What technologies should be used to create artificial intelligence systems? Subjective view at the problem

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***Abstract*—This paper provides an overview of the current state in the development of artificial intelligence systems. An attempt is being made to answer the question: what should be the perfect artificial intelligence system? The requirements to the tools for creating artificial intelligence systems are identified and substantiated.**

***Keywords*—artificial intelligence, shells, machine learning, knowledge bases**

I. Introduction

Artificial intelligence as a scientific direction was created in the mid-50s, and the main research conducted by scientists were related to knowledge representation models and methods for solving intellectual tasks. First of all, it became obvious that problem-solving technologies based on the algorithmic approach are not suitable for solving creative or intellectual problems, so specialized technologies are needed to create systems of this class.

During the lifetime of artificial intelligence (AI) as a scientific direction, a number of models of knowledge representation and methods for solving intellectual problems were created. The development of AI systems was supported first by specialized programming languages, then by universal tool, as well as problem-independent and specialized shells. Typically, AI system development tools and shells were intended for knowledge-based AI system design, while AI system development based on other methods were much more poorly supported by specialized tools. However, the situation has changed dramatically in the past few years. Numerous frameworks and libraries have entered the market that support the neural network approach to creating systems of this class. They are convenient, well implemented (they are developed by the leaders of the IT industry), and have a low enough barrier to entry for developers. As a result, AI has often been reduced exclusively to the neural network approach, and the approach based on knowledge is often characterized as outdated, lost its relevance. Is that so? What should AI technologies be, what properties should they have? The article contains the author's opinion on all these issues.

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II. Current state of artificial intelligence system development technologies

The first scientific research in the AI field led to the creation of a number of specialized programming languages, such as PROLOG, LISP, SMALLTALK, FRL, Interlisp, etc. These languages have many advantages, however, their use has shown a high complexity of creating software systems, which, as noted in [1] has led to fact, the development of intelligent systems has become almost inaccessible.

Together with the development of knowledge representation models and methods for solving intellectual problems, universal tools and specialized software shells were actively developed, mainly for creating systems with knowledge bases. Typical representatives of this class of systems are: IACPaaS, OSTIS, AT-TECHNOLOGY, Level5, Object, G2, Clips, Loops, VITAL, KEATS, etc. [1], [2], [3], [4], [5]. Significant differences between various tools are related to the level of instrumental support, development technologies, the formalisms used to represent knowledge, the methods for their formation and debugging, the used inference machine, and user interface design tools. Specialized shells designed to solve problems of a certain class are also widely used. The main advantage of this class of tools is significant reduction of development time and maintenance of software. The main disadvantage is limitations of the area of use.

Approximately from the last decade of the 20th century and the first of the current one, active development has received another direction of AI, - machine learning and big data analysis. This is due to the development of new computing platforms, a significant increase in their performance, as well as the creation of new theoretical

models and architectures, primarily based on neural networks. To date, we can see a boom in neural networks, that foster a number of tools - frameworks (for example, Deeplearning4j, TensorFlow and Theano, PyTorch), specialized libraries (e.g., Keras, PuzzleLib, Caffe, etc.) allows developers to create, train, test, and deploy a network of any complexity [6], [7], [8]. However, it is very important that the use of libraries for machine learning significantly save development time, thereby eliminating the most difficult stages of its development. Many machine learning libraries are free and available, which has led to significant progress in this area in recent years. In addition to tools, developers have access to ready-made, already trained, neural networks for solving various problems.

Unfortunately, the boom in the field of neural networks, as well as a significantly increased interest in AI, has generated not only a huge number of "experts" in this field, who, taking a ready-made model, data and running training, get perhaps even a good solution for simple cases, consider themselves experts in this field and reduce AI exclusively to a neural network approach. Moreover, they actively promote, and not without success, the assertion that the approach based on knowledge bases (while they usually mention only the production model of knowledge representation), hopelessly outdated, in modern AI systems it is used less and less and tends to complete extinction.

