

# Cloud Environment for Development and Use of Software Systems for Clinical Medicine and Education

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**Abstract**—A review of modern software systems which solve different medical problems shows that there is a need for unified software-information environment which could provide access: for physicians to intelligent systems of decision support; for experts to knowledge bases and databases for their refinement and keeping in actual state; for students to simulators and training courses in different fields of medicine. Thus a concept of a cloud environment for development and use of a medical intelligent systems community is proposed. This environment concentrates medical information and software resources in a single virtual space and provides users with a wide access regardless of their geographical position. Information resources are ontologies (they define the structure of terms), knowledge bases and databases. Software resources are problem solvers (applied ones and system tools). Applied solvers are expert systems for decision support, case record editors, simulators, etc. System tools provide creation and management for information and software resources.

**Keywords**— *medical intelligent systems, cloud environment, ontology, knowledge base, observations base, disease, expert system*

## I. INTRODUCTION

A task of informatisation of medicine is one of the priority directions of development in Russian Federation. It can be stated that information technologies have touched almost every no medical institution by now. Most of the deployed systems organize and control their business processes. There are also systems for workplace automation. As it was pointed out in [1], medical information systems still do not provide physicians with enough help and support in decision making and do not always improve its quality. Most of deployed systems are “perceived by practitioners just as an additional duty, which task is to form statistical reports for work analysis and for making bills for insurance companies” [1]. At the same time physician knowledge must include information of many types: symptoms, syndromes, nosological forms of pathologies, etiologies, pathogenesis, clinic, disease diagnostics, medication, non-drag treatment, drug actions mechanisms, methods of clinical use of medical supplies, methods of preventive measures and patient

rehabilitation. It is obvious that one cannot learn and remember the whole range of necessary knowledge as not only the volume of knowledge is great but knowledge itself is always changing [2]. Only computer systems for support of medical decision making, which are based on expendable (by a society of experts) knowledge bases and databases, are capable of this. Considering an importance and relevance of a task of intelligent support for medical practice, a direction of the Russian Federation Government #2769-p (29-dec-2014) clearly states: «... it is recommended to create and elaborate information systems for support of medical decision making at regional levels ...». Medical professionals and lecturers of world health institutions also note that a no less important task is to create medical educative (tutor) systems (teachware) and simulators for diagnostics and treatment of virtual patients [3].

Some progress can be noted in the field of development of medical intelligent applications. Systems [4-16] have functions for diagnosing a separate disease or a set of diseases. Systems mentioned in [5, 7] are capable of advising about drug usage limits when accompanying diseases are present during prescription phase of treatment. The system in [10] can be used for educational purposes.

One drawback of these tools is that they are scattered – a physician has to install several different systems, which differ in functions, interfaces, requirements to software and hardware environment. It complicates their use. Another shortcoming of many systems is that they (and their knowledge bases and databases) are not made available through the Internet for a wide range of experts for viewing, elimination of errors and inaccuracies, continuous and quick editing (in compliance with procedures for control of integrity and consistency). It can be noted that there is no unified information-software environment in Russian Federation today, which meets modern requirements of medicine and can provide access for physicians to intelligent systems for decision making; for students to training simulators and courses of studies in various fields of medicine; for experts to keep knowledge bases and databases updated.

The paper describes a concept and main components for information-software environment, which is based on the cloud computing technology and intended for creation of community of medical intelligent systems of various purposes.

## II. FUNDAMENTALS FOR CREATION AND FUNCTIONING OF MEDICAL CLOUD ENVIRONMENT

The following fundamentals for creation and functioning of the medical cloud environment are marked out:

- information resources (databases, knowledge bases, ontologies) are developed and managed separately from intelligent systems which process them;
- information resources have declarative representation and are formed/modified on the basis of a metainformation (ontology) by both – experts and intelligent systems;
- information resources have a unified format of internal storage for simplification of access to their content;
- information resources and software components are available via the Internet – that allows collaborative development and management by various concerned societies of users;
- metainformation (ontology), which is used for creation of information resources (knowledge bases and databases), must be unified for all sections of medicine;
- software components are developed for solving a class of tasks, which is defined by a certain metainformation;
- information resources are created for reuse by different classes of medical problem solvers;
- terminology, which is used in contents of information resources, is generally accepted and understandable by medical experts;
- information, which is common for different sections of medicine, is stored in separate reusable resources;
- information resources are stored in accordance with the hierarchy that is intuitively understood by experts.

