Control of machines and robots: creation of mivar decision-making systems for controlling autonomous tractors and special vehicles of the ministry of emergencies

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Abstract. To control machines and robots, it is proposed, in addition to well-known control systems of the reflex level, to use a logical level Mivar decision-making systems. In this report, the scientific background on the application of the Mivar technologies for controlling autonomous tractors and special vehicles of the Ministry of Emergencies is shown. The decision-making systems "ROBO!RAZUM" can, on conventional computers and in real time, control autonomous multilevel heterogeneous robotic systems to perform complex actions under conditions of heterogeneous dynamic obstacles and adaptively solve tasks even with malfunctioning technical vision. The main difficulties of the complex of tasks of the "tractor of the Ministry of Emergencies" are analyzed, which are successfully solved by the Mivar decision-making systems for controlling machines and robots.

1. Introduction

Mivar decision-making systems for controlling machines and robots are the development of the Mivar technologies, which were originally intended to create evolutionary databases and rules for adaptive synthesis of intelligent systems [1] in the scientific field of Artificial Intelligence (AI). A special case of such systems was self-organizing complexes of operational diagnostics [2]. The Mivar technologies are based on the epistemological knowledge model "Thing-Property-Relation", which describes the Mivar network "Object-Rule" for implementation with linear computational complexity of logical inference and / or automatic construction of action algorithms (decision making). Mivar databases with a variable structure and the Mivar networks with linear complexity and logical inference made it possible to remove the important limitation of a complete search of decision-making options, which at the end of the 20th century led to the second "winter of artificial intelligence". The corner stone of Mivar-based expert systems (MES) is the method which automatically constructs logical inference route in the mivar knowledge base [1]. The universality of the use of MES made it possible to talk about the possibility of a qualitative transition to a new level in the field of artificial intelligence [3] and the solution of a wide range of practical problems [4] with linear computational complexity [5].

The constructor (shell) of the CESMI WiMi "Razumator" expert systems [1] was created and entered in the Russian Software Register. The creation of the "Razumator" made it possible to put into practice
the theoretical hypothesis of 2004 on the interaction of groups of mobile robots on the basis of the mivar information space [1].

Along with this, it was proposed to use the metric of production expert systems [6], where the number N of elementary rules "If, Then" determines the possible number of combinations in the decision-making space as a metric of autonomy and intelligence of robotic complexes (RC) and cyber-physical systems (CPS) equal to the factorial of N (N!). Such an extremely large and even enormous decision-making space is the main limitation for smart cars and robots; therefore, it was proposed to add a new unit to the well-known trajectory control systems for cars: "decision-making systems" (DMS) [7] based on the mivar logical artificial intelligence [8].

Due to the fact that these autonomous cars have yet to be created and there are many legal restrictions on their use, it was decided to explore the DMS technology during creation of Mivars systems for monitoring compliance with the traffic laws [9] on the basis of "Razumator" and mivar expert systems [8]. In the process of studying the traffic rules of the road and comparing them with the task of planning the behavior of robots and machines in the state space using the well-known STRIPS programming as an example [10], a qualitatively new MIPRA technology was created for solving real-time planning tasks for robotic systems [11], the use of which made it possible to speed up the solution of the problem of "permutations and cubes in the pyramids" by several orders of magnitude. For example, for the permutation 300 arbitrary cubes MIPRA finds algorithm solutions in less than 90 seconds on a standard serial laptop [12]. In addition, let us recall that it was the use of mivar expert systems that made it possible in practice to create a virtual Russian-language textual consultant in the banking sector [13], which will create a system for understanding machines and robots of Russian texts for interaction with people and among themselves.

Recall that the mivar approach to understanding natural language comes from the fact that human language is, first of all, a means of modeling the real world, and only then – a means of communication. In this case, it is logical to use expert systems and databases to solve problems of understanding a natural language. Indeed, it is expert systems that solve the scientific problem of modeling knowledge about various subject areas, and databases are "responsible" for the accumulation and processing of facts and data in this subject area. As shown in our Russian-language works, understanding the meaning of texts is generally not possible without full-fledged modeling based on technologies of mivar expert systems. Now the desire to "talk with the robot" and set him the task just like his assistant person is quite real. Moreover, we believe that autonomous robots, as soon as they can understand people, can immediately communicate with each other in human natural language. Of course, emotions, ethics, and feelings are a separate problem, but we suggest that they will be attributed to the third level of AI research, which is proposed to be called "social". In the further work of scientists, these studies will be continued by creating a more complex mathematical apparatus, which will be more adequate for the problems of ethics and the social level as a whole.