Estimating the current state of AI technologies, the following can be stated:

1. AI technologies based on knowledge bases continue to be developed and used. These technologies have evolved significantly. According to a study published in [2], the most popular production model of knowledge representation in the 80-90 years is losing its popularity (according to estimates in [2], the number of systems with this model of knowledge representation has decreased by about 4 times), giving way to systems with other models of knowledge representation. The trend to decrease production can be explained by the expansion of the available tools that support other representation models that are most appropriate to the domain and tasks for which the production representation is not convenient. First of all, it is an ontological approach to the representation of knowledge. The most well-known technology is Protege, which supports the object-oriented representation model [9], as well as the relatively new (compared to Protege), IACPaaS [10] and OSTIS [5] technologies, which support the semantic model of knowledge representation. These three technologies are developed by research teams, which, on the one hand, ensures that the proposed technologies correspond to the current level of scientific research in this area and their continuous improvement, on the other, these technologies, admittedly, lack a "beautiful wrapper", context assistance systems, and other marketing elements, which are important for promoting technologies "to the masses". Research teams have neither the experience of promoting software products, nor the human resources.

2. Machine learning technologies, primarily neural networks, are currently leading. It is neural network technologies that are often declared as modern artificial intelligence technologies in contrast to knowledge-based technologies. Yes, in solving some problems primarily related to the analysis of images, text, they demonstrate impressive results, their use is undoubtedly justified for a number of applications and, importantly, world leaders of the IT industry made it easier for developers to use them. However, it is still difficult to agree that the neural network approach is a modern AI that simulates, albeit simplistically, the work of the human brain. Do not forget that a neural network is a fitting of a function implemented by a neural network for training data by selecting the parameters of this function. This is still very little like how the human brain learns.

Accepting and understanding the importance and need of all available technologies today, however, it is worth noting that the two types of technologies work very poorly together, despite some attempts to integrate them and imitate only certain functions of the natural intelligence. Therefore, the scientific community faces an important task of determining the future of artificial intelligence technologies and their development directions.

III. What is the perfect artificial intelligence system

In order to answer the question of what the perfect AI system is, it is necessary to understand what properties, abilities the natural AI has (the author understands that the perfect systems do not exist, in this case, the perfect requirement should be understood as a softer requirement - as close as possible to the perfect one). V.K. Finn listed 13 such abilities [11]. Here's their compressed enumeration: the discovery of the essential in the data; the creation of "goal-plan-action" sequences search for assumptions relevant to the purpose of reasoning; ability to reason: conclusions as consequences from assumptions; conclusions that do not follow directly from assumptions: conclusions by analogy, inductive generalizations of data, conclusions by explaining data (abduction), solving problems through various cognitive procedures; the ability to estimate knowledge and action; the ability to explain - the answer to the question "why?"; argumentation when making a decision; recognition as the answer to the question "what is this?"; the ability to learn and use memory; the ability to integrate knowledge, to form concepts and theories; the ability to refine unclear ideas and transform them into precise concepts; ability to change the knowledge system while learning and changing the situation.

The perfect AI system should have all these properties, and as V.K. Finn notes, that not all natural intelligence functions can be automated, some of them can be implemented only through "man-computer" interaction. Thus, if we really want to create an AI system, it must have at least a subset of these properties. It is important to note: in natural intelligence the result of one (or several) cognitive activities is always (!) integrated (consistent) with other types of cognitive procedures.

For example, if we have knowledge in an area and have an object with a set of attributes, then we, on the basis of our knowledge system, can make some logical inference (depends on the problem being solved). It is possible that the attributes of this object are not consistent with our knowledge system. We have a precedent and need to understand what to do. Next, we make some decisions (possibly wrong). When it is necessary to draw a logical inference about a certain object again, we proceed as follows: draw a conclusion based on our knowledge system, or compare an object with an existing precedent to make a decision (a reasoning by analogy). The accumulation of precedents with a known result (learning) creates a situation where a person needs to correct his or her knowledge system, etc. , so it is important that both knowledge (in the computer system is a knowledge base), and precedents (data) are clear to the person. Thus, terminology must be defined, which is understandable and accepted by a certain community, and the connection between cognitive procedures should be "seamless". Such system can claim to be called an AI system. In this case, the knowledge obtained either from a person or as a result of machine learning will be integrated into the knowledge base, which will be continuously improved. Knowledge itself will be available to both the AI system and the person who will be able get new knowledge (using the updated knowledge base) in a way that is not accessible to the computer system. As in real life, a person, using a computer, makes calculations, receives information from external devices, respectively, the AI system must "understand and accept" information from external devices.

Thus, if we are talking about the AI system, it should support a subset of cognitive procedures: the inference of consequences from assumptions - working with the existing system of knowledge, reasoning by analogy (this function is often overlooked and underestimated, although in real life, natural intelligence, it plays a significant role), learning as a way of correction the knowledge system and obtaining new knowledge, the ability to explain and justify their actions. At the same time, all procedures should be understandable to a person (described in his or her system of concepts), and the connection between different types of cognitive procedures should be a natural "seamless" way to carry out their "circle" with the participation of a person.

