies. The authors describe the architecture, components and implementation information and software components of this platform. A knowledge base editor for a knowledge base formation and a system ready for use by doctors are implemented as cloud services.

Keywords

ontology; knowledge base; drag therapy planning; decision support system; medical informatics;

1. Introduction

The World Health Organization states that rational use of medicines is such use when patients receive medicines according to clinical need, in doses that meet individual requirements, for an adequate period of time and at the lowest cost to themselves and society [1]. A variety of drugs, aggressive policies of pharmaceutical companies leads to the fact that more and more doctors use irrational a lot of drugs for patients. In modern medicine it is accepted that every disease needs an integrated approach. However, in order not to miss possible variants of development of disease, doctors often prescribe more drugs than it is necessary. Currently, the distinction between an integrated approach and irrational use of drugs is very thin. To remain committed to the first and avoid the second is a genuine contemporary art specialist with medical education [2].

The problem of choosing the optimal drug therapy is obvious, but at the same time, it is related to the complexity of the process of decision-making: cognitive abilities usually limited from five to seven variables for decision-making [3] that in the context of a rapidly developing scientific and practical medicine is the limiting factor for accuracy of prescribed therapy. The only effective solution that can significantly improve this situation is including systems based on artificial intelligence technology in the medical practice [4]. These systems integrate all available data - clinical, biological, genetic and create optimal patient-oriented solutions [5]. Building such systems is a process that requires a lot of time, intellectual, and financial resources.

The aim of this work is to describe a specialized platform for building intelligent systems for prescribing medication, requirements and algorithm of its work

2. Decision support system (DSS) for drug therapy planning. State of art

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Since the development of the first expert system and up to the present time, a huge number of different drug therapy planning systems have been developed.

Systems that helps doctors in treatment prescription, can be grouped into three main classes: knowledge-based expert systems, systems based on machine learning techniques and medical information systems.

The most well-known solutions are the MYCIN [6] and ONCOCIN [7] expert systems. The MYCIN system is designed to assist professionals in the diagnosis of some infectious diseases and prescribing necessary amounts of antibiotics depending on the patient's body mass; the ONCOCIN solves the problem of decision support for patients receiving chemotherapy. Among the most famous solutions are the AAPHelp expert system used to search causes of sharp pain and a decision about the need for surgery, the CASNET system, designed for diagnostics and choice of treatment strategy of glaucoma [8].

Among the modern developments we can highlight the system SPELTA [9] for the treatment of speech and language disorders; the system RTP-DSS [10] for prescribing radiation therapy; the IndiGO (Archimedes) system for the formation of individualized protocols of diagnostics and treatment of diseases in cardiology, endocrinology, and a number of other systems, e.g. [11,12,13].

Well-known advantages of such systems are assistance to physicians in selecting therapy and the possibility of generating explanations; weakness is focusing on specific (narrow) group of diseases, which limits their use in combined pathology. To "cover" all the nosology necessary for a doctor, he or she needs to use many different systems, which are usually incompatible and not interconnected. Another weakness of these systems is a feature of the knowledge and data bases implementation which does not allow the domain experts provide their maintenance without an IT specialist.

A typical representative of the second class of systems (based on machine learning methods) is the IBM Watson system [14]. For its implementation, a large training set was used for prescribing treatment for oncological diseases. This area of research is actively developing and currently proposed models, methods and systems that help physicians to prescribe treatment for different classes of diseases [15-19].

The main disadvantage of this type systems is large number of well-formalized case records necessary for their successful training. This task is practically impossible to provide for a wide class of diseases (the process of finding a training set, formalizing case records and preparing data is very long, expensive and time-consuming). Another significant drawback is the inability to generate explanations: on the basis of what criteria this or that treatment was prescribed.

The third category includes all kinds of information and reference systems. Representatives of this class are: Aarogya, Caresoft Hospital Information System, Medstar HIS, MMI Mediface, Clinical Rules, Droice Labs, ISABEL, Litmusdx [20, 21]. Such systems are based on various databases and medical guides. They have limited functionality and in fact are reference systems that help to check the compatibility of medicines, possible dosages, nosology, in which the drug is used, to output the doctor the treatment protocol according to the reference book, without taking into account the patient's personal data, reflecting the real clinical picture.

An analysis of existing systems in the field of support for prescribing treatment showed that at the moment there are no software solutions aimed at a wide range of diseases that help the doctor prescribe treatment taking into account the personal characteristics of the patient. Therefore, research on creating a software shell for creating decision support systems on a wide range of diseases is important task.

