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RESEARCH OF INCREMENTAL PATH PLANNING METHODS FOR MOBILE ROBOTS BASED ON THE D LITE ALGORITHM*

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Abstract: The article considers modern approaches to building mobile robot routes in dynamic environments. An analysis of classical and incremental routing algorithms is conducted. The feasibility of using the D* Lite algorithm for adaptive route planning tasks is substantiated. The architecture of a mobile robot route building software system based on the D* Lite algorithm is proposed. The results obtained confirm the effectiveness of using incremental methods to increase the speed and adaptability of autonomous robotic systems.

Keywords: mobile robot, D* Lite, route planning, autonomous navigation, dynamic environment, incremental planning.

ДОСЛІДЖЕННЯ ІНКРЕМЕНТАЛЬНИХ МЕТОДІВ ПОБУДОВИ МАРШРУТУ МОБІЛЬНИХ РОБОТІВ НА ОСНОВІ АЛГОРИТМУ D LITE*

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Анотація: У роботі розглянуто сучасні підходи до побудови маршрутів мобільних роботів у динамічних середовищах. Проведено аналіз класичних та інкрементальних алгоритмів маршрутизації. Обґрунтовано доцільність використання алгоритму D* Lite для задач адаптивного планування маршруту. Запропоновано архітектуру програмної системи побудови маршруту мобільного робота на базі алгоритму D* Lite. Отримані результати підтверджують ефективність застосування інкрементальних методів для підвищення швидкодії та адаптивності автономних робототехнічних систем.

Ключові слова: мобільний робот, D* Lite, побудова маршруту, автономна навігація, динамічне середовище, інкрементальне планування.

The modern development of robotic systems is characterized by the rapid expansion of the areas of application of mobile robots, in particular in industry, logistics, medical systems, service, military and rescue industries. One of the key conditions for the effective functioning of such systems is the ability to move autonomously in complex and changing environments, responding in a timely manner to the appearance of new obstacles and correcting their own trajectory of movement. That is why the task of building a route for a mobile robot is one of the most important in the field of autonomous navigation [1-2].

Traditional pathfinding algorithms, in particular the Dijkstra and A* algorithms, demonstrate high accuracy in static environments, however, in conditions of dynamically changing space, their application is accompanied by significant time costs due to the need to completely replan the route after each change in the configuration of obstacles, which creates significant limitations for systems operating in real time.

In this regard, incremental route construction algorithms that are able to adapt an already formed path without completely recalculating it are of particular relevance. One of the most effective representatives of this class of algorithms is D* Lite, which provides local route updating when the environment changes and allows you to significantly reduce computational costs. The purpose of this work is to study incremental methods for building a route for mobile robots and analyze the possibilities of using the D* Lite algorithm to increase the efficiency of autonomous navigation in dynamic environments, and the practical value of the work lies in the possibility of using the obtained results in the development of software control systems for mobile robots, oriented to work in conditions of uncertainty and constant change in the configuration of the environment [3-4].

The task of building a route for a mobile robot is one of the central ones in autonomous navigation systems, since the efficiency of the planning algorithm determines the robot's ability to reach the set goal in a timely manner, avoid obstacles, and adapt to changes in the environment. In general, the routing process consists of determining a sequence of permissible states that ensure the robot moves from the starting point to the target with minimal time, energy, or path length. Modern route building methods are conventionally divided into several main groups: classical graph algorithms, heuristic methods, stochastic approaches, and incremental algorithms. Classical algorithms, such as Dijkstra's algorithm, provide a guaranteed finding of the optimal path, but are characterized by high computational complexity, which significantly limits their use in large environments [5-6].

The principle of operation of the algorithm is based on the use of two evaluation functions for each graph vertex: the current value of the path cost and the predicted value. The coordination of these values allows determining the need for route replanning. In the event of a change in the environment configuration, the algorithm performs a local update of the cost values and rebuilds only the necessary fragments of the route. This approach provides a significant reduction in replanning time, which is critically important for mobile robots operating in real time. This is especially true for robots operating in warehouse complexes, production lines, autonomous transport systems, and search and rescue operations. For the practical implementation of the algorithm, a generalized architecture of the mobile robot route planning system was formed, which is presented in Figure 1.

