Algorithm for Selecting a Priority Task When Planning the Movement of an Autonomous Transport Platform

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Abstract. This article reveals the relevance of the area under study, determines the advantages and disadvantages of autonomous transport platforms, highlights the most vulnerable place of such platforms - the efficiency and safety of the algorithms under which they operate, regardless of the environment (static or dynamic), considers the creation of an alternative algorithm choosing a priority task when moving an autonomous transport platform. This algorithm should provide efficient system selection to optimize the performance of platform components and rationally allocate critical resources such as time and energy. The paper analyzes the existing concepts for the creation of such systems. The article presents a general scheme of the developed algorithm for selecting a priority task and a scheme for the interaction of platform subsystems. It also presents the basic configuration of an autonomous transport platform, a verbal algorithm for moving it to a given point, and describes the operation of a priority transition controller between subsystems.

Keywords: Autonomous · Transport · Platform · ATP · Algorithm · Subsystems · Tasks · Priority · Path · Planning

1 Introduction

Path planning is the most important task in the field of unmanned vehicle navigation. It mainly includes three aspects. First, the planned path must run from a given starting point to a given end point. Secondly, this path must ensure the movement of the object with avoidance of possible obstacles. Thirdly, the path must, among all possible paths that satisfy the first two requirements, be optimal in a certain sense [1].

A high degree of autonomy determines the need to adapt machines to a dynamically changing operating environment. They must make their own decisions in a complex and uncertain environment. Therefore, autonomous machines must have an intelligent control system and perform the tasks assigned to them [2].

ATP is an autonomous transport platform equipped with an automatic control system that can move without human intervention. Autopilot is a device or software and hardware complex that leads a vehicle along a certain trajectory given to it. Most often, autopilots are used to control aircraft (due to the fact that the flight most often takes place in a

A. A. Radionov and V. R. Gasiyarov (Eds.): RusAutoCon 2022, LNEE 986, pp. 46–56, 2023.
https://doi.org/10.1007/978-3-031-22311-2_5

space that does not contain a large number of obstacles), as well as to control vehicles moving along rail tracks. A modern autopilot allows you to automate all stages of flight or movement of another vehicle [3].

2 Relevance

The relevance of this topic is determined by continuous technological progress, covering all spheres of human activity. It encourages the creation of objects that do not require human control, which can perform not only everyday household tasks, but also tasks with increased risk, such as space and deep-sea research, maintenance of nuclear power plants, and elimination of the consequences of man-made accidents and disasters [1].

If projected onto the automotive industry, it is undergoing a significant transformation: the largest car manufacturers, together with IT specialists and developers, are moving towards the creation of vehicles with the possibility of fully autonomous driving. In the future, self-driving vehicles will become a mass phenomenon, but there are still many tasks to be solved on the way to the era of fully autonomous cars [3].

2.1 Advantages and Disadvantages

The advantages of autonomous transport platforms are:

- transportation of goods in hazardous areas, during natural and man-made disasters or military operations - safety;
- cost reduction of transporting goods and people due to savings on the wages of drivers;
- more economical consumption of energy, fuel and use of roads through centralized traffic management;
- saving time spent on transport platform management;
- minimization of emergencies, road traffic accidents with human casualties.

Also, autonomy has a number of shortcomings, which are gradually being eliminated, but at the moment they are still relevant:

- software reliability and efficiency of its algorithms;
- reliability of the technical component of the platform;
- suppression of unauthorized access to the platform;
- more expensive production of a transport platform than a classical platform under human control.

Some systems rely on infrastructure systems (such as those built into or near the road), but more advanced technologies allow the simulation of human presence at the level of steering and speed decisions through a suite of cameras, sensors, radar and satellite navigation systems [3].

3 Existing Concepts of the Navigation System of Autonomous Objects

Existing navigation systems for autonomous objects. The article by A. Guryev dated December 19, 2019 Strong Artificial Intelligence Model describes the concept of information representation and processing, which is called Action-Based Dynamic Semantic Network. It defines the process of selecting necessary actions to achieve goals based on needs.

During the life of the system, the algorithm put into action can change, improve, but it seems that it should have at least the following properties:

- the choice of the next action should not be random, but should be purposeful;
- the performed action should be assessed as success/failure. The failure of the action must be considered in the next selection;
- when choosing an action, prompting signals from the level of associations (connections of type 2 of the previous section) should be considered.

