About the project developing "MIPRA" – the intelligent planner in the state space for vehicles, tractors, and robots based on the architectural solutions of the Mivar systems for traffic enforcement

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Abstract. The task of creating a logical "strong" artificial intelligence (AI) to be used as new decision-making systems for autonomous vehicles, tractors, and robotic systems draws increasing attention of scientists around the world. Essentially, it is the creation of "brains" for vehicles and any other transport systems, including cyber-physical systems. The mivar technologies of logical AI allowed solving many problems at a qualitatively new level and reducing the decision-making time from billions of years to hundredths of seconds, which enables real-time vehicle control. This paper shows how the application of mivar products (mivar expert systems) allows solving another class of problems – state-space planning (STRIPS planning). In turn, the solutions of these problems enable the development of driver assistance systems at a new level and creation of a fully autonomous vehicle.

1. Introduction
Currently, there is a technological foundation for implementing a logically intelligent system helping a driver to control an automobile. Mivar traffic regulation enforcement system (MTRES) is an example of such a system. The system aims at solving the task of making recommendations for vehicle control and estimating the actions of the driver in real time. Solving this task requires logical intelligence; therefore, a Mivar Constructor of Expert Systems Wi!Mi "Razumator" was used [1]. "Razumator" allows the system to build algorithms for solving problems [2] in the given traffic situation. The theoretical basis of this system includes research in mivar technologies [3-4], including effective solutions in developing driverless automobiles with logical artificial intelligence [5-6], systems for intelligent image recognition [7], analysis of traffic accidents [8], and decision support systems for medicine [9]. It should be noted that the department of information processing systems of Bauman Moscow State Technical University conducts research on creating hybrid intelligent information systems [10] using meta graphs [11-12], cognitive computer graphics [13], neural network-based algorithms [14] and intelligent analysis methods [15]. This comprehensive approach [1-15] allows solving various practical tasks in the area of artificial intelligence.
In the IASF-2018 conference report [16], the architecture of MTRES was presented, and the prospects of using the approaches implemented in the systems were justified. Subsequent research yielded results [17] proving that the principles of developing MTRES are not limited to the tasks of assisting drivers of vehicles; the principles can be applied to implementing a mivar system for planning the actions of robots and robotic systems – MIPRA (Mivar-based intelligent planner of robot actions). The software product MIPRA was developed to solve STRIPS-planning problems in the modified conventional Blocks World domain [18].

Over the last decade, there has been a growing interest in the tasks of intelligent planning of robot actions due to the emergence of new methods and tools for training convolutional and recurrent neural networks [19-20]. There is also research looking into planning algorithms that use the sign world model as a basis for acquiring and preserving knowledge for future use in the planning of actions [21-23]. Special attention has to be paid to the works [24-25] looking into the use of hierarchical behavior planning algorithms in the coalition of agents [26] and the hierarchical reinforcement learning approach for the task of road intersection by a driverless vehicle.

This paper describes the architecture solutions of MTRES, which were essential to the development of the mivar intelligent system for planning actions of robots and robotic transport systems (MIPRA). This paper also demonstrates the advantages of using the principles of mivar logical planning in the area of intelligent transport solutions.

2. Statement of the problem of the mivar planning of actions for a robotic system

The task domain for MIPRA was described in detail in [17]. The task of planning the actions of a robotic system is a modification of the conventional Blocks World domain [18]. This domain consists of only the blocks themselves, a table, and a robot. The blocks form towers with different height, including towers one block high. The table only fits \(M\) towers. The task of planning comes down to making a plan of actions for the robot to rearrange the positions of blocks in the space from the initial state to the desired state. The robot is fitted with a manipulator for handling the blocks and machine vision systems for determining the positions of blocks in space.

3. Architecture solutions in developing MTRES and MIPRA

In this section, we demonstrate the pass from the architectural solution of the MTRES over to the creation of the logical intelligent planner MIPRA.

