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Some Features of Route Planning as the Basis in a Mobile Robot

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ABSTRACT

A mobile robot is a mechatronic system that can facilitate human labor. These systems are widely used in various fields of production. A key element of a mobile robot is its navigation system. For the successful use of the navigation system of the mobile robot and its subsequent efficient operation, it is necessary to plan the route. This will avoid errors in the movement of the robot, solve the tasks. Among the main tasks of route planning for a mobile robot, as a rule, are distinguished: building a map of the robot's motion environment, and adjusting the robot's motion path. The article discusses the main points of such a generalization, provides algorithms for solving specific problems.

Key words: Mobile Robot, Navigation System, Route Planning, Robot Movement, Voronoi's Line.

1. INTRODUCTION

Mobile robots (MR) are modern robotic systems. Such systems are used in various industries. Mobile robots are designed to help people. These robots can perform various functions in conditions when a person cannot do this.

The basis of the mobile robot is its navigation system. Such a navigation system should solve various problems for movement in space. To do this, the robot must be able to build a route of its movement. The solution to this problem is associated with the use of the theory of artificial intelligence, the theory of pattern recognition [1]-[4].

These theories using virtual reality models allow solving the following intelligent control tasks of mobile robots (MR) [5], [6]:

– optimal or adaptive MR route planning in an obstacle-based environment using local or global information;
– simulation in the virtual space of MR environment and its behavior;
– recognition of situations and optimal solutions adoption;
– programming (interpolation) and adaptive correction of MR movement along the planned route;
– adaptive motion control MR.

An intelligent mobile robot is a complex mechatronic system capable of environment sensory perception and analyzing its state for autonomous navigation and controlled movement to the destination in order to perform specific tasks (transportation of cargoes, study of terrain, etc.) [7], [8]. Thus, the selected subject of the study is very relevant.

2. A SMALL REVIEW ON THE SUBJECT OF RESEARCH

The tasks of planning the motion of robot are devoted to a large number of works, which describe the methods and algorithms of planning.

The goal article [8] is to design a navigation algorithm to improve the capabilities of an all-terrain unmanned ground vehicle by optimizing its configuration (the angles between its legs and its body) for a given track profile function. The track profile function can be defined either by numerical equations or by points. The angles between the body and the legs can be varied in order to improve the adaptation to the ground profiles. A new dynamic model of an all-terrain vehicle for unstructured environments has been presented. The model is based on a half-vehicle and a quasi-static approach and relates the dynamic variables of interest for navigation with the topology of the mechanism.

In [9] are developed an algorithm to generate a complete map of the traversable region for a personal assistant robot using monocular vision only. Using multiple taken by a simple webcam, obstacle detection and avoidance algorithms have been developed. Simple Linear Iterative Clustering (SLIC) has been used for segmentation to reduce the memory and computation cost. A simple mapping technique using inverse perspective mapping and occupancy grids, which is robust, and supports very fast updates has been used to create the map for indoor navigation.

A safe area search and map building algorithm for a wheeled mobile robot in complex unknown cluttered environments are investigated in [10]-[12].

For example, in [13] is generalized Region-Based framework that is suitable for any sampling-based planning approach. Presented three variants of framework for graph-based, tree-based, and hybrid planning methods.

A novel detection algorithm for vision systems has been based in [14] on combined fuzzy image processing and bacterial algorithm. This is the main goal of the work – it is creation of a temporary trajectory for the optimal path based on the genetic algorithm. Algorithms for collision-free navigation of mobile robots in complex cluttered environments are given in [14].

In [15] are presented a sliding mode based strategy for a unicycle-like robot navigation and guidance. The proposed navigation law is applied to the problems of patrolling the border of a moving and deforming domain and reaching a target through a dynamic environment cluttered with moving obstacles.

Robot Path Planning Model of Target Gravity Optimal RRT Algorithm is described in [16]. Proposed RRT algorithm based on target gravity function optimization.

