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A Core of Robotics Intelligence. A "Green Button" Idea

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1 ABSTRACT

The report provides an overview of AI methods and tools and of their applicability for creation of robot's intelligence. By a term "robot" we simultaneously refer to a decision support system in a form of an autonomous device (a traditional robot) and to some system presented in the form of special software that implements the functions of an intelligent assistant. The totality of works on AI can be divided into two areas, two types:

- imitation of human intellectual activity;
- decision support, autonomous decision making based on inference (usually first-order predicate algebra), or other tools.

Our company deals exclusively with systems of the second type.

Structure of the paper:

(1) An overview of AI: pattern recognition, machine learning, data meaning, neural networks, singular value decomposition (SVD). Here we discuss the advantages and limitations of the most well-known approaches in the field of applied AI methods today.

(2) Our experience in AI: knowledge base, ontology, inference machine, scenario approach, ontomodeller, Protege 2000. A brief history of the application of AI methods in our company since the late 90s of the last century is presented.

(3) Tactical situation analysis. In our systems, the concept of a tactical situation is the basis for the application of AI in real-time systems and in monitoring systems for various purposes. A tactical situation is a basic concept for determining the reaction to external circumstances and conditions that have arisen for a robot that ensures the fulfilment of a certain mission.

(4) Smart city applications. Developed within the framework of the European CRISALIDE project, an intelligent decision support system in the interests of a smart city, is one of the options for implementing basic AI technologies in the interests of urban governance.

(5) Future work: RIC technology, discussion: a "Green Button" idea. Based on our experience of theoretical and technological research, a technology system is proposed, a technological platform that can be called a core of robotics intelligence (RIC). This platform allows you to form a full cycle of intelligent control of the robot:

- obtaining data on the external environment (robot environment) from various sources, own and external;
- evaluation of options for fulfilling one's own mission and making a decision (close to the optimal solution);
- monitoring the implementation of the decision;
- proofreading of the solution if necessary;
- making a decision on the completion of a mission formed for a robot, or a general system for which a decision is made on automatic control without involving (directly) a person.

Accumulation of experience and self-training based on the analysis of tactical situations and the results of decisions made. We call this idea a "Green Button" idea.

Keywords: robotics, planning, artificial intelligence, smart city, green button idea

2 INTRODUCTION

The history of the practical application of AI methods and tools in our company goes back more than 20 years. During this time, we have formed a system of technologies, including in the field of AI, implemented applications in the interests of marine monitoring systems and Smart City. Among the AI tools used by our company, the following should be noted first of all: ontology system, expert systems (knowledge bases, inference machines), scenario system and singular value decomposition (SVD) method. According to our experience, the application of AI was carried out in two stages: during the development of applications and during their operation. All this allowed us to form a relatively small set of AI technologies in the form of a platform on which you can develop applications of various scale and purpose.

Currently, the entire set of works united by one name — AI, can be divided into two large groups. The first group – which formed this scientific direction – is an attempt to replicate the intellectual functions of the human brain. Despite great efforts in this direction, the progress is very modest. The second group is the endowment of applications or robotic complexes with intellectual functions based on formal logic and other approaches. It is safe to say that all of our AI developments belong to the second group.

During the period of our company's activity, which is since the early 2000s, we have developed a number of hardware and software systems, including tools and methods of artificial intelligence. Based on our experience in the development, production and exploitation of our products, it was concluded that there was a need to create some kind of intellectual core, which could be scaled over a wide range, namely from a micro-robot to large organizational and technical systems. For such a wide range of manufactured systems, we have an invariant representation of our technologies and development tools. Therefore, we can say with confidence that we have some basic core, which is the intellectual basis of all our products. The main motivation and the main idea behind the development and implementation of RIC is the maximum automation of the application of our products in the interests of the end user, a “Green Button” Idea. Let's take a look at the main elements of RIC and some examples of its implementation.

3 AN OVERVIEW OF AI

In the last decade, AI has received a “second wind” after decades of oblivion, when hopes for its widespread use and replacement of people's intellectual activity actually failed (70s of the last century). The revival of AI is due to the following factors: the sharply increased computing capabilities of modern computers and the rapid development of the global Internet. The modern power of computers has made it possible to implement complex algorithms and process large amounts of data. Widespread access to the Internet has dramatically increased the number of users of AI applications, such as voice analysis, pattern recognition, and search for useful information. The whole set of works that is of interest to us can be reduced to the following, fairly well-known, areas in the field of AI: Pattern recognition, machine learning, data meaning, neural networks, singular value decomposition (SVD). It is not possible to analyse the whole variety of works and applications in AI within the framework of this article. We will briefly review only those that we have explored as a platform for practical applications.