The IACPaaS platform [17] might be taken as a tool for implementation of the cloud computing medical environment. It is an information-software Internet platform for providing support in development, management and remote usage of applied (intelligent) multi-agent cloud services (problem solvers) and their components.

## III. AN ARCHITECTURE OF THE MEDICAL CLOUD ENVIRONMENT AND ITS COMPONENTS

### A. General Information

In general case the cloud environment consists of information and software components (Fig. 1). The first ones are: ontologies, databases, knowledge bases. Ontologies define the structure of terms for databases and knowledge bases [18-21]. Software components are applications – applied problem solvers and system solvers (tools). A solver

is constructed of agents of various purposes, which exchange messages. Messages are formed by templates. Applied solvers are decision support systems, case-record editors, software simulators. Tools provide creation and management of information resources and software components. The latter are gathered in a library of reusable components of solvers. It contains agents and message templates that are (and can be) used in different applications (problem solvers).

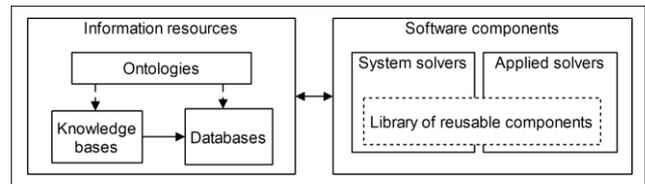


Fig. 1. General structure scheme of medical cloud environment

### B. Information resources

In accordance with the ideology of the IACPaaS cloud computing platform and with the technology for creation of viable intelligent cloud services the development of knowledge bases and databases is performed on the base of metainformation. An important requirement for metainformation is to provide its universality for different sections of medicine and its reusability in problem solvers.

The following ontologies are implemented by now: *the ontology for diagnostics of acute diseases* [22, 23], *the ontology for diagnostics of chronic diseases* [24], *the ontology of treatment* [25], *the ontology of formulary* [25], *the ontology of case record and the observations ontology* [26].

Knowledge bases are grouped into sections which correspond to fields of medicine: therapy, surgery, urology, ophthalmology, etc. Each section includes subsections. For example, *therapy* section contains the following subsections: *respiratory diseases, diseases of the digestive system, heart and vascular diseases*, etc. Each subsection contains knowledge bases with information about disease diagnostics and knowledge bases with information about disease treatment (Fig. 2).

Each knowledge base with information about diagnostics (e.g. the base of knowledge about diagnostics of bronchial asthma) includes a formal description of its possible causes, required conditions for its genesis and clinical picture. The latter one contains description of clinical manifestations of signs, which are based on correspondent observation data. Bases of knowledge about treatment include: medication, surgical and rehabilitation treatment. Each base of knowledge about treatment (e.g. the base of knowledge about treatment of stomach ulcer disease) includes a formal description of groups of drugs and variants of their usage in various clinical cases.