Throughout the paper [17] highlight three themes: (1) The terrain map modeling and the obstacle detection; (2) the obstacle avoidance path planning method; (3) motion planning for the legged robot. Concretely, a novel geometric feature grid map (GFGM) is proposed to describe the terrain. Based on the GFGM, the obstacle detection algorithm is presented. Then the concepts of virtual obstacles and safe conversion pose are introduced. Virtual obstacles restrict the robot to walk on the detection terrain. A safe path based on Bezier curves, passing through safe conversion poses, is obtained by minimizing a penalty function taking into account the path length subjected to obstacle avoidance.

In [18], [19] are address the issues of motion planning in a legged robot walking over a rough terrain, using only its onboard sensors to gather the necessary environment model. The proposed solution takes the limited perceptual capabilities of the robot into account. A multisensor system is considered for environment perception. The key idea of the motion planner is to use the dual representation concept of the map: (i) a higher-level planner applies the A* algorithm for coarse path planning on a low-resolution elevation grid, and (ii) a lower-level planner applies the guided-RRT (rapidly exploring random tree) algorithm to find a sequence of feasible motions on a more precise but smaller map. This paper contributes a new method that can identify the terrain traversability cost to the benefit of the A* algorithm. A probabilistic regression technique is applied for the traversability assessment with the typical RRT-based motion planner used to explore the space of traversability values.

We see various approaches for building navigation systems for mobile robots. This underlines the importance and complexity of the issues under consideration. Among these issues should be highlighted: mapping among the movement of robots and route planning.

3. MAPPING THE ENVIRONMENT OF THE ROBOT MOVEMENT

MR has a number of sensors and an appropriate control system that allows the robot to make a movement. For movement MR uses various remote sensors. But for this, MR must have a map of the environment where the movement will take place. Such a map has information about the surface topography, which may be supplemented in the process of moving the robot.

Consider the drawing up process a map of the environment. Suppose that at the initial time the external medium is not investigated, and the robot is in the center of the free section 0 (Figure 1), which is considered the origin of the created map [20], [21].

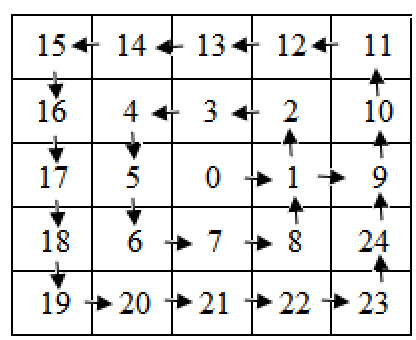

Figure 1: Trajectory of the robot's movement when drawing a map

Sites with numbers 1-8 are considered potentially passable. To clarify their patency, the robot performs a sequential scan of these sections. Scanning starts from site number 1. If this section is free, then moving in the medium direction of the first segment center as shown in Figure 1. Moreover, the displacement amount is equal to the maximum of the overall sections dimensions. Then it is considered that the robot has moved to the center of the next free area. In this case, the center coordinates of this section, can be determined by formulas 1 and 2, are plotted on the map [8], [22]:

$$X_i = X_{i-1} \pm \Delta S \times \cos\alpha, \qquad (1)$$

$$Y_i = Y_{i-1} \pm \Delta S \times \sin\alpha, \qquad (2)$$

where:

X_{i-1} is the abscissa of the previous section;

Y_{i-1} - the ordinate of the previous section center;

ΔS - movement amount;

α - the heading angle of the robot, the difference between the course and the azimuth (Figure 2 [23]).

