COMPARATIVE ANALYSIS OF MODIFICATIONS OF RRT ALGORITHMS FOR ROUTE PLANNING OF A MOBILE ROBOT

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Annotation**:** In this paper, a comparative analysis of modifications of the RRT algorithm for route planning of a mobile robot has been carried out. The advantages and disadvantages of such modifications as CW-RRT, BRRT, TG-BRRT, CW-TG-BRRT and H-BRRT in terms of efficiency and complexity of implementation were investigated and compared. The analysis results identify the most appropriate modifications of the RRT algorithm for different mobile robot route planning scenarios, which can be useful for researchers and developers in the field of robotics.

Key words: Industry 4.0, robotics, comparative analysis, modifications, RRT algorithm, route planning, mobile robot.

ПОРІВНЯЛЬНИЙ АНАЛІЗ МОДИФІКАЦІЙ АЛГОРИТМІВ RRT ДЛЯ ПЛАНУВАННЯ МАРШРУТУ МОБІЛЬНОГО РОБОТА

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Анотація: У цій роботі проведено порівняльний аналіз модифікацій алгоритму RRT для планування маршруту мобільного робота. Було досліджено та зіставлено переваги й недоліки таких модифікацій, як CW-RRT, BRRT, TG-BRRT, CW-TG-BRRT і H-BRRT з погляду ефективності та складності реалізації. Результати аналізу дають змогу виявити найбільш підходящі модифікації алгоритму RRT для різних сценаріїв планування маршрутів мобільного робота, що може бути корисним для дослідників і розробників у галузі робототехніки.

Ключові слова: Industry 4.0, робототехніка, порівняльний аналіз, модифікації, алгоритм RRT, планування маршруту, мобільний робот.

With the development of robotics and the widespread introduction of robots in various fields in the modern world of industry and technology, embraced by the Industry 4.0 phenomenon, the use of mobile robots is becoming increasingly widespread [1-7]. These robots are widely used in various fields such as manufacturing, warehousing, medical diagnostics and many more [8-12]. One of the key aspects of their work is the ability to effectively plan routes to achieve given goals. Path planning algorithms such as RRT (Rapidly-exploring Random Tree) provide efficient methods to solve the path planning problem of a mobile robot. However, given the varied requirements and conditions in different applications, there is a need to modify these algorithms to achieve optimal results. A comparative analysis of modifications of RRT algorithms for planning the route of a mobile robot becomes relevant in the context of the development of Industry 4.0. It is required to identify the most effective modifications of RRT algorithms that will improve the quality and speed of route planning, which will ultimately lead to increased productivity and efficiency of mobile robots in various fields of application [13-16].

The purpose of this study is to conduct a comparative analysis of modifications of RRT algorithms for route planning of a mobile robot in order to determine the most suitable modifications for specific application conditions. The results can be useful both for researchers in the field of robotics and route planning, and for developers and manufacturers of mobile robots seeking to improve the efficiency of their systems in the conditions of Industry 4.0.

RRT (Rapidly-exploring Random Tree) is a state-space path-finding algorithm that is used in robotics to plan the trajectory of mobile robots. It is based on the idea of quickly exploring random directions to build a state tree that represents a set of possible trajectories. RRT builds the tree gradually, expanding it in the direction of randomly selected points, which allows you to quickly find a path to the target point. The tree of modifications of the RRT algorithm is presented in Figure 1.