IV. Requirements for artificial intelligence system tools

Here are the basic requirements for AI tools.

Support the development of several intellectual activities with "seamless" integration.

This requirement is discussed in the paragraph above. It is undoubtedly fundamental and means that the tools for creating AI systems should be much richer in their functionality than frameworks and tools designed for systems of other classes, because they should allow developers to create knowledge bases, ontologies, solvers, focused on logical inference from the knowledge base. Using them it is possible to describe the algorithms of learning, also oriented to the knowledge bases, reasoning on precedents, generation of explanations and other cognitive activities. Is it hopefully to develop different types of cognitive activity with a set of tools? The answer is yes, you can, but in this case it is difficult to integrate technologies, you need to create additional software modules that provide a link to them into a single whole. And this link is not reduced to a set of formats. It is important that the results obtained are embedded in all other cognitive procedures.

Availability of means to support the viability of the created systems and their development tools.

This requirement is vast and, in fact, includes many other requirements. Its implementation, like the previous requirement, indicates the maturity of the development. This requirement should be given key attention both when creating tools and AI systems based on them. Unfortunately, it is common practice for most implementations to declare the functionality of a software to demonstrate results. However, developers find it difficult to list the mechanisms providing the viability of the created system. But modern statistics state that the process of evolution, maintenance of the system after implementation of its release in terms of labor costs is many times higher than the stage of actual development.

In general, this requirement should be provided by the following solutions:

- declarative representation of components, shifting the efforts of developers from programming to designing software components;
- automatic generation of software components;
- creation of technology that separates competencies among developers with sequential or parallel work on the formation of models and components, by providing the architectural integrity of the project;
- availability of tools for intellectual support of development of software component, a visual and understandable representation of components to software developers.

In the implementation of these requirements key role belongs to the tools with which the system is created. The longer the life cycle of any system, the more

obvious the need for developers to improve their adaptation mechanisms due to changes of user requirements, domain, and operating conditions. It is important that users of the tool can also improve it, so the means for expanding the tool should be as close as possible to the means for developing the AI systems themselves, and the complexity of this process is comparable to the complexity of developing the corresponding components of the AI systems.

Integration with external software and components.

The AI system should be able to interact with third-party systems based on different interaction models.

Collective development.

The AI system development requires the participation of many specialists, so the tool must have the means to ensure the collective development of system components, including collective development one component (for example, a knowledge base can be developed by several experts). To do this, a hierarchical system should be provided for managing access rights to components, monitoring changes, coordinating between components through user accounts and cloud tools for creating and managing components.

Support for the creation of evolving shells, knowledge portals and/ or ecosystems in various domains based on universal tools.

It is known that there are two approaches to creating tools: universal tool complexes designed to create a wide class of software and specialized tools for development of either a class of tasks or a set of tasks in a particular domain. The evolution of the development of two opposite approaches has shown that these approaches do not conflict with each other, if there are specialized tools, this is preferable for developers due to a significant reduction in the complexity of creating systems of this class, which is supported by specialized tools. It is important that development of such shells or ecosystems is supported by universal tools for permanent modification and evolution of systems based on it.

V. Discussion

The development of AI systems is a complex and time-consuming work that requires the participation of specialists in various fields and domains - programmers, cognitive scientists, interface designers and domain experts.

We have to admit that the scientific community has not yet given a clear and understandable definition of AI systems, which has given rise to many interpretations and definitions of a wide range of "experts".

The situation requires a serious redefining and consolidation, first of all, of the scientific community.

1. It is important to determine what an AI system is. It is justified to give this definition, based on the range of cognitive abilities of the natural intelligence. As a basis I propose to take the list proposed by V.K. Finn (perhaps a little modified). In this case, it is easy to understand the "level" of the intelligence of the AI system. For example, a system based on neural networks implements (imitates) one function of natural intelligence - learning, a system based on knowledge base, implementing the search and criticism of hypotheses with the generation of explanations - three functions of natural intelligence, etc. In this case, it is clear what functions the AI system lacks and what needs to be further implemented to increase its intelligence.

2. Technologies for AI system development. It is obvious that they should develop in two directions - the creation of universal tools and specialized, taking into account the specifics of the architecture, methods and models of AI, as well as having a set of tools for automating development. In this case, the scientific community faces a significant challenge in the development of universal and specialized methods of imitation of cognitive abilities providing coherence with other cognitive abilities, and technology developers have to provide instrumental support for their implementation. An important task is the transition from particular models to their generalization (see Fig. 1 Evolution of development of diagnosis process ontologies of Intelligent System Laboratory of Institute of Automation and Control Process FEB RAS).