To implement the first property, the system must have information, firstly, about the goals, needs of the system at a given moment in time, secondly, about the expected results of each action known to the system, and, thirdly, about the conditions for successful completion of the action.

The big advantage of the proposed approach is that all three types of information (goals, expected results of the action and the necessary conditions for the action) can be represented by one entity - the concept-characteristic. For example, the characteristic "something near" may be present in the expected results of the action "Approach something", in the necessary conditions of the action "Take something", and also be a goal at some point in time.

The system has a list of goals, consisting of pointers to concepts-characteristics (the significance of this goal is also stored). With this list, as well as with the list of actions with active associative links ("hints"), the action "Select action" works. Also, each action known to the system includes two lists of pointers - one to the prerequisites for performing the action, and the other to the characteristics of the result. Based on this information, the Action Selection algorithm determines which action to choose, constructing a new composite action from separate known actions if necessary.

In general, it becomes clear how the concept of action, which originates from an elementary effector, is overgrown with auxiliary structures (receptors, concepts-characteristics). These structures form a kind of action model that allows you to evaluate the result of the action before the actual execution, which makes it possible to plan actions to achieve the desired result.

For example, if there is a goal "Hunger / Loss of charge", from the action model "Eat food / Replenish resources" (in the necessary conditions of which there is a concept-characteristic "Food nearby / Power stations nearby"), the goal "Food nearby / Power stations nearby" will be added, and for its implementation, the action "Approach food / Get to the station" was created [3].

Part of the concept of A. Guryev was used in the development of an algorithm for choosing a priority task when moving the ATP.

It is also known about older concepts underlying the adaptive behavior of autonomous objects, namely, about two closely related areas of research: "Artificial Life" and "Adaptive Behavior". "Adaptive behavior" - meant the study of the architecture and principles of functioning that allow animals or robots to live and act in a variable external environment, as well as the analysis of the evolution of animal cognitive abilities and the evolutionary origin of human intelligence [4–6].

Adaptive Behavior, as well as Artificial Life, mainly uses a phenomenological approach to the study of adaptive behavior control systems, i.e., it is assumed that there are formal rules for adaptive behavior, and these rules are not necessarily associated with specific microscopic neural or molecular structures, that are present in living organisms.

Research on adaptive behavior is ongoing at a number of universities and laboratories. Let us briefly characterize the work of one of the leading laboratories - the AnimatLab laboratory, which is headed by Jean-Arkady Meyer, one of the initiators of this direction.

The general approach of this laboratory can be summarized as follows. The animat shown in Fig. 1 exists in a real or simulated environment. It has sensors that receive information from the external and internal environment of the animat, and effectors through which it interacts with the environment, as well as a control system that coordinates the perception and actions of the animat. An animat's behavior is considered adaptive if the control system keeps the animat's vital variables (e.g. V1 and V2 in Fig. 1) within acceptable limits. ON picture (Fig. 1) the dashed arrow shows a possible trajectory that goes beyond the allowable area (gray background is an invalid variable area). The solid arrow shows the "corrected" trajectory, corrected with the help of a control system that ensures that the variables are maintained in the allowable (light) region.

The above scheme is of a general nature and does not reveal the internal structure of the self-government mechanism.

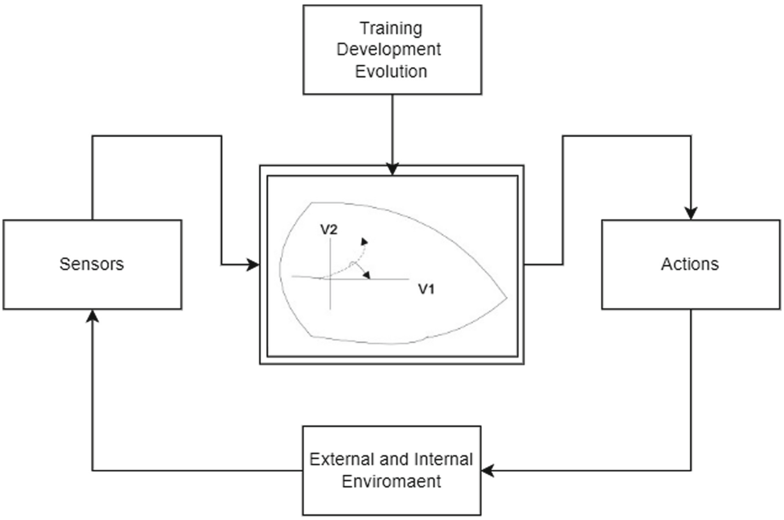

Fig. 1. The general scheme of the animat's behavior. The AnimaLab approach.