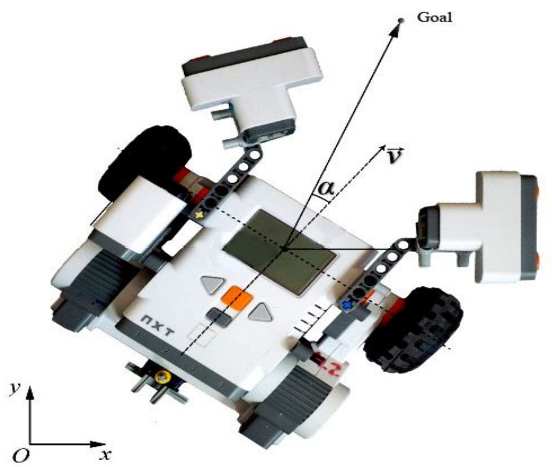

Figure 2: Mobile robot [23]

In formula (1) the sign "+" is chosen if the i-th area is located to the right of i – 1 and the sign "–", if to the left. In formula (2), the sign "+" is selected if the i-th section is located higher than the i – 1-th, and "–", if lower.

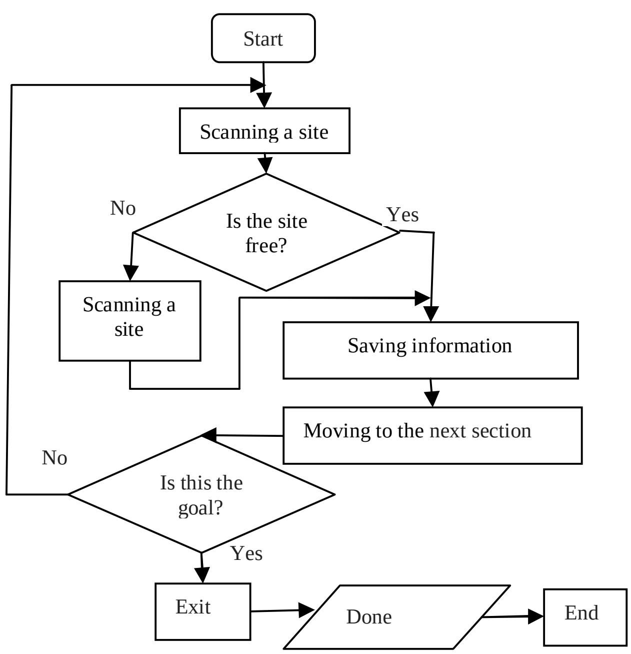

Figure 3: Algorithm for mapping the terrain

After examining sites 1-8, the robot expands the research area and proceeds to scan areas 9-23, etc. This process continues until there are no unexplored areas left in the external environment. Then, in the robot's memory, a map of its working area is formed. Based on this, the algorithm for mapping the terrain can be presented in accordance with Figure 3.

After drawing up the environment map, the robot must use it in the moving process to the target. However, the resulting map cannot be absolutely accurate due to measurement errors. Therefore, after each move, the robot must perform the map refinement, position on it.

4. CORRECTION OF THE ROBOT'S TRAJECTORY AND ROUTE PLANNING

The task of correcting the moving trajectory and avoiding obstacles is related to the tracking mode organization by copying motion errors and correcting the trajectory.

Errors in the control actions development from the control computer to the "robot" are caused, on the one hand, by the accumulation of errors in the linear displacement sensors, and on the other hand, by disturbing influences, as a rule, these are input actions interfering with the control objective achievement, from the environment.

The errors of the linear displacement sensors are proportional to the distance traveled. If we neglect the disturbing effects, then the path segment length, according to which it is necessary to write off the accumulating errors, is expressed as follows [8], [22]:

$$S = \max(x_1, x_2, x_3) \times \Delta t, \qquad (3)$$

where:

Δt is the time interval for writing off;

x_1, x_2, x_3 – robot movement speed.

In the same time:

$$S = n \times E, \qquad (4)$$

where:

n is the proportionality coefficient;

E – the maximum permissible error in any dimension.

Hence, starting from formula (3) and formula (4), we can find the write-off interval [8], [22]:

$$\Delta t = \frac{n \times E}{\max(x_1, x_2, x_3)}, \qquad (5)$$

In the presence of disturbing effects, the write-off interval does not remain constant, since motion errors acquire a random character.

