The use of multi-agent systems in forestry

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Abstract. The purpose of the study is to review the current situation in the forestry sector, as well as to identify and accomplish tasks that could change the situation in this area. It focuses on the disclosure of operation principle of the multi-agent approach, as well as the identification of problem areas in forestry. The scientific novelty comes down to a promising direction in forestry that reduces the processing time of incoming information since the multi-agent approach gives a parallel process of assessing data that retrieved by an unmanned vehicle. In addition, the approach simplifies the structure of the agent’s algorithm. With that research, the technology of operation of multi-agent systems was disclosed, and examples of the application of this approach in production were presented. It is emphasized that the use of unmanned aerial vehicles with a multi-agent approach to recognition of terrain in the field of forestry will improve the quality of the data obtained, increase the amount of information received and processed, and increase the reliability of this process. The main advantages of the proposed approach are minimal control during remote use, forest resource taxation and analysis of the terrain for emergency situations.

1. Introduction

As a result of the introduction of the forest code in 2006, over the past decades, forestry has undergone a lot of negative changes, ranging from a reduction in the volume of forest management work to the conditional elimination of forest management. This step led to a catastrophic drop in the level of technical equipment in the field of forest monitoring and management. Also, today there are several problems associated with the use of human resources. This is since the controlled area occupies huge areas and is not always accessible to an ordinary person, which leads to poor information about the state of the forest. And of course, the amount of data received, as well as their reliability - here you need to make a lot of efforts to obtain high-quality and reliable material, which is not always the case. Therefore, regular monitoring and management of forest resources is an important and primary task that must be performed to restore and maintain the forest industry.

These unfavorable changes have resulted in the need to develop new methods for monitoring forestry, including forest inventory.

To address these challenges in the forestry industry, unmanned aerial vehicles equipped with multi-agent approach technology may be excellent. Let us consider the advantages of using these technologies.
2. Methods and Materials

The newest unmanned aerial systems make it possible to quickly receive information about the forest. The advantages of using unmanned aerial vehicles in the forestry include a number of factors:

- high resolution aerial photographs and stereopairs of very high-resolution images for creating high precision digital terrain models;
- prompt receipt and processing of images from any territory;
- the ability to shoot under the clouds;
- profitability of surveying in small areas (figure 1).

![Unmanned aerial vehicle architecture](image)

**Figure 1.** Unmanned aerial vehicle architecture.

At the same time, a multi-agent system can solve complex problems using the principle of self-organization and evolution of intelligent agents.

The union of an unmanned aerial vehicle and a multi-agent system will allow covering huge areas of forestry, due to mobility, endurance, and high-speed location, and will also allow performing a lot of functions for the management and control of forest resources. Here are some of them:

- control simplification during remote use;
- observation and assessment of forestry for illegal logging;
- current state of forestry control;
- tracking fires in forest areas;
- obtaining up-to-date indicators on forest inventory;
- monitoring the number of animals.

Through constant monitoring, reliable information about the current state of forests will be obtained, as well as the replacement of outdated data with current ones. This will make it possible to effectively manage the sector.

2.1. Research methodology for multi-agent systems

Why multi-agent systems? This is primarily because of the ability to solve complex problems from a technical and practical point of view.

The popularity of the use of intelligent information systems is growing every day in the industries, logistics, retail trade, thereby increasing the efficiency of internal work processes, as well as the quality of services provided.

Today, multi-agent systems occupy a leading position in the field of artificial intelligence research and demonstrate excellent results in solving many problems, such as: control, management, analysis,
planning and many others. Based on a positive work assessment of multi-agent systems, it can be easily argued that the use of these systems in the forestry is relevant.

The idea of multi-agent systems is based on the fact that several agents can communicate, transfer some information to each other, interact with each other and solve the task delegated to them. In this intellectual system, tasks are distributed among agents, and each of them considered as an element of the general structure.

Each agent has its own role, its area of responsibility and its own requirements for work experience.

Let us imagine that we are faced with the task of recognizing what is captured in any image. What happens with the classical recognition method? The input to a certain algorithm is an image that works with this image, and upon completion it produces the result.

What happens with a multi-agent approach? Our original image is split into fragments and an algorithm is launched for each of them (figure 2).