3. Platform architecture

In this section, an architecture of the platform for medication prescription is described. Itl is based on the ontological approach and consists of information and software components (Fig. 1).

3.1. The basic requirements and principles of creation

We will highlight the following main requirements for the formation of a specialized software shell (hereinafter referred to as the system) for prescribing medication:

- The system must be extensible, not depend on a specific disease (or group), field of medicine.

- This requirement is key, because it is clearly impossible to develop and maintain multiple different systems. Moreover, a doctor who should be assisted in making decisions by such systems cannot and should not use many different systems.
- Knowledge in the system should be formed and modified in its lifecycle by the domain expert (or expert groups) based on his or her own experience in the treatment of diseases (author's methods, if this is acceptable in a medical facility), or in accordance with accepted clinical guidelines.
- This requirement imposes, first, a requirement for the form of representation of knowledge about treatment (they must be understandable to experts), and second, for tools (editors) of their creation and maintenance (they must hide from users the features of knowledge representation languages, have an intuitive interface).
- Tools for creating knowledge bases, as well as ready for use the decision support system should be accessible to a wide professional community without any additional installation on user computers.
- To do this requirement the editor for formation of knowledge bases and the ready for use system should be implemented as cloud services.
- The system should prescribe treatment taking into account the personal characteristics of the patient, with detailed justification of the decisions made.

One of the solutions to the implementation of these requirements is the use of the ontological approach. If you have the appropriate editors (controlled by the ontology) it will provide clarity in the formation of knowledge, the possibility of implementing a single (unified) ontology-based solver, as well as the formation of a detailed explanation [22].

3.2. Conceptual architecture of the specialized intelligent platform for prescribing drug treatment

The platform includes information and software components (Fig. 1).

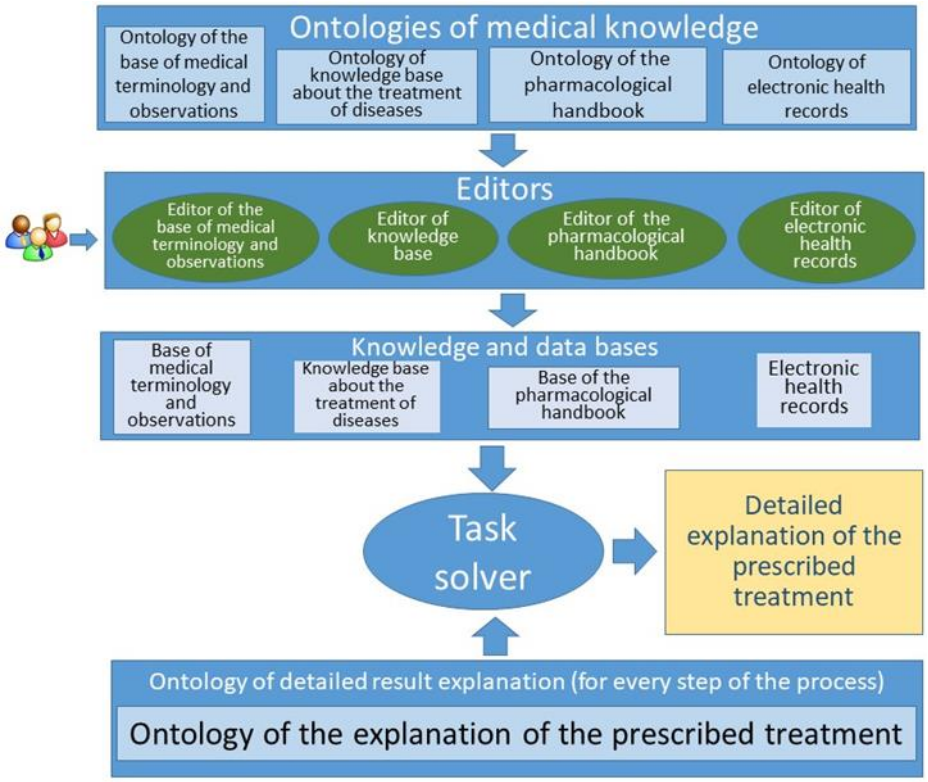

Figure 1: Conceptual architecture of the platform

Information components include ontologies, data and knowledgebase generated on their basis. Software components include knowledge and data editors, as well as a task solver.

