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Features of the Construction and Control of the Navigation System of a Mobile Robot

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ABSTRACT

The use of robots is one of the promising areas for development in various industries, human activities. Mobile robots are of particular importance. These robots are able to replace humans in difficult and dangerous situations. Mobile robots are able to perform any tasks that have different levels of difficulty. An important element of mobile robots is the navigation system and the management of such a system. The navigation control system of a mobile robot determines the possibilities of using such a robot. This necessitated the importance of considering the features of the construction and control of the navigation system of a mobile robot. The paper highlights the key features of this consideration.

Key words: Mobile Robot, Robot Control, Navigation System, Robot Vision, Technical Vision.

1. INTRODUCTION

Mobile robotic systems are used today in a variety of industries. Such devices ideally should move confidently in an unfamiliar and unpredictable situation in the real world [1]. Nevertheless, the main problem of all currently existing mobile devices that move independently, without human control, remains navigation.

Thus, one of the actual robotics tasks is the task of navigating the robot in space that is analyzing the situation and choosing the route by the robot itself without human intervention. For successful navigation, the robot system must be able to build a route, manage traffic parameters; determine the rotation angle of the wheels and the speed of their rotation, correctly interpret the information around the world from the sensors, and constantly monitor their own coordinates [2].

The study of problems and the development of methods for navigating mobile robots in an unfamiliar environment can make a great contribution to the artificial perception theory development, pattern recognition, navigation and adaptive movement control of mobile robots in the presence of dynamic constraints and unknown obstacles.

Thus, the selected subject of the study is very relevant.

2. REVIEW OF THE LITERATURE

In [3] represents the current status of a long term research effort leading to the development of perceptually-based navigation systems for autonomous robots. The focus of the research is on environmental modeling, planning, plan monitoring, and vision. These four components arc tightly coupled in a system, which provide the flexibility and extensibility required for an experimental tested for robot navigation.

In [4] 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. The algorithm has been created using a simple equation system. This is an advantage over other algorithms with more complex equations which need more time to be calculated. Additionally, it is possible to optimize to any ground-track-profile of any terrain. In order to prove the soundness of the algorithm developed, some results of different applications have been presented.

In [5] presents an analysis of the complex space, using the principle of attraction and repulsion of poles and zeros. To develop the algorithm an integrated system is developed, which includes: an external camera (to take the view of the global navigation surface), the assistant robot, and some communication devices. The navigation is supported by algorithms of digital image processing and carried out using the technique of roots location.

In [6] are described allows for real-time performance through a combination of fast but shallow processing modules that update the map's state while slower but more discriminating modules are still computing. The routes featured different road types, environmental hazards, moving pedestrians, and service vehicles.

In [7] are developed of a navigation system using smartphone and bluetooth technologies to help the visually impaired navigate work zones safely. Authors are developed and tested a new system to provide audible messages to help visually impaired pedestrians safely navigate through or around work zones. This system uses Bluetooth beacons attached to work zone infrastructure that send messages to a pedestrian's smartphone app rather than the traditional method of beeping buttons that announce a message when pressed.

In [8], the problem of navigation and control of the movement of a wheeled mobile robot by means of reference beacons is considered. Criteria for the controlled movement quality of such robots are defined, the formalism of the mechanics used in the construction of their mathematical models is briefly considered. The location of the mobile robot can be determined with the aid of beacons whose coordinates are known, and their current direction is determined by means of a vision system, while the environment map was not compiled, but navigating along landmarks. However, it should be emphasized that the problem does not have a solution if the beacons and the robot are on the same circle, since in this case the circles coincide.

Work [9] is aimed at visual odometry – the method of measuring coordinates using technical vision. Although the navigation system with the help of odometer sensors gives a good accuracy has a small cost, but there is a lack of this technique – increasing the amount of information during the movement inevitably leads to accumulation of errors. In practice, accumulated orientation errors cause most positioning errors, the number of which increases in proportion to the path traversed by the robot.

In [10], in order to demonstrate the path to the goal, an algorithm based on the behavior of the "ants colony" searching for a food source is proposed, even if they do not know its location, as a result, a probabilistic model is constructed. However, this technique differs in the complexity of calculations.

Thus, there are a large number of studies that examine various aspects of the navigation systems of mobile robots. Moreover, the main issue is to follow the general principles for constructing such systems. This we will consider below.

3. FEATURES OF NAVIGATION SYSTEMS

The mobile robot has a sensors number for perception of its environment, a actuators number (effectors) for influencing the environment and a control system that allows the robot to perform purposeful and useful actions (Fig. 1) [11], [12].

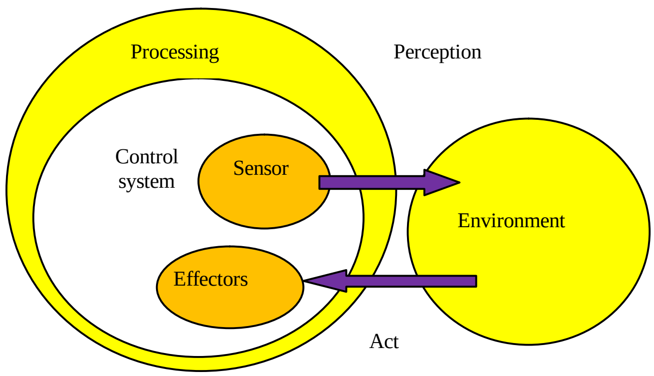

Figure 1: Basic elements of all robotic systems [11], [12]

Mobile robots use remote sensors, temperature sensors, chemical sensors, radiation sensors, etc. to perceive the surrounding environment, as well as propulsion devices as effectors for influencing the environment.