![Traditional scheme of building a software system vs. Multi-agent approach](image)

**Figure 2.** Traditional and multi-agent scheme of building the system operation.

As a result, we get a decrease in processing time due to parallel work, as well as a simplification of the structure of the algorithm itself. It is important to mention, that according to this approach, a geographic information system (GIS) is required. This system will have to collect data from all kinds of recognition processes, as well as to organize new processes.

Analyzing the application of this approach in forestry, it should be noted that the place of multi-agent technology in the structure of GIS for forest area management comes down to processing images obtained as a result of flying over the subordinate territory by an unmanned aerial vehicle, and their recognition, after which, directly, the data is transmitted to the handler program, which currently is a GIS or a part of it, for their further use (figure 3).
Figure 3. Implementation of multi-agents in GIS decision making block-scheme.

The form of interaction between agents is characterized by the fact that efforts to achieve a joint goal while separating functions, roles, and responsibilities is cooperation. That means that in order to successfully interact, these agents will thus require the ability to cooperate, coordinate, and negotiate with each other, in much the same way that we cooperate, coordinate, and negotiate with other people.

Figure 4 shows intelligent agent structure. The input is a special device that is responsible for collecting information about the state of the environment, the output is an executive body that affects the external environment. Solver is a decision-making procedure, this block must have the ability to analyze incoming data, store information about its state and the state of the environment and influence the operation of the object for which it is responsible.
The communication between artificial agents characterized by a protocol that consists of many different rules. These rules determine how to synthesize important and correct messages.

Groups of agents interacting with each other to achieve a common goal depend on several global characteristics, such as social structure, distribution of roles between agents, etc.

The architecture of the agent presented in the form of a context, or a server environment, which is the basis in which it operates. All agents have names, or rather an unchanging identifier. Not only the original agent can work in the context, but also its copy. Intelligent agents can independently create their own copies, sending them to various servers to perform certain actions. After such an agent arrives at the next server, its code and data are transferred to a new context and erased in the previous place. In the new context, the agent can do everything that is not prohibited there. When finished working in a context, the agent can send itself to another context or to the sender's outgoing address. Agents are able to shutdown themselves or at the command of the server, which then transfers them from the context to a location intended for storage.

2.2. Application of multi-agent systems
Agent-based systems are widely used in the industry. For example, IBM uses an agent-based approach for manufacturing semiconductor chips. In Japan, the multi-agent system acts as an abstract train operator interface. Multi-agent systems act to simulate and design adaptive manufacturing systems, and to control, monitor and analyze systems in real time. The role of such systems in the enterprise plays an important role in the agent-based approach. Multi-agent systems operate in the background at various enterprises on an ongoing basis and at any given time participate in solving the assigned tasks.

Multi-agent systems collect information, extract new knowledge from it and, depending on the data obtained, change their behavior over time.

The introduction of multi-agent technologies in the forestry industry will create its own managing agent for each zone of the forest area, and form a flexible, observable and controlled in real time decentralized self-organizing system.

Currently, multi-agent systems are used in the following areas:
- management of distributed or networked enterprises;
- multifunctional logistics;
- virtual organizations;

![Figure 4. Intelligent agent structure.](image-url)
- management of the educational process in distance learning systems;
- companies with developed distribution and transport networks (Procter & Gamble);
- management of distribution channels;
- modeling of user preferences (Ford).

Using multi-agent systems in production can provide the following advantages:
- time for solving problems reduction;
- decrease in the amount of transmitted data;
- terms of approval reduction.

The main advantages of using multi-agent systems in forestry are: a decrease in the level of control during remote use, taxation of forest resources, a quick analysis of the territory for the detection of fires, illegal logging, as well as control over animals.

3. Conclusion
Now, multi-agent systems are at an early stage of development and are just beginning to be used in various fields of activity. At the same time, scientific and practical results, as well as the results of industrial implementations, show that the use of multi-agent systems in forestry will significantly increase the transparency of operations, reduce the time for their execution, and also increase the efficiency of data acquisition.

The use of unmanned aerial vehicles equipped with a multi-agent system in the field of forestry will improve the quality of the data received, increase the amount of information received and processed, and increase the reliability of this process. The architecture of multi-agent systems allows them to be easily scaled and also high automation and intelligent decision-making will significantly reduce the risk of emergencies.

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