Currently, an important aspect of scientific research is determining the causes of unmanned vehicle accidents. For example, if autonomous cars or robots fall into a traffic accident when driving on roads. In this case, here, mivar technologies will allow reconstructing events [14] and identifying the intruder on the basis of objective data and logical-computational processing. In addition to the tasks of intelligent management and analysis, the mivar approach demonstrates its effectiveness in presenting and processing knowledge about various areas of human activity, for example, knowledge about human health [15]. It is also necessary to emphasize that MESs can work in collaboration with other subsystems in the circuit of hybrid intelligent information systems [16, 17]. Such complexes may be equipped with software modules based on Metagraphs [18-20], cognitive computer graphics [21], neural network algorithm [22], and methods of predictive analysis [23]. Thus, an important limitation has been overcome and a great scientific reserve has been created for the possible use of mivar technologies for controlling autonomous tractors and special vehicles of the Ministry of Emergencies.

2. Decision systems for controlling robotic tractors
From the very beginning of the development of robotics, scientists considered various tasks, starting with the simplest and even "toy" ones. The mathematical capabilities of software systems were not enough to solve more or less "real" problems, because they also tried to plan the actions of robots on the basis of exhaustive search or complex mathematical calculations. Now it is absolutely clear that besides the usual robot control systems, it is necessary to add additionally: decision-making systems and systems for understanding the natural language. Decision making systems belong to the logical level of research in the field of AI, and control systems previously used in robotics that simulate the movements and decisions of animals belong to the reflex level. Many scientists are still trying to combine these levels and use only management systems, however, in the field of decision making and the creation of expert systems, a huge amount of knowledge has been accumulated that is advisable not to recreate, but to use and train for new subject areas. It may be recalled that expert systems are developing in parallel with intelligent robotics and there are practical examples of the joint use of the mivar expert systems (as decision-making systems) together with conventional robot control systems of reflex level.

It is advisable not to try to re-create "expert systems" and waste valuable time, but to use the results of neighboring areas of AI, for example, mivar expert systems with linear computational complexity and processing speed on conventional processors of more than a million rules per microsecond. We especially note that the time of processing information and making decisions in mivar expert systems satisfies the requirements of the real movement of robots and now even exceeds the capabilities and speed of pattern recognition systems. Moreover, practical experiments conducted in our laboratories showed that mivar expert systems can even work, conditionally speaking, "on smartphones" when processing tens of thousands of decision rules in the same real time for the movement of robots.

The main limitation, at present, of using mivar expert systems is the lack of knowledge bases created. We know about this problem and we have our own achievements in accelerating the creation of knowledge bases and removing this limitation. The following analogy can be given with previous historical periods in the development of technology. The analogy is as follows: we created a high-speed train, but there are practically no railways yet. As soon as enough railways are built, then the advantages of trains - mivar expert systems will become obvious to everyone. We have already developed training courses for training people of "cognitive analysts" in creating mivar knowledge bases of various subject areas. "Cognitologists" will be one of the new highly paid professions that will replace the existing easily algorithmized professions, which in turn will be taken by robots. Creating knowledge bases for robots is simple and understandable, although it requires attention and accuracy. Approximately in the same way now they teach human children from birth and at school. Consequently, the creation of mivar knowledge bases is quite possible, scales well and can be performed in parallel.

In addition, if in some subject area there are already "well-written instructions", then our mivar technologies for understanding the natural language make it possible quite simply and even automatically to create mivar knowledge bases from the text of instructions, which, after verification and testing, will be accepted into work and loaded into robotic complexes. From the currents of the studied subject area – the tractor and the special machinery of the Ministry of Emergencies, it is important to recall that all of them are now controlled by people according to written instructions. Yes, such "human" instructions may need to be specified. But it is important that there are such instructions, and even people are obliged to follow them, which does not deny the adoption of independent decisions in the most difficult situations, which is still based on rules and recommendations.