3.1 Pattern Recognition

Pattern recognition is the automated recognition of patterns and regularities in data. It has applications in statistical data analysis, signal processing, image analysis, information retrieval, bioinformatics, data compression, computer graphics and machine learning. Pattern recognition has its origins in statistics and engineering; some modern approaches to pattern recognition include the use of machine learning, due to the increased availability of big data and a new abundance of processing power. These activities can be viewed as two facets of the same field of application, and they have undergone substantial development over the past few decades“ [Wikipedia]. This idea works well when we have a large statistical sample of initial data. Typically, millions of test images are required. Difficulties arise for rare phenomena when one attempts to use expert, formalized knowledge.

3.2 Machine Learning

Machine learning (ML) is a field of inquiry devoted to understanding and building methods that “learn” – that is, methods that leverage data to improve performance on some set of tasks.[1] It is seen as a part of artificial intelligence. [Wikipedia]. Just like Pattern recognition, this idea works well for cases where we

have a large statistical sample of initial data. The main drawback is the lack of interpretation of the results obtained. The main advantage of this method is that a decision is made that was not predetermined in advance.

3.3 Big Data

"Big data primarily refers to data sets that are too large or complex to be dealt with by traditional data-processing application software. Data with many entries (rows) offer greater statistical power, while data with higher complexity (more attributes or columns) may lead to a higher false discovery rate.[2] Though used sometimes loosely partly because of a lack of formal definition, the interpretation that seems to best describe big data is the one associated with large body of information that we could not comprehend when used only in smaller amounts" [Wikipedia].

3.4 Neural Networks

"A neural network is a network or circuit of biological neurons, or, in a modern sense, an artificial neural network, composed of artificial neurons or nodes.[1] Thus, a neural network is either a biological neural network, made up of biological neurons, or an artificial neural network, used for solving artificial intelligence (AI) problems" [Wikipedia]. This approach is now very widely used in various subject areas and is very popular. However, we do not use this approach in our applications due to a key drawback – the lack of interpretation of the results obtained. As an alternative, we use the singular value decomposition of matrices.

3.5 Singular Value Decomposition

"In linear algebra, the singular value decomposition (SVD) is a factorization of a real or complex matrix. It generalizes the eigendecomposition of a square normal matrix with an orthonormal eigenbasis to any matrix. It is related to the polar decomposition" [Wikipedia]. This approach allows us to solve the same problems as neural networks, but here we can explicitly control the accuracy of the solution and confidence in adequate results. The use of SVD in our applications has shown its high efficiency. Recognition of tactical situations using SVD gives this method a high degree of versatility.

4 OUR EXPERIENCE IN AI

Knowledge base, ontology, inference machine, scenario approach, onto-modeller, Protege 2000. A brief history of the application of AI methods in our company since the late 90s of the last century is presented.

4.1 System of Ontology

The main motivation for the development of the concept of ontology was an attempt to combine software from different subject areas (domains), and, above all, to form a system of non-intersecting sets of concepts. The first tool for developing ontologies was our OntoModeler software product, Fig. 1, developed in the late 90s of the last century. To describe the logic and business intelligence, a special scripting language with Pascal syntax was developed. These technologies were the basis for the development of knowledge bases and logical scenarios. Also, OntoModeler was integrated into a GIS of its own design, see Fig.2.

The increasing complexity of GIS, the emergence of modern web technologies and technologies of distributed heterogeneous systems have dramatically increased the cost of maintaining and upgrading our key technologies. In the mid-2000s, a decision was made to switch to the JEE platform as the main software development environment and Protege 2000 as the main tool for developing and maintaining ontologies, see Fig.3. A special Plug-in was developed to create scripts based on the Drools language.