The concept of multi-agent systems in solving the problems of distributed artificial intelligence, which is focused on the intellectual sphere, has received rapid development [7–9, 11, 12].

A similar approach is presented in the work of Russell [13]. This concept considers a holistic "organism", called an agent. An agent is everything that can be considered as perceiving its environment with the help of sensors and acting on this environment with the help of actuators. The sequence of acts of perception of the agent is called the complete history of everything that was ever perceived by the agent. The agent's choice of actions at any particular point in time may depend on the entire sequence of percepts observed up to that point in time.

It is assumed that intelligent agents are able to maximize their performance indicators. The implementation of this property is simplified if the agent is able to assume the obligation to achieve the goal and strive for its satisfaction. Goals allow you to organize behavior by limiting the choice of intermediate steps that the agent tries to implement. The disadvantage of this approach is that the agent can limit the choice of intermediate stages, while in real life this is not always possible.

To solve this problem O. Yu. Yakovenko [14] decomposes the decision-making process into several stages: situation recognition; goal setting; building a plan to achieve the goal, and the set of consistent sequences of states that are guaranteed to transfer the object to the target state is the plan. When building a plan, a certain parameter is minimized (or maximized), which is called the cost of the plan. This is necessary in order to choose some of the most preferred subsets from the entire set of possible plans. The main disadvantage of this approach is its inability to plan actions in real time.

In the work of G.S. Osipov [15] on artificial intelligence, to solve modeling problems in planning behavior over discrete sets of actions, constructions equivalent to systems of rules are used. Among the rules, there are those that do not correspond to any actions, but only replenish the set of state factors, and rules that are some actions. Based on these rules, the decision is made. The disadvantage of this approach is not the ability to learn. To develop my algorithm, a part of the concept of G.S. Osipov was also used.

4 Work Goals and Objectives

The purpose of this work is to improve the efficiency of the algorithm for moving the ATP in dynamic space by developing new principles for its construction. To achieve this goal, the following priorities were identified:

1. to perform an analysis of existing trajectory planning algorithms and methods for finding a path in a dynamically changing space;
2. to develop an algorithm for choosing a priority task when planning the movement of ATP;
3. to choose the principles of organization and functional structure of the intellectual system for controlling the movement of ATP in a dynamically changing space;
4. to approve the algorithm for routing and controlling the movement of ATP in real time in a dynamically changing space;

5. to develop a simulation computer model and conduct experimental studies of the functioning of the ATP movement control system in order to test the operability of planning and control algorithms in dynamically changing environmental conditions.

In one of my articles, a patent search was implemented on existing ATP developments, and the methods and algorithms on which their behavior is based were also considered. This article has not yet been published. This article analyzes points 2 and 3 (on this material, another article was written for the Regional Master's Conference XVII, which also has not been published at the moment).

5 ATP Configuration

The object of research is autonomous transport platforms. When choosing the principle of organizing the internal structure, the main criterion was the possibility of implementing the tasks set for civilian platforms, such as delivery robots.

The main structural elements of the Autonomous Transport Platform were also identified:

- mechanical part (base, 4 wheels with motors);
- power cell (1 solar battery);
- sensors (2 infrared sensors to prevent collisions);
- navigation (GPS-module);
- controller (a system that provides interaction and control of nodes).

It is assumed that an autonomous object is self-managing and there are several subsystems in its structure, each of them is responsible for a specific job and all of them are interconnected. Moreover, the subsystems come into activity depending on the task, the goal towards which the movement occurs. Or, one might say, at a certain need of an autonomous object.

On picture (Fig. 2) shows a diagram of the interaction of subsystems. The subsystem of self-management includes the subsystem of self-preservation. The mechanical part is the effector subsystem, the remaining subsystems, respectively: the energy source is the battery, the sensors are the IR subsystem - elements, the GPS module.

Each of the presented subsystems is responsible for a specific work and they are all interconnected. Moreover, the transfer of control from one subsystem to another is carried out on the basis of an assessment of the priority needs of an autonomous object.