3.2.1. Information components of the platform

To achieve this goal, a set of information components have been developed [23, 24]: the ontology of knowledge base about the treatment of diseases, which allows us to describe various models and schemes of drug therapy taking into account the patient's personal data, the clinical picture of the disease, and drug compatibility; the ontology of the explanation of the prescribed treatment; the ontology of the pharmacological handbook; the ontology of the base of medical terminology and observations; the electronic health record (EHR) ontology.

The ontology of knowledge base about the treatment of diseases allows us to create knowledge on the treatment of a particular disease or a certain group of diseases that have common pathogenesis principles, an etiological component or clinically important symptomatic manifestations.

Every element of the ontology includes a complex structured block of conditions, which allows us to describe in a formal representation the necessary clinical criteria that determine the conditions and its use in the treatment of a disease.

Active substance - a list of drugs from which one drug with the best characteristics for a specific clinical case is selected. Each drug is described by a group of terms (Option for prescribing) that define its clinical necessity (Fig. 2).

Figure 2: Fragment of the ontology of the knowledge base on the treatment of diseases implemented on the IACPaaS cloud platform (screenshot)

The ontology of the explanation of the prescribed treatment describes the structure of the explanation of the result of the system. The explanation generated on the basis of the ontology forms three main blocks: prescribed treatment (a set of active substances indicating the form, dosage - daily and course, as well as an explanation of what the purpose of each of the active substances is); rejected treatment - a set of rejected active substances indicating why a particular active substance was not prescribed; a set of active substances for which there was not enough initial data from the EHR, for example, information about diseases and the presence of allergies to medicines.

The ontology of the pharmacological handbook includes elements that allow you to describe the drug in the form of an International Nonproprietary Name (INN) or a fixed combination of INN, and to describe a section of specific pharmacological terms.

The ontology of the base of medical terminology and observations describes the structure of medical terms and observations used in practice, and the structure of terminology necessary for the integrity of the description of medical knowledge. Synonymy is used in the structure of this ontology. A feature, factor, and fact or event can have qualitative, quantitative, or composite values. If the value is composite, then it consists of many characteristics.

The Base of medical terminology and observations formed by the corresponding ontology is a universal resource, used for the formation of diagnostic and therapeutic knowledge bases in various fields of medicine. Currently, the base of medical terminology contains more than 27 thousand different signs and their characteristics.

The EHR ontology defines the structure for describing human health throughout his life. This structure allows you to describe all cases of medical care, preventive measures and promptly provide access to information about the examination, cases of in-hospital and out-of-hospital, sanatorium

treatment of the patient, emergency calls, contains a section on contraindications to the use of certain types of treatment for a particular patient and a list of intolerable drugs. A resource created on the basis of this ontology (EHR) allows doctors quickly find existing and add new information about all cases of providing medical care to a patient, and generate medical documents in an automated mode.

3.2.2. Software components of the platform

The software components include a task solver and the tools for editing knowledge and data.

The task solver is an ontology-oriented algorithm (ontological reasoner), which for the purpose of prescribing personalized treatment bypasses the declarative knowledge base about the treatment of a certain disease in accordance with the ontology and compares information from the knowledge base with the input information, which is the EHR. The goal of this algorithm is to find the elements (observations) in the EHR that affect treatment prescription in order to select the most effective therapy. A personified active substance is prescribed with an indication of its dosage, compatibility and characteristics of the course of treatment. A detailed explanation is also formed for why this or that active substance is prescribed / not prescribed and what observations need to be additionally carried out in order to prescribe the active substances necessary for a given disease.

The implementation of the solver is performed using a multi-agent approach and consists of two agents (root and worker agents). The root agent is a manager, it initializes (starts) the process via a message to the working agent, passing to it all the input information resources and finish it based on the messages from the worker agent. The work agent directly implements the main business logic. In accordance with the knowledge base about the disease, it analyzes the models of therapy, their types, goals, and treatment schemes at each step, checking the corresponding conditions, the values of which are analyzed based on EHR. As a result of this agent's work is an information resource with a detailed explanation of the prescribed treatment for the patient, or an explanation of why an active substance is not prescribed.

Tools for editing knowledge and data are presented by a number of editors (see Fig. 3). All editors are controlled by their ontologies. Editors' interfaces have three different types and are oriented to domain experts. The knowledge/data editor, automatically generated by the ontology editor generator, has the means to view data and knowledge with varying degrees of detail and in various forms, to control the correctness of the information entered, taking into account the restrictions defined in the ontology, the completeness of the formation of a knowledge base or data.