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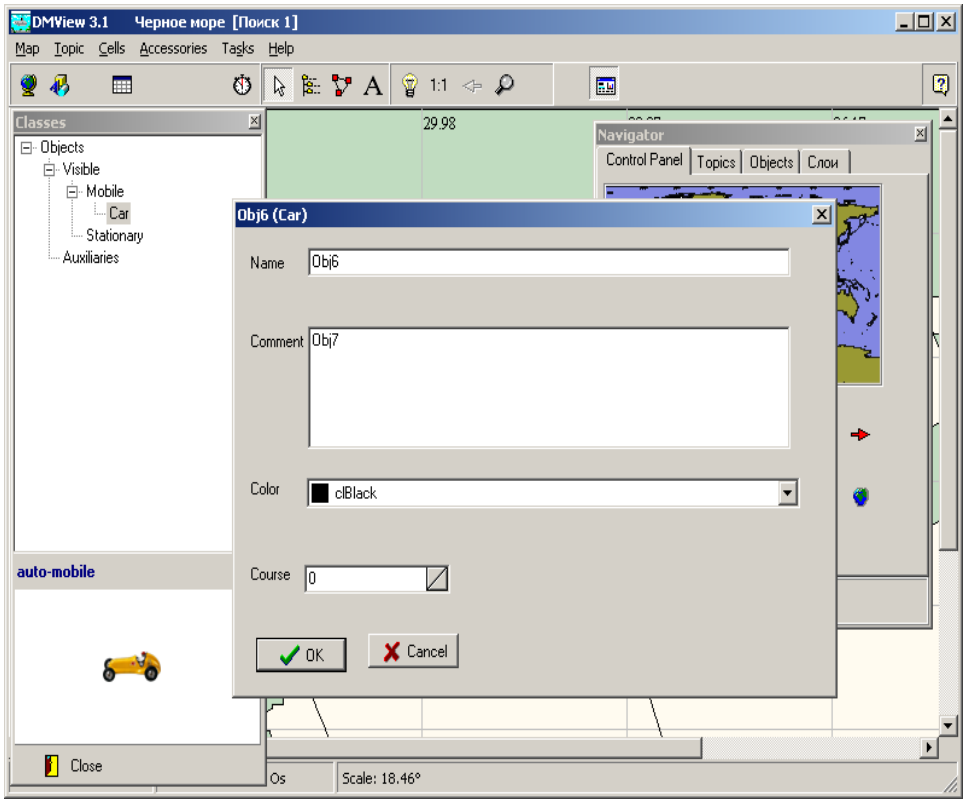

Fig. 1: Ontology editor main window

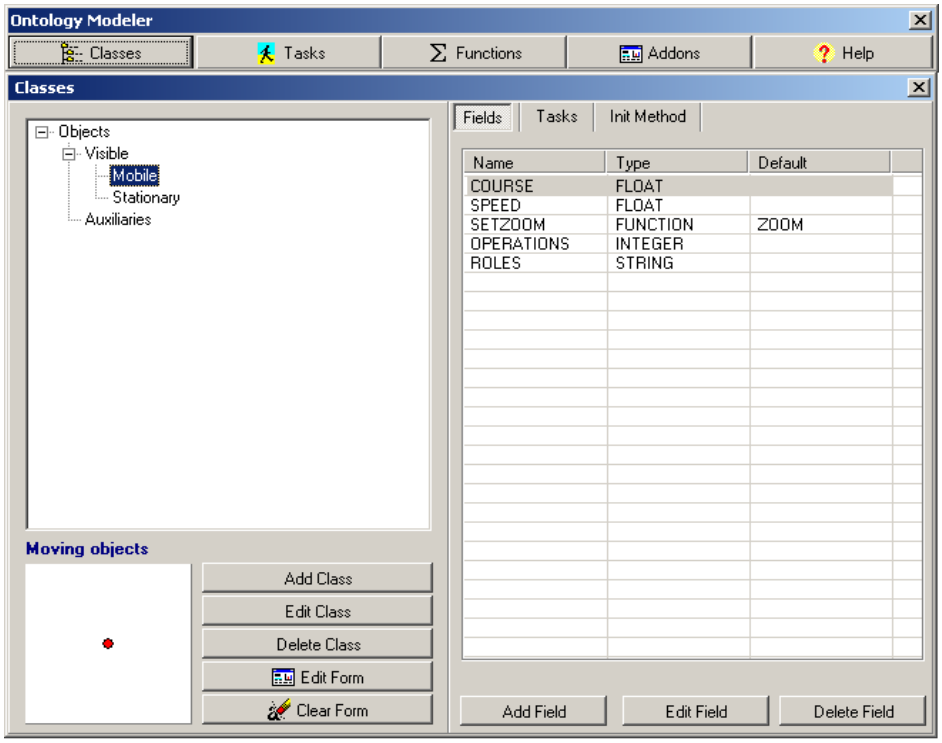

Fig. 2: Integration OntoModeler in to GIS

The application of the Protege 2000 system made it possible to speed up the development of an ontology system and to integrate various software components, such as GIS for various purposes, databases and knowledge bases, to implement a fairly powerful scripting system that allows implementing fairly complex business analytics without involving programmers. This approach made it possible to reduce the application development time, its cost, reliability and maintainability during exploitation by dozens of times.