Subsystem of self-government. This subsystem is responsible for moving the object. For its work, the control subsystem uses signals from other subsystems, which are the values of the needs of these subsystems. The self-management subsystem evaluates these needs, as well as calculates its own need in time, and forms the ATP goal vector. In accordance with the chosen strategy, the self-management subsystem activates a certain ATP subsystem for a period of time. Acts as a controller.

Subsystem of self-preservation. The possible reaction of the self-preservation system is very diverse: an alarm signal, a change in the safe distance, a change in the parameters of movement, a force impact, and the neutralization of an external source of threat within

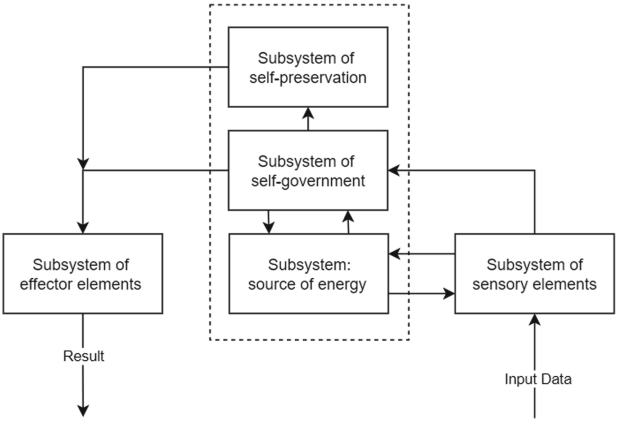

Fig. 2. Scheme of subsystems interaction.

the available resources. The developed autonomous object in the future will have the following features: a low battery alarm (switching to battery charging), changing motion parameters [16–18].

Subsystem of sensory elements. The alleged autonomous object has an infrared vision system, which allows avoiding collisions with objects and a GPS module for orienting on the ground and building a direction vector to the target.

Central source of energy. It is assumed that the energy source ensures the satisfaction of all needs for the implementation of the necessary functions for a long time. Moreover, this energy source in each case allows you to achieve the specified power. It is replenished with the help of solar energy when the movement of the object completely stops.

Subsystem of effector elements. Due to their presence, there is a force change in the motion parameters of an autonomous object. In our case, the object has the ability to move on the surface [19].

6 Movement of the Platform to a Given Point

Behavior planning, or AI planning, is the ability of an intelligent system to synthesize a sequence of actions to achieve the desired target state [10, 11].

The transport platform has initial coordinates, then the coordinates of the point you want to get to are transferred to it. Based on the results of the calculations, the vector of the direction of movement is constructed. The path is a straight line. There is an assessment of the energy resources expended and, if they are sufficient, the platform starts moving in a straight line towards the finish point.

If there are obstacles along the way, then the system is notified by infrared sensors and the priority is given to the self-preservation system, which decides to turn with a concomitant advance to the front to the side, until the obstacle disappears from the visibility of the sensors. As soon as the obstacle is gone, the priority is given to the self-management subsystem, in which the path is recalculated. Then the platform makes a turn towards the finish point until a direct motion vector is obtained [20].

In the process of reaching the end point, the power reserve is calculated and, if the power reserve is less than the distance to the target, then priority is given to the power source subsystem, which will immediately stop and charge up to the required amount of energy with a small margin to reach the finish line. The model of the general behavior of the platform and the choice of the priority system is shown in picture (Fig. 3) [21].