In connection with the solution of these tasks, it is possible to plan actions for a mobile robot in the environment, plan a route or a path through which the mobile robot will move, and choose the shortest path to reach the target, and correct the path of the robot's movement in the environment.

According to the adopted robot control algorithm, its motion, starting from some initial state, is further determined entirely by this and target states and does not depend on the history of the motion.

The route laying of motion is associated with the process of processing the relief matrix including information on two components, deterministic and random [23].

The deterministic component consists in changing the relief, that is, in raising or lowering the surface, and the random component is associated with the presence of individual obstacles and their placement on the surface areas. In this regard, there is a need to create graphical models of the relief that determine the relationship between pairs of obstacles, on the basis of which it is possible to build a network of passes between them. This ratio is the proximity ratio that is formed in such a way that the sum of the distances between the main target points (MTP) of obstacles associated with this ratio is the smallest among the other possible relations on the same points set.

The predetermined, on a MTP set, the proximity relation defines an obstacle graph on which a connections set corresponds to a cross-sections set of passages between obstacles pairs. From the definition of the obstacle graph it follows that the planar faces of the graph correspond to surface areas where three or more passes converge, these sections are called areas, and several faces of the graph having common edges are said to be adjacent.

Transitions between adjacent edges are performed only through common edges, then the transition system will be represented by a route graph, in other words, the route graph defines the transitions set between sites, while the route graph edges and the obstacle graph cross each other at some passages plane points between obstacles. After that, a route is chosen whose task is to select the shortest path on the route graph connecting the two vertices.

To solve the route planning problem, we propose to use skeleton algorithms as the basis, which reduce the free space of the robot to a one-dimensional representation, for which the path planning task becomes simpler. Such a representation with a smaller dimensions number is called the skeleton of the configuration space.

An example of the application of the "Skeletonization" technique is shown in Figure 4 – Voronoi's line for free space, which is the geometric locus of all points equidistant from two or more obstacles [24], [25].

Figure 4: Voronoi's line for free space

In order to plan the path using Voronoi's line, the mobile robot first moves from the current configuration to the point on the Voronoi line.

It can be easily shown that such an operation can always be performed by moving along a straight line in the configuration space (the possible values space of the generalized coordinates for material points system). Then the mobile robot follows the Voronoi line until it reaches the point closest to the target configuration. Finally, the robot leaves the Voronoi line and moves toward the target. And at this last stage the motion along a straight line in the configuration space is again performed [24], [25].

One of the "Skeletonization" technique examples: Voronoi line is the geometric locus of points equidistant from two or more obstacles in the configuration space.

Thus, the initial task of planning the path is to find a path on the Voronoi line, which is usually one-dimensional and has a finite point’s number at which three or more one-dimensional curves intersect.

Movement along the Voronoi line may not provide the shortest path, but the detected paths will differ by the presence of maximum distances from obstacles.

5. CONCLUSION

A mobile robot is designed to perform various tasks, as a result of which it is possible to replace human labor or provide significant assistance to a person. The main element of a mobile robot is a navigation system. Such a system allows the movement of the robot. For this, it is important to know the environmental conditions in which the robot will carry out its movement.

Thus, route planning is an important element of the navigation system of a mobile robot. Route planning increases the efficiency of the work performed.

The paper summarizes the solutions of individual problems for the navigation system of a mobile robot: building a map of the environment of the robot's movement, adjusting the robot's trajectory and planning the robot's route.

An algorithm for mapping a terrain is proposed, which allows one to accurately determine the parameters of one's own location and environmental objects location. The route laying principles of mobile robot movement are considered. To solve the problem of planning the route, it is suggested to take as one of the "Skeletonization" algorithms, namely, the Voronoi line for free space, but it is expedient to apply it in configuration spaces with small dimensions.

As the following research tasks, it is necessary to note the development of a robot motion control algorithm when avoiding obstacles, as well as a general robot motion control algorithm.

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