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USE OF ARTIFICIAL INTELLIGENCE METHODS IN A MULTI-AGENT APPROACH IN THE TRANSPORT AND LOGISTICS SYSTEM

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The transport and logistics system (TLS) is a complex and dynamically changing system with numerous parameters and large volumes of information. Tracking and processing this data, as well as evaluating possible courses of action, require significant resources. To automate algorithmic and system-level tasks within the TLS, artificial intelligence (AI) can be used.

Artificial intelligence is a set of technological solutions capable of emulating human cognitive functions, including aspects such as self-learning, autonomous decision-making, and the generation of insights. At the same time, it enables achieving results comparable to human intellectual activity in the context of performing specific data processing tasks of practical significance. Twelve classes of AI systems are distinguished, among which particular attention, in addressing the problem posed in this study, should be given to the class “By completeness and complexity of systems.” In this classification, multi-agent systems (multi-agent systems) occupy a leading position.

Multi-agent systems are characterized as systems consisting of multiple interacting intelligent agents. It is also noted that they are capable of solving problems that are difficult or impossible for a single agent or a centralized system. Given that the transport and logistics system (TLS) is a complex system with a large number of participants, multi-agent systems can effectively address the challenges that arise.

These systems make it possible to consider a broader range of solutions aimed at efficient real-time resource planning, data analysis for decision-making, and the training of computational agents. These tasks are essential in the design of transport and logistics systems.

Transport and logistics systems (TLS) are characterized by a high degree of uncertainty and rapidly changing dynamics, due to numerous interconnections and interdependencies determined by a wide range of individual factors. TLS involve large datasets that are complex to process, which increases the likelihood of errors. In logistics practice, it is proposed to apply methods of analysis and decision-making in TLS by tracing dependencies using multi-agent systems or agent-oriented programming.

Before considering a multi-agent system within a transport and logistics system (TLS), it is necessary to define the concept of the transport and logistics system itself. Based on the analysis of scientific sources, it has been found that authors generally provide only descriptions of the structure of TLS and its internal interconnections, while a unified definition of this concept is lacking.

As a result of the literature review, a definition was identified that considers TLS primarily from the perspective of its transport component. However, TLS is currently a rapidly evolving system, and certain elements of this definition have become outdated and do not fully reflect the features of its functioning in the modern world.

At present, significant attention in the organization of TLS is given to digital support. In this regard, it is appropriate to consider TLS from the perspective of frame theory, which is активно used in artificial intelligence.

A frame is a type of structured representation within a semantic network. This concept was proposed by the American scientist in the field of artificial intelligence, Marvin Minsky. By studying human cognitive processes for application in artificial intelligence, he developed frame theory, which organizes all knowledge about a specific class of objects or events into a unified data structure.

Similarly, a modern TLS should contain information about each object or event in order to respond promptly to emerging challenges. Based on the above, the following definition can be proposed: a transport and logistics system is a set of classes of objects, including transport, transport infrastructure, and its stakeholders, which together form a unified knowledge structure aimed at ensuring interconnected transport processes and influencing material and related flows to meet consumer demand.

Multi-agent technologies make it possible to achieve a high level of personalization in decision-making: each user can be described through a set of relevant concepts and relationships. This enables the establishment of specific goals, preferences, and constraints for each user, taking into account individual characteristics, and supports targeted decision-making.

In recent years, multi-agent technologies have been rapidly developing and are implemented at the intersection of artificial intelligence methods, object-oriented programming, parallel computing, and telecommunications. Multi-agent systems are more flexible and capable of responding promptly to changes within the system, which is particularly important for transport and logistics systems.

Currently, decision support systems in TLS are mostly based on classical approaches that do not allow for rapid adaptation to the frequent changes occurring in the modern world. Within the framework of this master’s thesis, algorithms for the functioning of a multi-agent system are being developed, enabling prompt responses to changes across the entire transport and logistics system.

Multi-agent systems (MAS) combine three key technologies: distributed artificial intelligence (distributed AI), distributed problem solving, and parallel computing. This enables prompt responses to influencing factors. Without the use of multi-agent systems, tasks within the functioning of a transport and logistics system (TLS) have to be addressed sequentially; however, under conditions of high system dynamics, solutions obtained at earlier stages may quickly become outdated and irrelevant.

Multi-agent technology is fundamentally based on agents. Agents are entities capable of collecting data about the environment and making decisions independently. A group of interacting agents that share a common goal is referred to as a multi-agent system (MAS). Within such a system, large networks of small agents can be organized to perform parallel operations and negotiate with each other to distribute tasks and make decisions according to predefined algorithms.

Since agents form the basis of a multi-agent system, it is important to define that an agent is a computer system situated within a particular environment, capable of autonomous actions in that environment in order to achieve its assigned goals. An agent possesses the following characteristics:

– a defined set of final states that the agent adopts as its current behavioral strategy (goals);

– the presence of stable knowledge about itself, the environment, and other agents that does not change during its operation (knowledge);

– the presence of variable knowledge about itself, the environment, and other agents (knowledge that may change over time, although the agent may not be aware of these changes and may continue to rely on it in its reasoning) (beliefs);

– the presence of states or situations that are desirable for the agent to achieve for various reasons, although they may be conflicting, and therefore the agent does not expect all of them to be achieved (desires);

– tasks that the agent undertakes at the request (assignment) of other agents within the framework of cooperative goals or individual agent goals through collaboration (commitments to other agents);

– an awareness of what it must do due to its commitments to other agents (i.e., tasks assigned to and accepted by it), as well as actions arising from its own desires.

It should be noted that the needs and capabilities network model (NC network) is used as a methodological basis for developing open multi-agent systems. This model is based on a holistic approach, where an object is represented as a set of autonomous "physical entities," each having its own set of needs and capabilities. The multi-agent approach enables the creation of software agents that seek to optimize their target parameters.

An undeniable advantage of multi-agent systems is their ability to self-organize. They are capable of independently managing internal processes without external intervention. Such systems are cybernetic or dynamic adaptive systems and can evolve by increasing their complexity and forming structures for future development based on accumulated experience (information retention).

When considering the modeling of transport and logistics systems (TLS), it is important to take into account that the models, methods, and algorithms applied rely on a distributed approach to problem solving (Distributed Problem Solving). This approach assumes that a complex task is decomposed into a set of smaller subtasks, and conflicts between the obtained solutions are resolved through self-organization.

It is also important to emphasize that the system does not produce a single global decision; instead, through numerous parallel and asynchronous interactions, it identifies an optimal solution despite the presence of multiple, often conflicting criteria, which is particularly important when developing solutions for TLS.

Having examined the capabilities and functioning of multi-agent systems, it can be concluded that multi-agent technologies are capable of solving multi-criteria planning problems in transport and logistics systems, taking into account all necessary data and the decision-making criteria of each agent within the system.

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