3. Moving from demonstration prototypes to viable implementations. This requirement is important for all types of software systems, but it is especially important for AI systems. It is obvious that neither the knowledge base, nor the learning process, nor the realization of other intellectual functions can be complete and require permanent revision. Therefore, it is proposed to evaluate the implementation of AI systems not only from the point of view of listing simulated cognitive procedures, but also from the point of view of mechanisms implementing their viability. There is undoubtedly a significant role of tools for the creation of the AI system.

4. Use terminology. Today, there is a wide range of terminology used. The same concepts are called and interpreted differently, and vice versa. It is necessary to bring it (at least within the scientific community) to a common interpretation and designation.

5. Development of tools (universal and specialized). In my opinion, different implementations, different tools and approaches to creating tools for implementing AI is a positive factor in the development of AI. It is unlikely that in the near future we can expect "Babel", if we do not take into account the libraries and frameworks for creating systems based on neural networks, implementing, as discussed in this article, only one of the cognitive abilities. Creating tools is an extremely difficult and, unfortunately, often very thankless job that requires understanding both your own vast experience in this

field, and analysis of the literature to generalize methods and models in order to create universal or specialized tools that implement them. Thus, sharing the experience of 30 years of development of the Protege system, M. Musen stated that new scientific results, the availability of alternative / competing systems and tools, feedback and user requests - these are the main drivers of the development of the Protege system [9]. Another issue is that today tool systems, even those created within the same professional community (IACPaaS and OSTIS platforms), although in different countries, supporting a very similar list of basic requirements and key principles of development, do not support compatibility with each other. At the same time, both platforms have already accumulated a large range of reusable modules, components and implemented systems. For example, the IACPaaS platform has more than 200 active developers, and for example, an ecosystem created on its basis for solving a complex of intellectual problems in practical medicine and education [12], see Fig. 2, contains a terminological base of more than 27 thousand concepts, their properties and values, ontologies for diagnosis, monitoring, treatment of diseases (which is important independent of the section of medicine), knowledge bases only for the diagnosis of diseases containing more than 100 thousand vertices (knowledge bases have a semantic representation), as well as knowledge bases for drug and rehabilitation treatment, problem solvers for decision support systems, computer simulators, and other reusable components. Therefore, it is important to create an interested community of developers of AI tools and applications, which would develop a set of requirements for compatibility and integration of various types of tools and application systems (and, perhaps, a list of the main properties for which you need to compare tools with each other).

6. Intellectual property. This issue is also quite relevant and topical. It is important to preserve the intellectual property of knowledge in knowledge bases, services, and their components.