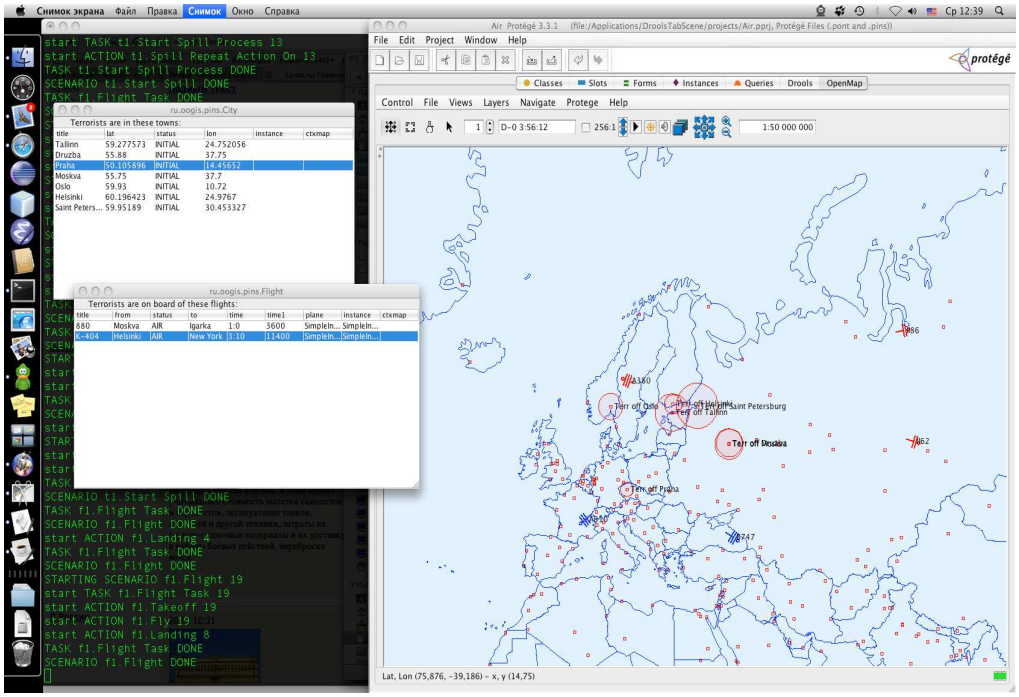

Fig. 3: Protege 2000 Applications

4.2 Scenario Approach

A scenario is the same as algorithm, but with the possibility of executing 2 or more parallel development branches that are executed simultaneously. A fully-fledged scripting system was developed in the Protege 2000 system as a special Plug-in, which implemented a visual script editor that allows you to implement business intelligence in a visual representation, which drastically reduced the time for its implementation, since the work was performed directly by subject matter experts without involving programmers. Note that there are two approaches to visual computer modelling: a scenario approach – when the content and sequence of steps to implement some business intelligence are known, and a rule-based approach for the case when the business intelligence or process is not known in advance. We use both approaches. An example of a simple scenario, its scheme, is shown in Fig. 4.

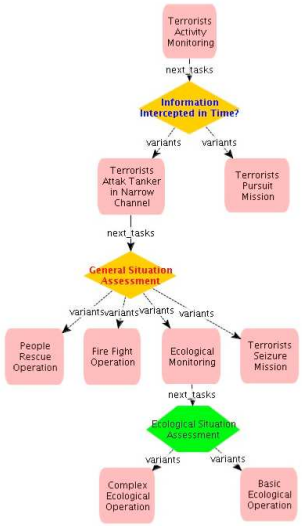

Fig. 4: A simple Scenario

The scenario scheme is a two-dimensional graph, the vertices of which are the stages (phases) of decision making, and the arcs are the transitions from one phase of decision making to another. The difference between a scenario and an algorithm is visually demonstrated, where the stages are performed in strict sequence one after another.