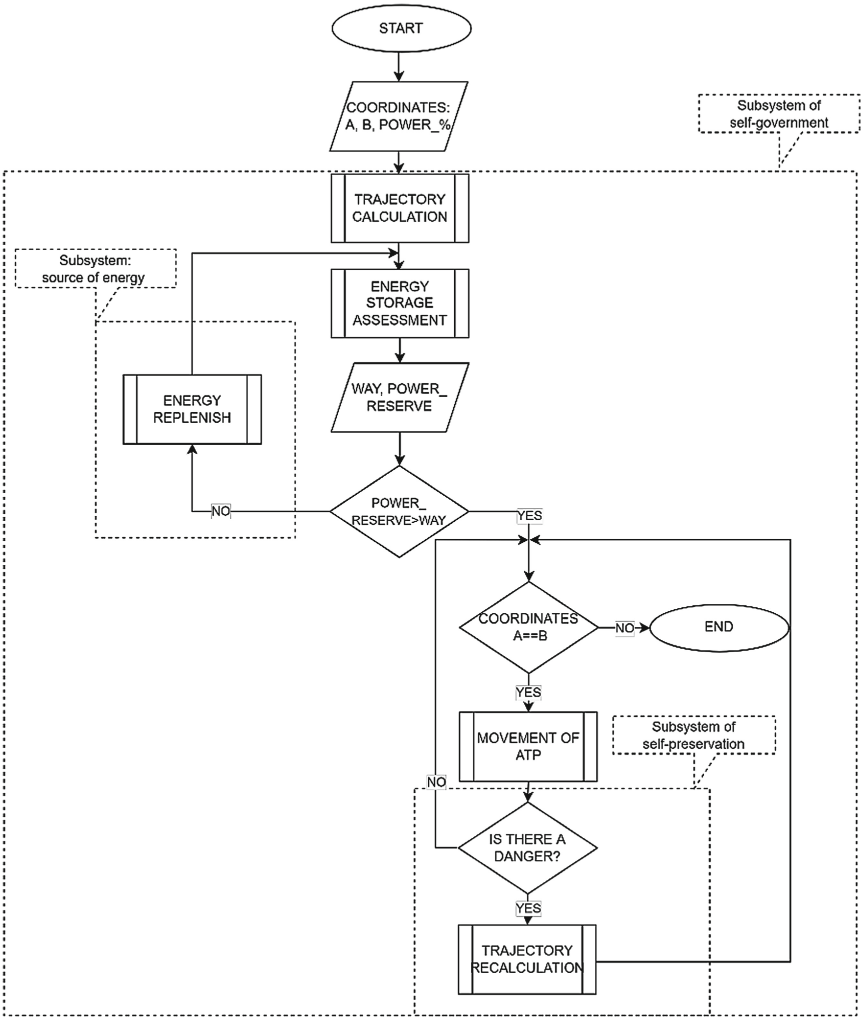

Fig. 3. Scheme of platform behavior.

Description of the algorithm:

1. 1All necessary data are submitted to the input, such as: ATP coordinates, finish line, battery level;

2. Calculation of the trajectory of movement, obtaining distances and estimating the energy reserve;
3. The next step is a comparison of the possible passage of the path on the remaining charge and the calculated path to the "finish";
4. If the charge is not enough, then we recharge the battery;
5. Otherwise, if there is enough energy, then we compare the current coordinates and the finish coordinates. If they are equal, then it's over. If not, then proceed to move;
6. If the sensor detects a danger on the way, then we recalculate the trajectory (the action continues until the obstacle disappears from the field of view of the sensors);
7. Then the algorithm goes through again, until the current coordinates are equal to the coordinates of the "finish" [20]

Priority transition controller. For each of the subsystems, it is assumed that there is a certain signal for the transition of priority to it.

There is a certain criterion for transferring control to the self-preservation system: this is the distance closer than which objects can cause a dangerous situation, cause damage to themselves and the platform. Depending on the speed at which the platform is moving, the safe distance is recalculated. Therefore, the faster the ATP movement, the less time the platform has to change the trajectory in front of the obstacle. The safety distance is dynamically recalculated according to the surrounding circumstances.

To transfer control to a self-sustaining subsystem, the criterion is the remaining range, which is also dynamically calculated from the energy consumption of the platform from external consumers. If this power reserve is + 15% (conditionally) less than required before the finish line, then the priority goes to the self-sustaining system, which in turn ensures the recharging of the batteries [22].

7 Conclusion

Based on the analysis of work on the creation of autopiloted autonomous intelligent objects, the main problems of their creation were identified. Despite the intensive development of such areas as robotics, artificial intelligence, etc. approaches to the creation of a universal algorithm have not been proposed. All previously created works, for the most part, were narrowly specialized for a specific situation or for a specific object, but most importantly, they all contain complex mathematical calculations that reduce the speed of the ATP [23].

As you know, speed is one of the most important characteristics for autonomous platforms, since the safety of others and the ATP itself depends on it.

In this paper, the first steps have been taken to solve this problem, thanks to the development of a simple algorithm that distributes the priority of subsystems, which facilitates the work of ATP, since only the necessary subsystems are involved at the right time.

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