Figure 1 shows the architecture of MTRES. The system input information includes data from machine vision systems [27], automobile sensors, and a navigator [28]. The information is processed to fit the format of the parameters of mivar models, which are made by experts in collaboration with knowledge engineers. Mivar models correspond to the section of the Russian Federation traffic regulations. After that, the parameters are saved in the working memory. It is a section of the memory where a set of the facts describing the subject domain, i.e., the road situation, is accumulated.

The statement of the problem of making recommendations on controlling a vehicle requires sending the current road situation parameters in the system, where the algorithm of making a maneuver is constructed. Each step of the maneuver is placed in a stack of actions. The finished stack is sent in the driver alerting system, thus terminating the processing of the task.
If the system has to evaluate the actions of the driver, the system is given the information about the performed maneuver along with the characteristics of the road situation. "Razumator" constructs a set of actions required from the driver. This set is then compared to the actions performed by the drivers. The result of the comparison is given to the driver alerting system.

This structure of MTRES was presented at the beginning of 2018 [16]. Further research revealed that the proposed system architecture approaches could be successfully used to develop MIPRA [17]. Figure 2 shows the architecture of MIPRA.

The structural differences between the architectures of MIPRA and MTRES are related to the definition of information streams given below. A planning task is submitted to the input of MIPRA. A mivar model is created for this task. The models' generation algorithm aims at decomposing the planning task into sub-goals, the completion of which yields the desired result. The mivar model is loaded in the working memory, where it will organize the planning process. The user of the system signals the start of work, and MIPRA gives the robot a plan of performing the first step. The plan of a step is a set of actions. Subsequent performing of these actions allows getting closer to achieving an intermediate goal. After the step actions are performed, information about the current state of the subject domain is loaded into MIPRA. Based on the current situation, a new step plan is constructed and submitted to the robot for execution. The iteration "loading current situation → generating step execution plan" is repeated until all the conditions of achieving intermediate goals are met.

![Figure 1. MTRES architecture.](image1)

![Figure 2. MIPRA architecture.](image2)
4. Results of applying the architecture solutions of MTRES in MIPRA

Practical experiments [17] revealed that the mivar planner does not need many hours of computing on a powerful multi-processor to solve this task. On a regular computer, the mivar planner solves the tasks of rearranging blocks in the following time: 10 blocks — 0.98 seconds; 50 blocks — 3.44 seconds; 100 blocks — 10.57 seconds; 200 blocks — 38.32 seconds; 300 blocks — 84.07 seconds. The mivar approach implemented in MIPRA allowed working with more than three towers on the table and with a variable number of blocks even in dynamically changing conditions. We should note that the computational complexity of planning of actions in a domain 300 blocks large (MIPRA generates individual mivar models of each planning task in the domain; the model has 3311 parameters and 1200 rules) using conventional exhaustive search methods will be 1200! (factorial) with the total computation time of more than several billion years.

5. Conclusions

The principles of developing the system of traffic regulations' enforcement MTRES [16] demonstrated their efficacy for developing the mivar intelligent planning system in the state space [17].

The mivar approach and the system architecture concepts used in developing the MTRES allowed moving to the development of a new class of system - intelligent planners with logical reasoning. The developed software product MIPRA, which is based on the mivar system "Razumator," qualitatively reduces the computation complexity and accelerates the speed of constructing the algorithm for solving the STRIPS tasks for rearranging blocks in the Blocks World domain by many orders of magnitude.

The investigation of MIPRA allowed preparing a theoretical and practical basis for proving that the use of mivar technologies allows drastically reduce the computational complexity of the task of planning the actions of robots, groups of robots, multi-level heterogeneous robotic systems [25] and cyber-physical systems of different purpose and application.

The theoretical basis, the test setup, and the practical results obtained in the development of MIPRA were used in the further development of the MTRES. The obtained theoretical results allow the real-life implementation of the project called: "smart cars on smart roads in the smart city" [29].

6. References

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