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4.3 Micro Service Architecture

The expansion of the scope of our solutions has led to the fact that scaling has fairly wide limits: from smartphone applications to large heterogeneous distributed systems. The technology system that uses Protege as an ontology editor is a rather heavy solution and can not be universally applied. In this regard, we have developed a system of technologies for which a lightweight ontology editor and a scripting system in the Drools language have been created, which allows the user to create flexible and lightweight development tools based on scenario approach in almost any integrated software development environment, for example, in JetBrains products.

5 TACTICAL SITUATION ANALYSIS

In our systems, the concept of a tactical situation is the basis for the application of AI in real-time systems and in monitoring systems for various purposes. A tactical situation is a basic concept for determining the reaction to external circumstances and conditions that have arisen for a robot that ensures the fulfilment of a certain mission.

5.1 JDL Model as a Spiral Processing of Information

In our systems, the concept of a tactical situation is the basis for the application of AI in real-time systems and in monitoring systems for various purposes. A tactical situation is a basic concept for determining the reaction to external circumstances and conditions that have arisen for a robot that ensures the fulfilment of a certain mission. The levels of this model correspond to such fundamental concepts as measurements, data, information, knowledge and understanding. At the same time, these concepts are not absolute, but relative. It all depends on the scale of the model. For example, on micro-robot level, unmanned device, manned vehicle, weather monitoring centre or other purpose.

Measurements, data and information can be interpreted as some attributes of a certain entity (robot), real (physical world), or abstract (digital world). Knowledge is a direct clarification, the work of “artificial consciousness”, “intelligence” at the level of such a concept as “phenomenon”. This is the level of a “simple” robot that performs a set of embedded business intelligence, its activities are quite well regulated, despite the fact that it can be performed using an inference machine.

“Understanding” is the clarification of the essence of occurring phenomena on the basis of self-learning, i.e. it is the rectification of embedded business intelligence in the form of scenarios based on self-learning or on-the-fly revision by a supervisor.

5.2 Cycle of Control

The control cycle (CC) is the logical basis of any control, artificial or physical entity, including decision support systems. CC is inherent in human nature from the very beginning and, according to the hypothesis of I. Kant [], is pre-established. It is simply not always realized and is often realized fragmentarily and probably not consciously. The control centre is implemented by some system consisting of two parts: Command&Control. This is military terminology, but recently it has been directly applied when considering such concepts as a decision support system (DSS) and the analysis of tactical situations. From the point of view of technical cybernetics, “command” is a given control function, and “control” itself is a technical implementation of the control function, i.e. issuance of a control action and, through feedback, control of its execution.

5.3 Tactical Situation Definition

The basis of the analysis of the tactical situations (TS) is the situation. The situation is not formed arbitrarily, but taking into account a certain class of vehicle. In turn, the TS does not arise without a specific task (tasks), which is solved by the monitoring system, DSS and/or decision maker. That is, TS is closely related to the concept of “task”. In human activity, it is quite natural to solve a number of problems almost continuously. DSS is also developed to solve a certain set of problems, and not in general for any problems. Therefore, we can say with confidence that the starting point for starting the analysis of the TS is the formation of a list of tasks that the decision maker solves and the DSS supports their solution. The process of fulfilling (solving) the task takes place against the backdrop of a changing environment and the emergence of new TS. The analysis and evaluation of the TS allows the decision maker to make the following types of decisions:

(a) continue the task according to the previously developed plan; (b) adjust the plan; (c) make a new decision in connection with such a change in the situation, which led to a change in the TS.

TS analysis is carried out by processing the input stream of measurements, data and information and evaluating the problem being solved. If the performance indicators of the problem being solved do not correspond to the specified (expected), we say that the TS has changed. But this is only for those cases when we can set the criterion and performance indicators. The decision on a "specifically new" vehicle may be done in two ways:

(a) logical, or scenario, based on the logic of first-order predicates; (b) mathematical, or imitative conclusion. Having identified a new vehicle, a new cycle begins.

To clarify, let us give a simple everyday example: various situations can lead to the threat of a car tipping over on the road in motion: – slippery road (rain, snow, ice, etc.); – high speed of movement; – sharp turn; – sharp movements of the steering wheel; – poor pavement of the road surface (clay, sand, gravel), etc. and so on. Therefore, it is advisable to create a list of threats and associate them with possible TS.