In robotics, an end effector is the device at the end of a robotic arm, designed to interact with the environment. The exact nature of this device depends on the application of the robot. In the strict definition, which originates from serial robotic manipulators, the end effector means the last link (or end) of the robot.

The first robot navigation systems were created on the basis of scanning sensors, including television, locational and stereo range meters. The special computing scheme of the robot ultimately brought electrical signals to analogues of various obstacles and concluded about the expediency of this or that movement. The standard signs of obstacles perceived by the robot were the wall, awning, pit - a breakage, slope, danger for the range finder and other simplified or enlarged details of the scene.

Typically, the robot technical vision task during navigation is divided into three levels, corresponding to the far, middle and near navigation (Fig. 2) [3]. It should also be noted the importance of applying the general principles of building technical vision systems. This is due to the fact that technical vision has great potential for use in various fields [13]-[16].

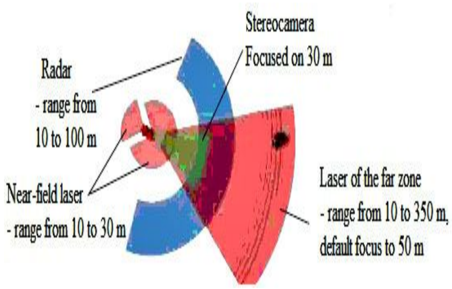

Figure 2: Navigation zones [3]

The long-range navigation system is intended for planning the main route of the robot's movement. The main function of machine vision in this case is the recognition of landmarks. Representations of the external environment are based on the map of scopes (robot patency), robot location, and sequence of areas locations through which the route passes [3], [12].

The system of intermediate (middle) navigation contains a map, which is a map subset of the long-range navigation system with more detailed content [3]. The navigation task is to ensure movement within a uniform visibility, that is, the robot passes through corridors of free space (a straight terrain strip where maneuvering is not required). The intermediate navigation system assumes the alternation of such corridors and their consequent adjustment by increasing the width and dividing the route into smaller sections. The intermediate navigation system provides a general analysis of images for subsequent segmentation and recognition, qualitative distances determination, accumulation of landmarks and route planning.

The near-navigation system is intended for direct measurement of distances in combination with a multidimensional determination of the intermediate safe zone subspace within which the robot moves, and also the analysis of the terrain structure. The system should measure distances, assess the terrain structure, determine the safe circumvention of obstacles and plan the certain routes passage. A particular task of the near-navigation system is to follow the roads. It consists of planning the sequence of perceived changes in the road, overcoming crossed and curved sections, steep descents and lifts of the road, as well as providing navigation in the presence of another robot. Thus, this task, being a private for the entire robot navigation, was associated with the first stages of the robots navigation systems development [3].

4. FEATURES OF CONTROLLING A MOBILE ROBOT

The process of creating a navigation system usually includes the following steps:

- drawing up a map of the environment;
- robot's trajectory correction;
- route planning (choosing the optimal path leading to the target);
- local movements management;
- bypassing the robot dangerous sections of the route.

Algorithmic solution of the above problems should be based on information about the surface relief, which can be supplemented in the process of moving the robot. For routing a route, global information about the movement area is used, for example, in the form of a relief matrix, each element of which corresponds to a certain surface area. The indices of the matrix individual element determine the linear coordinates of the terrain section, and the element value is the relative height of this section.

The control of local movements along a known route is carried out on the basis of information about the surface nature in the near vicinity of the robot [17], [18].

If you determine the movement route as a reference points (subgoals) sequence of the movement, including the initial and final (target) position of the robot, the route laying task involves the subgoals number formation and the subsequent selection of a subset that optimizes the robot movement.

The laying process the route of robot movement is preceded by the drawing up of a environment map. With the local robot movements, the tasks of correcting the motion and traversing dangerous surface sections trajectory are related [19], [20], [21].

When working with single obstacles, you can use less complex control algorithms [22]-[25].

One of the building features an intelligent mobile robot management system is that it is built on a hierarchical, multi-level principle, according to which the degree of intellectuality increases with increasing hierarchical rank of the subsystem.

It should also highlight the strategic and tactical levels of control of the mobile robot.

The strategic level of the mobile robot's control system (CS) is used to form the robot's expedient behavior when it reaches its goal.

At the CS output, it develops indications of the goal location for the movement control system:

- target waypoint;
- the necessary state of the mobile robot drives;
- command control modes of the information-measuring system.

Tactical level of CS motion is used in planning the program trajectories of the robot movement in an environment with obstacles, taking into account the dynamic characteristics of the robot.

The generalized control system is practically independent of a particular control object and the environment of its operation.

5. CONCLUSION

A mobile robot is one of the varieties of robots. A mobile robot is capable of performing various tasks in conditions that are dangerous or harmful to humans. A mobile robot can also replace a person in production, for a more successful solution of tasks.

The main structural component of a mobile robot is a navigation system. This system helps the robot navigate in space and complete the tasks that were set for such a robot. This minimizes the errors that the robot can make and increase the efficiency of the work performed.

For the successful implementation of the navigation system of the robot, it is necessary to take into account the features of the functioning and construction of such navigation systems. Among these features, it is necessary to take into account various actuators for influencing the environment and the robot control system. It is also necessary to take into account the levels of technical vision that are used in the navigation system of a mobile robot.

Thus, as the following research tasks, it is necessary to note the development of various robot control algorithms. Among these algorithms, one can distinguish: robot movement correction, route planning, obstacle avoidance algorithm. All these algorithms obey the control features of the navigation system of the mobile robot, which is also considered in the work.

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