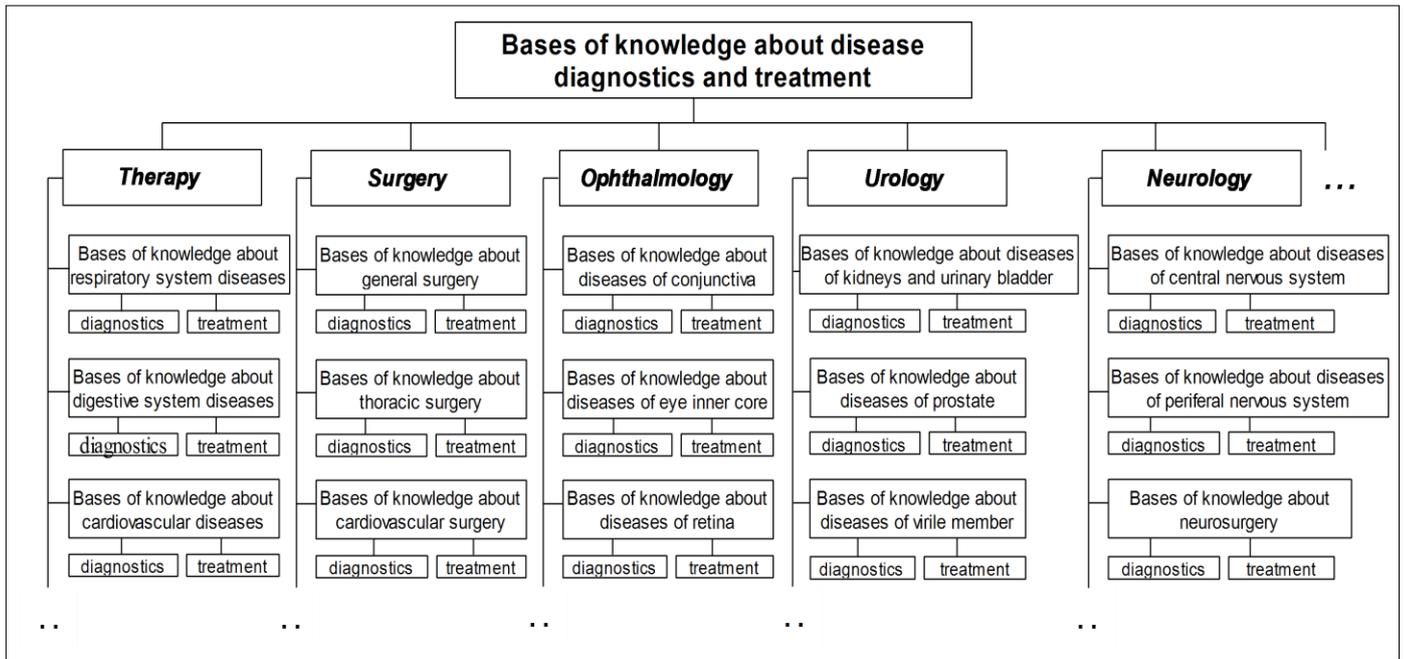


Fig. 2. Sections of medical cloud environment

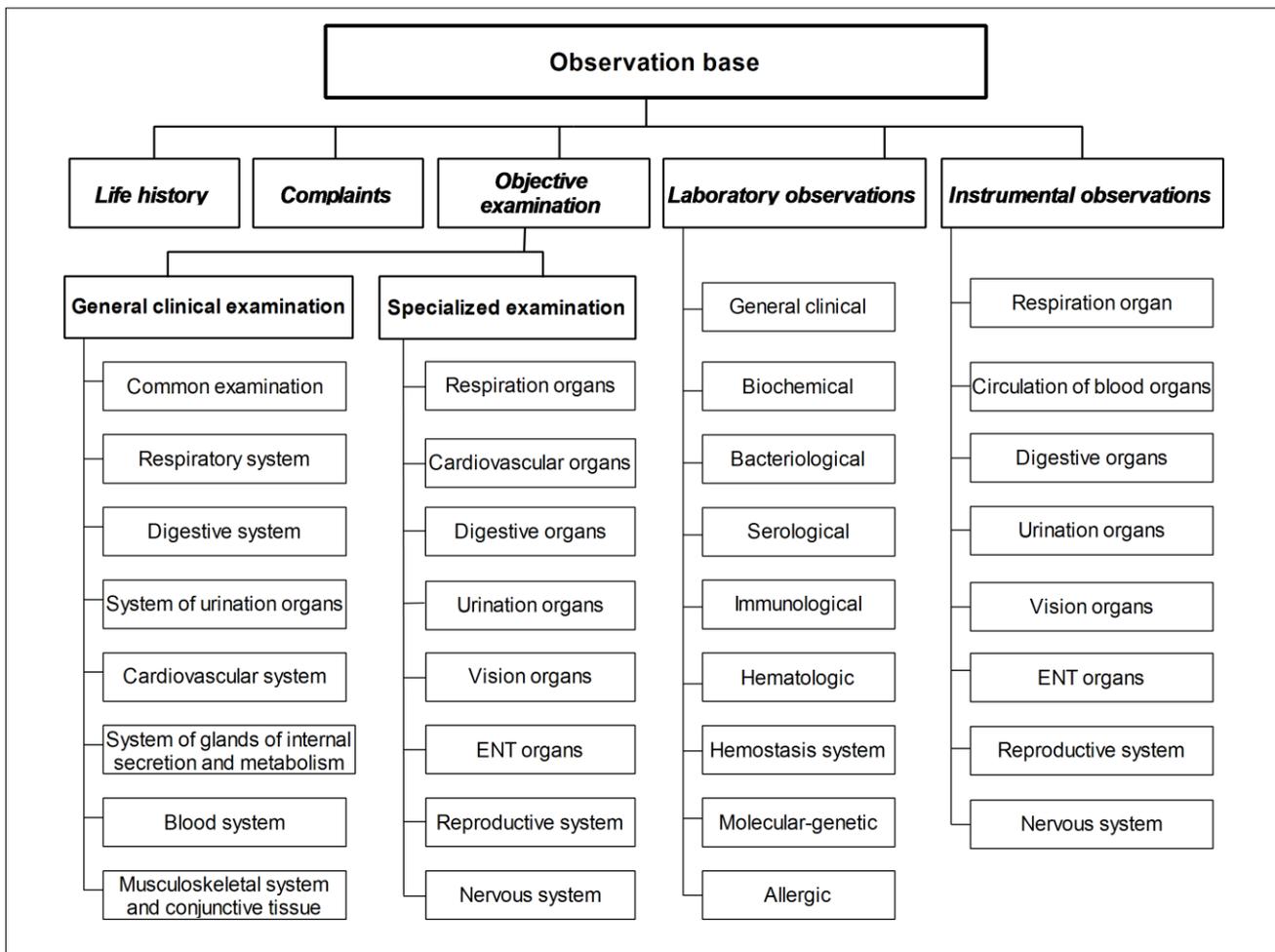


Fig. 3. Structure of Observaion base

Databases are formed in accordance with correspondent ontologies (in same way as knowledge bases are). Databases which describe observations include partitions which are common for a traditional case record structure: life history, complaints, objective examination, laboratory and instrumental examinations. Objective examination consists of two sub-partitions: general clinical examination and specialized examination. Sub-partition general clinical examination consists of the several groups of observations – see Fig.3. Specialized examination includes groups of observations with formal description of uncommon and pathognomonic signs that are used by surgeons, neurologists, urologists and other specialists.

C. Software components

Software components include system tools and applied solvers. First ones are problem-independent and are granted by the IACPaaS platform. They are: *the extensible editor for directed graphs of information*, *the editor for directed graphs of meta-information* [27], *the solver editor*, *the agent editor*, *the agent and message code template generator*, *the agent and message byte-code loader* [28], and a special medical solver – *the inductive former for base of knowledge about disease diagnostics* (on the basis of a case record archive) [29]. It is based on the ontology for diagnostics of acute diseases and it lets one to form well-interpreted (understandable to experts) knowledge bases.

Applied solvers are divided into four classes:

- data and knowledge input systems (they are based on *the extensible editor for directed graphs of information*);
- intelligent systems for disease diagnostics;
- intelligent systems for treatment prescription;
- software training simulators.

The fundamental feature of the proposed cloud environment is that all classes of medical systems might and should use a shared set of information resources. E.g., *the expert system for diagnostics of acute diseases* and *the medical software training simulator for diagnostics of acute diseases* use the same bases of knowledge about diagnostics of diseases (based on *the base of observations* and of the correspondent ontology). In addition, the first solver uses *the case record archive* and the second one uses *the base of training tasks* (see Fig.4).