6 SMART CITY APPLICATIONS

Developed within the framework of the European CRISALIDE project, an intelligent decision support system in the interests of a smart city, is one of the options for implementing basic AI technologies in the interests of urban governance. In the CRISALIDE project an Innovative Decision-Making Tool has been developed for Contributions on:

- Urban Information Systems;
- Urban Decision Support Systems;
- Geo-Information-Infrastructures, Data availability;
- Urban Planning.

We consider the CRISALIDE as an instrument for end users. Decision making support system (DMSS) can help CRISALIDE users to satisfy human's demand for space. CRISALIDE is a software and hardware complex based on intelligent GIS, which provides the ability to integrate maps of various formats, implement a scenario approach in urban development modelling, 3D modelling, support for 2D + t modelling, support for 3D + t modelling, support for decision-making based on expert knowledge, the ability to monitor changes and assess the possible impact of decisions on the urban environment.

The software and hardware complex provides the consumer with a universal set of technological and functional solutions within the framework of the basic configuration with the possibility of expanding functional tasks in accordance with the requirements of the customer and the subject area, multi-platform and the absence of mandatory additional paid software.

The main end users of the developed CRISALIDE system are state authorities and local self-government, public and private enterprises and organizations directly related to the functioning and development of the urban environment. The introduction of the CRISALIDE system allows us to solve the following tasks: to develop e-government, to improve the quality of public administration through the creation and implementation of modern information technologies. The proposed system of intellectual decision-making support makes it possible to predict the development of urban infrastructure both within the city as a whole and in selected districts and quarters, to identify a deficit or surplus of construction facilities and/or infrastructure, as well as to take into account the socio-economic aspects of the development of municipalities and regions. Main services can be presented by text, graphics and voice forms. A list of services is very big and covers all of city life routines. Most of the services are presented by Internet through different gadgets. But, as was noted by Erich Fromm, today people would like to know and can to do primitive operations, especially how to use gadgets, but do not wish to understand things. It is the biggest demand of our civilization. According to this evidently fact our proposal is to include in to a plan of CRISALIDE project next generation a systems of services, pointed to understanding process. So, understanding should be as a service from Internet. The CRISALIDE project will be consists next main parts as follows:

(1) Knowledge clouds as services for individuals.

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(2) Private business analytics for understanding development.

(3) An intelligent social networks development as a platform or environment for knowledge and understanding existences and processes.

7 A “GREEN BUTTON”

In this article, we have presented a far from complete list of technologies that can be used to develop the intelligent core of a robotic complex. A robotic complex can be either completely autonomous or automated, i.e. with human participation. The main feature of RIC is the ability of the installed software to provide decision support, both in stand-alone and automated versions. At the current time, our technologies allow us to form a relatively simple logic of the robot's behaviour, which can act autonomously. But when solving more complex problems, such as, for example, in the CRISALIDE project – the operation of a decision support system for managing the urban environment, the participation of a whole team of people of various specialties is required.

A reasonable question arises: is it possible in automated systems to entrust the formation of proposals for making decisions offline? Theoretically, such a possibility exists, but what about practice? Let's translate these questions into a technological plane. The very first step is confidence in the chosen technological solutions. What does it mean, for example. TS analysis can be considered as a problem of pattern recognition, or simply recognition. Stereotypically suggests the idea of using neural networks. But, the main drawback of neural networks is immediately remembered – the lack of interpretation of recognition results. Believing in such an autonomous decision generation system becomes a matter of faith, which will not fully suit pragmatically minded people who are ultimately responsible for the decision made.
The use of SVD eliminates this drawback, since we can control the accuracy of decision making. Why are we discussing this issue at all? We are discussing, because here, maybe. two extremes: the first is that we do not need an automated DSS, we only need well-trained decision makers. The second extreme is the need to create DSS, which will eventually replace a person in any decision-making process. Our arguments are as follows: even if the decision maker is well prepared and has extensive experience, he is not immune from mistakes. It is a human trait – to make mistakes. DSS, even if it cannot offer the optimal solution, it can protect against making a misguided decision in advance.

At the current level of development of AI technologies, it is impossible to create a DSS that will always make optimal decisions. But you can set up the DSS so that it will not make gross mistakes and make decisions that are close to optimal. We will not consider the concept of “close to optimal” in this article, since this is a separate special topic. The local conclusion that we can draw now is that there is a set of technologies that allows you to automate the DSS as much as possible. We call this hypothesis the “Green Button” idea. The general scenario for implementing the Green Button idea is as follows.