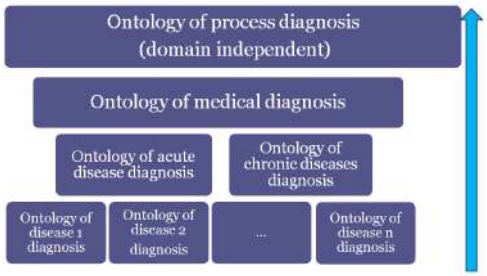

Figure 1. Evolution of diagnosis process ontologies

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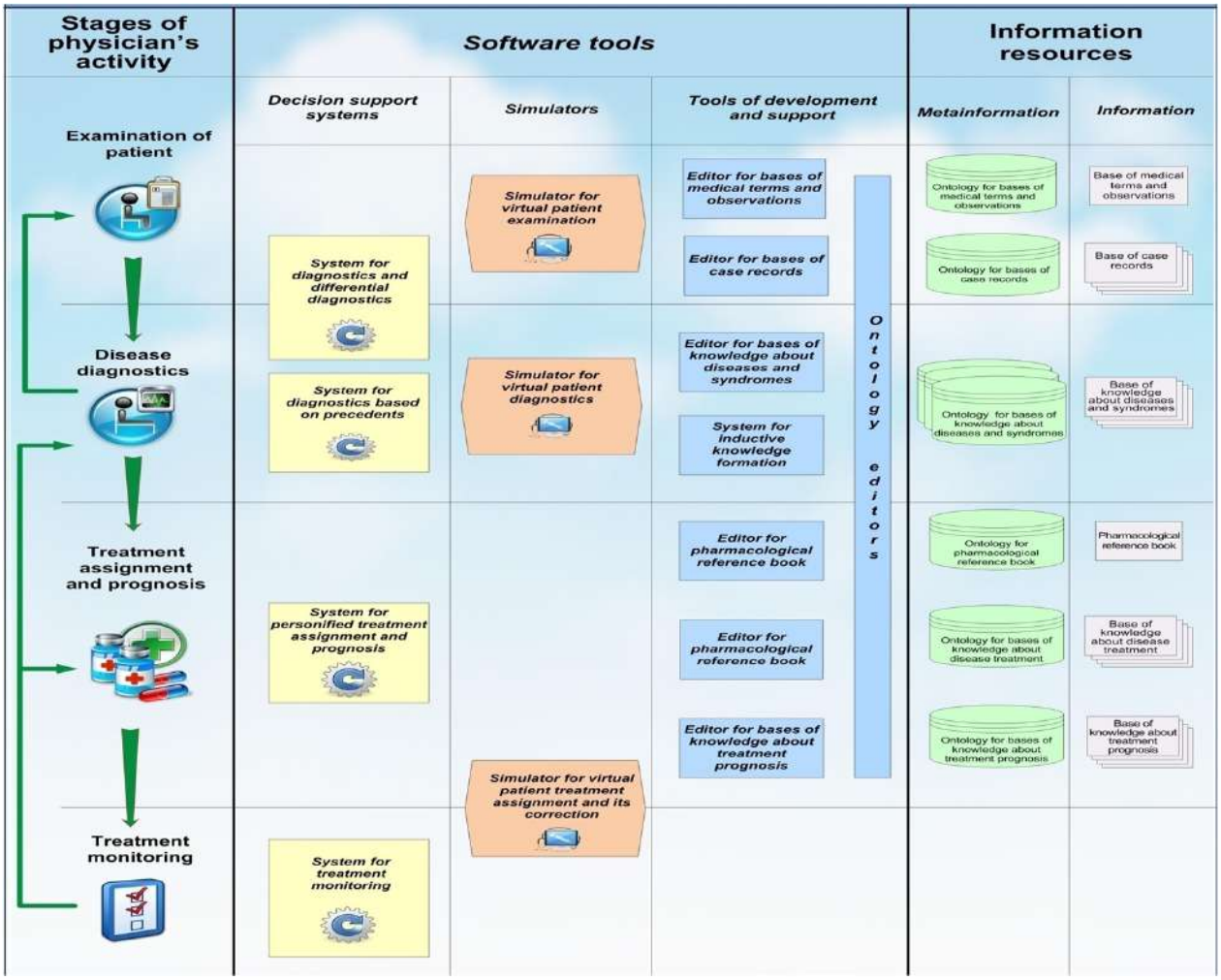

Figure 2. Cloud infrastructure for creating AI systems in medicine

Какими должны быть технологии для создания систем искусственного интеллекта? Субъективный взгляд на проблему

Грибова В.В.

Искусственный интеллект как научное направление возник в середине 50-х годов, и основные исследования, проводимые учеными, были связаны с моделями представления знаний и методами решения интеллектуальных задач. Прежде всего, стало очевидно, что технологии решения задач на основе алгоритмического подхода плохо подходят для решения творческих или интеллектуальных задач, поэтому необходимы специализированные технологии для создания систем такого класса.

За время существования искусственного интеллекта (ИИ) как направления, был создан ряд моделей представления знаний, методов решения интеллектуальных задач. Технологически это поддерживалось сначала специализированными языками программирования, затем универсальными инструментальными системами и проблемно-независимыми и специализированными оболочками. Как правило, инструментарий для разработки систем ИИ поддерживал проектирование систем ИИ на основе знаний, разработка систем ИИ, основанная на других методах, гораздо более слабо поддерживались инструментально. Однако в последние несколько лет ситуация коренным образом изменилась. На рынок вышли многочисленные фреймворки и библиотеки, поддерживающие нейросетевой подход к созданию систем такого класса. Они удобны, хорошо реализованы (их разработкой занимаются лидеры IT-индустрии), имеют достаточно низкий порог вхождения для разработчиков. В результате ИИ зачастую стал сводиться исключительно к нейросетевому подходу, а подход, основанный на знаниях, многие характеризуют как устаревший, потерявший свою актуальность.

Так ли это? Какими должны быть технологии ИИ, какими свойствами обладать? Данная работа содержит мнение автора по всем указанным вопросам.

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