Moreover, medical solvers might and should (as much as possible) be constructed of reusable software components – computational and interface agents, message templates.

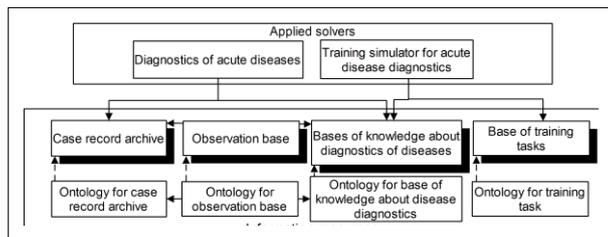


Fig. 4. Example of reusing of information resources

**Example 1.** *The expert system for diagnostics of acute diseases* (which works with the case record archive where the diagnosis is unknown) and *the medical software training simulator for diagnostics of acute diseases* (which works with diagnostic task where the diagnosis is known) use the same agent which performs checks of some hypothesis (about a disease) for some case record.

**Example 2.** *The interface controller agent of the extensible editor for directed graphs of information* is also reused in: *the editor for base of knowledge about diagnostics of a disease*, *the editor for case record archive* and other information editors. This agent interacts with others using the same message templates.

Each solver of the IACPaaS platform is intended to be reusable with various information resources that have the same ontology as a basis. The combination of a solver and a particular set of information resources is called a service. Thus, a user who wants to perform diagnostics of various acute diseases should construct several services with the use of different knowledge bases (*the service for diagnostics of ophthalmological diseases*, *the service for diagnostics of cardiovascular diseases*, etc) and a single solver.

IV. CONCLUSION

The paper describes the cloud environment for creation of the community of medical intelligent software systems. The relevance of this task lies in the need for concentration of information and software resources for development and use of various types of intelligent medical software systems in a single virtual space. Another goal is to provide an access to such systems for physicians and students regardless of their geographical position. The third solved problem is providing an access to information resources for highly-qualified experts for keeping knowledge up to date.

A set of components for the medical cloud environment has already been implemented by authors and implementation of others is in progress.

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