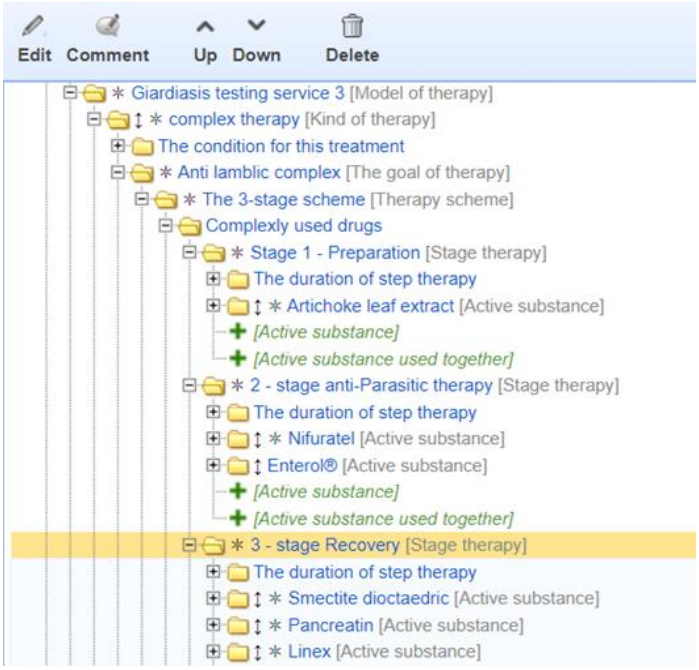

Figure 3: Giardiasis Treatment Knowledge Base Editor Interface

4. Results

The specialized platform for prescribing a personalized treatment of diseases has been implemented and it is available for use on the IACPaaS cloud platform (https://iacpaas.dvo.ru) [24]. Based on this platform some decision support systems have been implemented. Taking into account that creating a system is kept to creating the knowledge base, the following knowledge bases have been developed: infectious diseases - “Knowledge base for the treatment of Gardiasis” (Fig. 3), neurology - “Knowledge base for symptomatic therapy of cognitive impairment”, gastroenterology - “Knowledge base for the drug therapy of peptic ulcer disease of the stomach and duodenum” [23], hematology - " Knowledge base for the treatment of anemia in children" (see Fig. 4). Currently, the developed systems are being tested in medical institutions.

Figure 4: Knowledge base for the treatment of anemia

Fig. 5 present the EHR of a patient diagnosed with anemia and the formed treatment with the explanation. According to explanation, treatment was prescribed that corresponds to the goal of therapy "Activation of hematopoiesis", since only the condition was met.

Figure 5: EHR of the patient

The system of treatment of coronavirus infection in Chinese by methods of Chinese medicine was developed on the platform. Using the platform made it possible to deploy the system for use in a very

short time (the development task is only to formalize the knowledge base by experts using clear and convenient knowledge editors controlled by ontology). This system was developed at the request of the Association of Non-Governmental Medical Institutions, which includes 56 thousand private medical institutions from different provinces of China. The system was developed in early February 2020 for its operational use by doctors sent to the epicenter of the epidemic in Wuhan in February 2020 [26].

5. Discussion

The features of the developed platform, which differ it from other medical systems, are:

- orientation to a wide range of diseases; in order to develop a specific system, it is necessary to add knowledge about the treatment of the disease;
- all information resources are formed with the editors of knowledge/ data bases controlled by the relevant ontologies;
- the knowledge base is separated from the task solver, which allows domain experts to provide continuous improvement of knowledge bases without the participation of programmers (without changing the ontological reasoner);
- the unified ontology on which forms the knowledge bases about treatment planning and the ontological reasoner allows you to prescribe treatment for combined pathology with analysis of possible duplication of prescribed treatment;
- the ontology allows you to describe several models of the treatment for a disease that, with the accumulation of precedents, allows you not only to verify the knowledge base, but also to provide an analysis of the effectiveness of each therapy;
- the result of this system is not only treatment options, relevant personal characteristics of the patient, but also detailed explanation of why one or another active substance is prescribed/not prescribed, or the advice to the physician of the need to conduct additional examination for therapy prescription;
- the platform and ready-to-use system are implemented as cloud services. This allows you to increase the audience of users, as well as domain experts develop knowledge bases about treatment, regardless of their geographical location.

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