7.1 Access to Environment Data

This is a connection with the outside world in real time. To do this, we have created a whole family of different servers that receive data from a variety of meters and interacting external systems, providing heterogeneity and distribution. The RIC must have access to external information, preferably in real time or near real time. The more channels for obtaining information about the external situation, the better for the adequate behaviour of RIC and, ultimately, the successful completion of the assigned mission. Our experience with real-time systems shows that practically the entire set of information about the external environment can be formed in the form of typical channels, regardless of the type of physical field that needs to be registered. The first and the simplest option is geographic (spatial) coordinates and one physical measurement: temperature, relative humidity, atmospheric pressure, etc. The second option is associated with the processing of data from the analysis of a certain plane or volume, associated with the registration of objects in various environments: the surface of the earth, the air atmosphere, the aquatic environment. For these systems, integrated processing can be reduced to the problem of pattern recognition on a plane or in a volume. As a result, we get an abstract representation of the surrounding world in some functions and arrays of measurements, as well as selected physical objects.

7.2 System of Ontologies

A set of technologies allows you to formalize the subject area and form a number of non-intersecting concepts and relationships between them. Such a system is also called a knowledge base system. The system of ontologies and/or knowledge bases is a way of interpreting the environment (paragraph 6.1) and business intelligence, which ultimately determines the mission of RIC. Thus, a system is obtained that can be interpreted by different logics. As a rule, we use first-order predicate logic and generic tools that support it. The most important property of ontology (in our opinion) is a unified system of concepts for such different entities as decision makers, applications and databases. This significantly reduces the development time of such intelligent systems, their maintenance, scaling and modernization.

7.3 Scenario System

The scenario system allows you to formalize the customer's business analytics, which is the basis of the DSS. Actually, with the help of this idea, the “Green Button” is implemented. Those. automation from an automated system (with human participation) to a fully autonomous system (without human participation). This idea is very productive for cases when, for various reasons, the decision maker cannot make a decision under the circumstances and conditions.

7.4 Tactical Situations Processing

This is the basis of the DSS, which connects a number of fundamental concepts: the tasks (mission) of the object and/or system in whose interests the DSS was developed, the current situation (data, geography and time), the system of restrictions. The technical basis of TSP are: SVD classifier (recognition) and script interpreter. The implementation of TSP allows you to abstract from the elements of what is happening (data, measurements, information) and operate with such concepts as knowledge and understanding. Either the decision maker, or the decision maker + RIC, or RIC evaluates what is happening from the point of view that the mission is feasible, or not, needs to be corrected, or should be replaced by another, or cancelled completely. To understand what we are talking about, very roughly TSP can be interpreted as a pattern recognition process, but! The images here are abstract and have no direct physical interpretation. Plus, many of these “images” refer to cases of “rare events”. In this case, a number of well-established AI methods, in particular neural networks, are not applicable. In this regard, we apply the SVD method, which can be applied to large statistics (like neural networks), as well as to “rare events”, the abstract images of which are formed by experts.

7.5 Web interface

Interacting RIC system with decision makers and other DSS users. Interaction through touch and through voice communication.

The proposed idea of the “Green Button” has been tested in our systems since the mid-2000s. In the current conditions, a mechanism is being developed to control the degree of automation of the decision support process: from complete autonomy to the participation of the decision maker or the decision maker team in the decision selection process. Our current solutions do not directly evaluate or manage the degree of automation. When solving this issue, we will be guided by the fact that the degree of automation will be determined by the decision maker.

8 CONCLUSION

Development of RIC technology, discussion of it led to a “Green Button” idea. Based on our experience of theoretical and technological research, a system of technology is proposed, a technological platform that can be called a core of robotics intelligence. This platform allows us to form a full cycle of intelligent control of the robot and decision making process for large scale systems:

- obtaining data from the external environment (robot environment) from various sources, own and external;
- evaluation of options for fulfilling one's own mission and making a decision (close to the optimal solution);
- monitoring the implementation of the decision;

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- proofreading of the solution if necessary;
- making a decision on the completion of a mission formed for a robot, or a general system for which a decision is made on automatic control without involving (directly) a person.

Accumulation of experience and self-training based on the analysis of tactical situations and the results of decisions has been made. In general we call this idea a “Green Button” idea.

Our next step is to provide a set of real work applications with embedded such system. The firs one will be an extension of CRIALIDE project, maritime monitoring systems, autonomous mobile devices of different types for ground, aerial and maritime purpose.

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