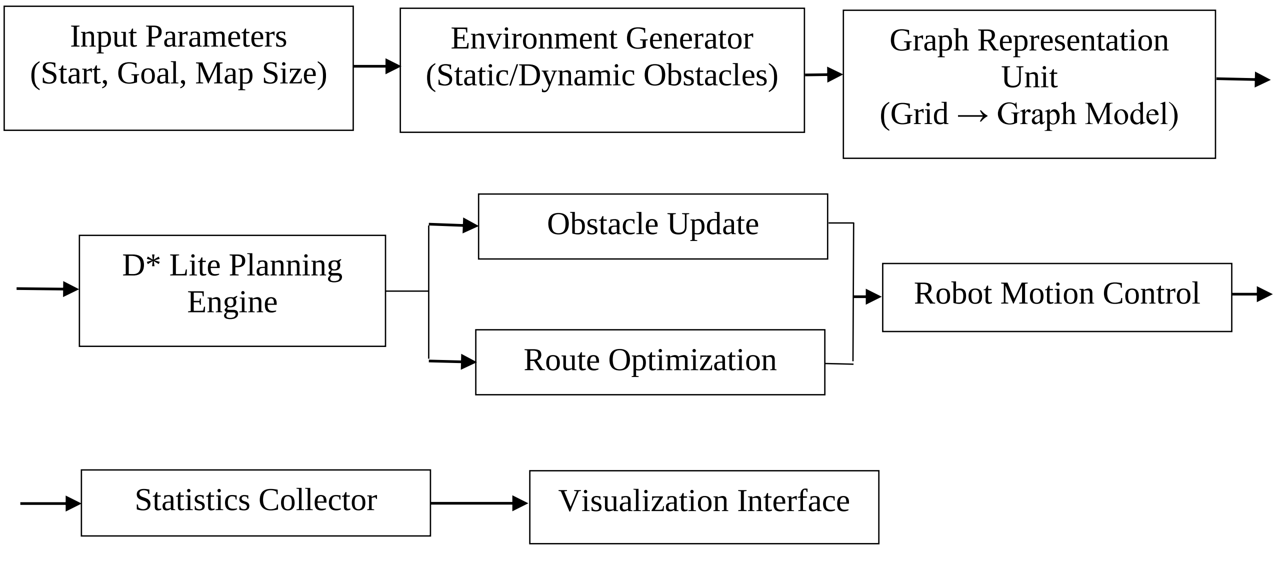

Figure 1 - General architecture of a mobile robot path planning system based on D Lite*

The A* algorithm is an improved version of graph search that uses heuristic evaluation to accelerate route finding. Due to this, it is one of the most common algorithms in autonomous navigation problems. However, when the environment configuration changes, A* requires a complete restart, which significantly reduces its efficiency in dynamic conditions. To solve this problem, incremental planning algorithms have been developed, among which D* Lite occupies a special place. Its main advantage is the ability to reuse the results of previous calculations. Unlike classical algorithms, D* Lite updates only those graph vertices whose state has changed due to the appearance of new obstacles or changes in the cost of transitions [7-8].

The proposed architecture is built on a modular principle, which ensures its scalability and the possibility of further expansion of functionality. At the initial stage, the user sets the environment parameters: map dimensions, coordinates of the starting and target points, as well as obstacle characteristics. The environment generation module forms a discrete map of space, where each cell describes a certain state: a free area or an area occupied by an obstacle. The obtained data is transferred to the graph representation module, where the map is transformed into a graph structure suitable for the operation of the D* Lite algorithm.

The central element of the system is the route planning module, which implements the calculation of the optimal path between the starting and target points. In case of a change in the position of dynamic obstacles, the update module is activated, which transfers new data to the algorithm for local replanning. The route optimization module provides trajectory correction taking into account new environmental conditions, minimizing the path length and the number of changes in the direction of movement. This allows you to obtain smoother and practically implemented trajectories [9-10].

After the route is built, the motion control module performs step-by-step movement of the robot. In parallel, statistical data is collected, including the time of route construction, the number of replannings, the length of the path and the average response time of the system. The visualization module provides a graphical representation of the environment, the route and the current position of the robot. This allows not only to control the navigation process, but also to analyze the effectiveness of the algorithm [11-12].

As a result of the study, modern approaches to building mobile robot routes were analyzed and the main advantages of incremental planning methods in dynamic environments were identified. The analysis showed that classical route search algorithms, despite their high accuracy and prevalence, have significant limitations when working in conditions of variable environment configuration due to significant computational costs for re-planning. The study of the D* Lite algorithm confirmed its effectiveness for autonomous navigation tasks of mobile robots, the main advantage of which is the ability to perform local route replanning by updating only those sections of the graph that have undergone changes, which provides a significant reduction in computing time and increases the system performance in real time. Within the framework of the work, a generalized architecture of a software system for constructing a mobile robot route based on the D* Lite algorithm was proposed, which includes modules for environment generation, graphical representation of space, route planning, processing of environment changes, robot movement control, statistics collection and visualization of results. The proposed structure demonstrates the possibility of effective integration of the algorithm into modern autonomous robotic systems. The results obtained confirm the feasibility of using incremental routing methods to increase the adaptability and productivity of mobile robots. Further development of the research should be directed towards integrating the algorithm with real sensor systems, improving obstacle motion prediction models and implementing multi-robot coordination in complex dynamic environments.

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