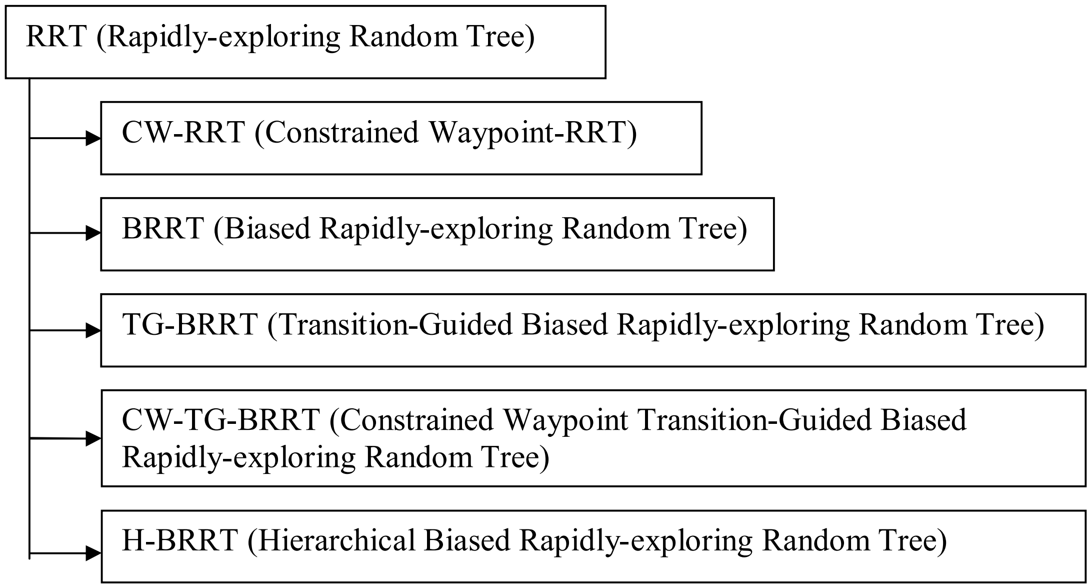

Figure 1 - Tree of modifications of the RRT (Rapidly-exploring Random Tree) algorithm

Let us briefly describe the features of each modification of the RRT algorithm:

CW-RRT (Constrained Waypoint-RRT) is a modification of the RRT algorithm that takes into account restrictions on the path, such as obstacles or restricted areas. CW-RRT seeks to find a path that passes through certain waypoints while satisfying specified constraints;

BRRT (Biased Rapidly-exploring Random Tree) is a modification of the RRT algorithm that adds “distortion” or “bias” to the random selection of points for exploration. This allows the algorithm to quickly find paths towards the target point, reducing the number of random explorations in unproductive areas;

TG-BRRT (Transition-Guided Biased Rapidly-exploring Random Tree) is a further development of the BRRT algorithm, which adds information about transitions between states (for example, areas with uniform movement) to control the exploration of space. This allows dynamic conditions and system behavior to be taken into account when planning the path.

CW-TG-BRRT (Constrained Waypoint Transition-Guided Biased Rapidly-exploring Random Tree) is a combination of CW-RRT and TG-BRRT that takes into account both path constraints and state transition information. This allows efficient path planning under conditions with constraints and system dynamics.

H-BRRT (Hierarchical Biased Rapidly-exploring Random Tree) is an algorithm that uses a hierarchical structure for path planning. It divides the state space into levels and plans the path at each level taking into account the hierarchy of tasks. This allows different aspects of the path planning problem, such as time constraints or preferences, to be taken into account at different levels of the hierarchy.

Based on the research conducted, a table comparing the advantages and disadvantages of modifications of the RRT algorithm was developed; the comparison results are presented in Table 1.

Table 1 - Comparison of advantages and disadvantages of modifications of the RRT algorithm

Algorithm	Advantages	Flaws
CW-RRT	Considers path constraints, allowing path planning in complex environments	Additional complexity due to the need to define and manage waypoints
BRRT	Finds ways to the target point faster thanks to the “bias” to explore in the direction of the target	There is a risk of getting stuck in local minima due to too much bias
TG-BRRT	Considers dynamic conditions and state transitions for efficient path planning	Requires additional information about system dynamics and state transitions, which may be difficult to obtain or calculate
CW-TG-BRRT	Combines the advantages of CW-RRT and TG-BRRT, taking into account path constraints and state transition information	Requires complex implementation due to combining two approaches
H-BRRT	Uses a hierarchical structure for path planning, which allows different aspects of a task to be considered at different levels of the hierarchy	Requires additional work to divide the state space into levels and organize a hierarchy, which can be difficult to implement

Each of these algorithms has its own characteristics and is suitable for different scenarios of mobile robot route planning. The choice of a specific algorithm depends on the requirements for path planning, the characteristics of the environment and the task of the robot.

CONCLUSIONS. A comparative analysis of modifications of the RRT algorithm for planning the route of a mobile robot revealed several key conclusions. The basic RRT algorithm is easy to implement, but can require a large number of iterations to find a path in complex environments due to the random selection of points to explore. Modification of CW-RRT, which takes into account path restrictions, allows you to more effectively plan routes in conditions with obstacles or restricted areas. BRRT, thanks to the "bias" to explore in the direction of the goal, finds paths faster, but there is a risk of getting stuck in local minima. TG-BRRT takes into account dynamic conditions and state transitions, but requires additional information about the system dynamics. The combination of CW-RRT and TG-BRRT in the CW-TG-BRRT algorithm combines the advantages of both modifications, but requires complex implementation. The use of a hierarchical structure in H-BRRT allows different aspects of a task to be considered at different levels of the hierarchy, but requires additional work to organize the hierarchy. The choice of a specific algorithm depends on the requirements of the problem, the characteristics of the environment, and the available resources. Each of the considered algorithms has its own advantages and disadvantages, and the optimal solution requires analysis of the specific application context.

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