Here you can recall that mivar expert systems "hold in their head", i.e. process simultaneously, without errors, oblivion and emotions, firstly, a thousand times greater amount of knowledge; secondly, they develop solutions and algorithms for achieving goals hundreds of times faster than humans; and thirdly, they easily and instantly adapt and change the algorithms of actions in case of a change in the general situation. It just so happened that created for situational control centers of a huge country, with millions of production rules, mivar expert systems are able to work on the simplest and cheapest computers (on a single processor core) in real time with the processing of millions of rules of accumulated human experience for autonomous robots.
3. The main features of the subject area of the tractor and the Ministry of Emergencies

The analysis of the information of various Customers, relevant subject areas of application of tractors and special vehicles of the Ministry of Emergencies made it possible to determine the boundaries and tasks for mivar decision-making systems. Tractors, special vehicles and robotic complexes (RCs) based on them are used to eliminate the consequences of emergency situations and natural disasters. Such tasks place increased demands on control systems (CS) and give rise to a wide variety of situations. Note that the full autonomy of the RCs is necessary in the absence of communication channels with operators, which happens quite often in emergency situations. Given the capabilities of Mivars and the speed of decision-making > 5 million rules/s, this expansion of requirements for CS is not critical. According to our estimates, the number of production rules for such tasks will not exceed hundreds of thousands. For brevity, we will call this set of tasks of the Ministry of Emergency Situations a "tractor".

The following important features of the tasks set as "tractor" were revealed:

1) Tractors and RCs based on them move through the territory which changes dynamically. For instance, tractors routes or obstacles positions may change, even terrain itself may change.
2) RCs are complex multi-level devices when a part of such an RC or a separate mini-RC can autonomously perform some tasks: an unmanned aerial vehicle (UAV) to explore the Ministry of Emergency Situations from above and create actual maps.
3) In tractors with technical vision systems (TVS), they are external when they move along the "field" with poor visibility or when their TVS is faulty. Then the tractors will use a "map" pre-loaded into the DMS, which is quickly updated according to data from external TVS and from internal inertial sensors.
4) Tractors can work together and help each other solve complex problems (group management of the RC). For example, two tractors can move together over rough terrain, and if the first tractor "falls into the swamp", then the second tractor can pull it out. If the RC breaks down, then another can drive up to it, carry out diagnostics and repair.
5) The intellectual capabilities of mivar DMS also give rise to new requirements for RCs – "tractors", which must be able to interact with each other both physically and informationally. For example, RCs can exchange information through various physical channels, including optics, by analogy with people. RC can approach and special "cable" to connect to each other.
6) Tractors must be able to work with different types of obstacles. For example, the problem of dividing the types of obstacles into two types has been solved: passable and impassable. We introduce the third type of obstacle, which we will call the "movable obstacle". So, a rather large and even "open" set of types of various obstacles is possible, but all of them can be taken into account in the knowledge base of the mivar DMS, and then in the work of the RC and their multi-level and heterogeneous groups.
7) Tractors must be able to carry out tasks even in conditions when the system of technical vision is out of order or cannot function due to weather conditions. Each RC has a map area and a system of inertial sensors that are precisely defined by all movement RC and its position in space. The first option: without vision, a route is built on the basis of a previously loaded map and moving along it is based on information from inertial sensors. If the first RC abuts the obstacle on the open road, then the detour search procedure starts, which will be described in subsequent papers.

Suppose a group of RCs have a common map and the task of moving cargo through the disaster zone, where there have been changes in the landscape and were obstacles. Tractors combine vision systems of all RCs and perform updating information to update the maps. The created mivar bipartite graph of possible displacements where explicitly allocated "nodes" – which may correspond to actual positions of RCs and "edges" – for which RC can move from one vertex to another. Further, the RC in the mivar DMS finds the route of movement, determines obstacles and, according to the rules from its knowledge base, performs actions to move goods if the route is clear. If there are passable or movable obstacles, then planning is carried out to overcome these obstacles and complete the task. The necessary scientific
studies have been carried out and it is possible to proceed to the stage of creating knowledge bases and training mivar SPR for autonomous tractors and special vehicles of the Ministry of Emergencies.

4. Conclusion
In addition to the well-known control systems of the reflex level, it is necessary to add decision-making systems of a logical level, which are created on the basis of widely known technologies of expert systems. The Mivar technologies made it possible to remove important limitations of the previous generation of expert systems and move to a new level of research in AI.

Certain elements of artificial intelligence have been created and the Mivar system decision "ROBO!RAZUM" can manage real-time autonomous tractors and special vehicles for Emergency Situations, which represent the multi-level complex heterogeneous robotic systems.

These autonomous RCs can perform tasks and move in space even with defective vision system. We need RCs which can perform complex operations along the way with possible use of external vision systems or using machine vision and internal map of possible movements in a heterogeneous dynamic environment and deal with obstacles and adaptive decision tasks.

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