Correction of the movement of the mobile robot using the modified algorithm

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Abstract. Currently, automation of processes in which a robot can replace a human is widespread. To solve this problem, robots must be able to move independently from one position to another. Currently, many different approaches have been developed to solve this problem, such as neural networks, the method of potential fields, fuzzy logic methods, genetic algorithms, and computer vision. One of the most effective methods of solving the navigation problem is the method of building a navigation system based on the use of algorithms for localization, mapping, and automatic obstacle avoidance. One of the most effective obstacle avoidance algorithms is the D-star algorithm, which, despite its effectiveness, has some drawbacks. The method of potential fields and neural networks also showed good results, but each of them separately has several significant drawbacks. Based on the method of building a navigation system, the method of potential fields and neural networks, a modified method has been developed that allows a mobile robot to perform autonomous movement in an environment with obstacles. This modification eliminates some of the problems that arise when implementing the navigation system and combines the advantages of the methods used.

1 Introduction

In today's world, process automation is gaining momentum. It makes it possible to replace humans in carrying out some actions. The use of robots in hard-to-reach or dangerous places can keep people safe from serious injuries.

To solve this problem, robots need to be able to move independently from one point to another, avoiding obstacles. This is especially important because obstacles can damage the robot and then it will not be able to continue performing its intended actions. Many corporations are engaged in the development of effective methods, many of them are classified. In this paper, we present an algorithm to solve the problem of moving in an environment with obstacles with minimized deviation from the trajectory.

2 Description of the algorithm

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A modification of the D* algorithm [1-4] allows a mobile robot (MR) to perform autonomous movement in a nondeterministic environment, avoiding collisions with obstacles. The main advantages of this technology are:

- The possibility of using a robot without a gyroscope, accelerometer, and GPS-tracker, which can significantly reduce the price of the manufactured device.
- Taking advantage of the basic D* algorithm and potential fields method to quickly and efficiently build a trajectory to avoid obstacles.
- Possibility of application on different types of mobile robots (tracked, wheeled, omni-wheeled, etc.)
- Possibility of further development of the method to solve the set tasks.
- Flexibility in use: with small modifications it is possible to solve most of the navigation problems, regardless of the robot's capabilities. The only necessary conditions are:
  - Rangefinder or stereo camera.
  - Capability of the MP to perform translational and rotational movement.

The movement of the MP using the modified D* algorithm is described [5-8]: by the following system of equations

$$\begin{cases} \dot{x} = v_{max} * \cos(\varphi) * dir \\ \dot{y} = v_{max} * \sin(\varphi) * dir \\ \dot{\omega} = \omega_{max} * turn \end{cases}$$

where:

- v_{max} – maximum forward speed,
- ω_{max} – maximum rotational velocity,
- Direction of translational movement *dir*:

$$dir = \begin{cases} -1 - backward, \\ 0 - no\ translational\ motion, \\ 1 - forward \end{cases}$$

- Direction of rotation *turn*:

$$turn = \begin{cases} -1 - to\ the\ right, \\ 0 - no\ rotation, \\ 1 - to\ the\ left \end{cases}$$

- Angle φ: $\varphi \in [0;\ 90]$

The main disadvantage of this method is the error resulting from external forces (such as friction) and the peculiarities of the various motors. Since it is impossible to track the occurrence of such errors without a gyroscope and accelerometer during motion, it was decided to use artificial intelligence to minimize the occurrence of such errors [9-10]. Thus, the use of the accelerometer and gyroscope will be necessary only for the initial setup and calibration of the robot. That is, the robot will be trained to ride on a specific surface characterized by a coefficient of friction. It is possible to teach the robot to move on different surfaces, and then it can choose the optimal mode of motion correction by itself.

This method allows you to minimize the number of sensors required by the robot, but at the same time limits the cases of use. We must choose either versatility or fewer sensors.

In this problem, it is quite difficult to determine the voltages applied to the motors necessary for the robot to move clearly along the calculated trajectory, because too many factors affect the movement of the MR [11-18]. The idea of solving this problem with neural networks emerged. Since we cannot select a training sample due to the features mentioned above, i.e., we cannot determine the optimal stresses for each situation, it is necessary to consider learning without a teacher with reinforcement.

At the heart of this idea is the principle of child learning. Consider, for example, walking. The child does not know which muscles need to be engaged at what point in time, he just tries to repeat after adults and learns from his mistakes. The brain is designed so that it remembers cause-and-effect relationships, which actions led to "success" and which – to "failure". So, too, artificial intelligence must somehow evaluate the "success" of its decisions. For this purpose, it is necessary to introduce a reward function characterizing success. Figure 1 shows a schematic of how such a method of learning works.

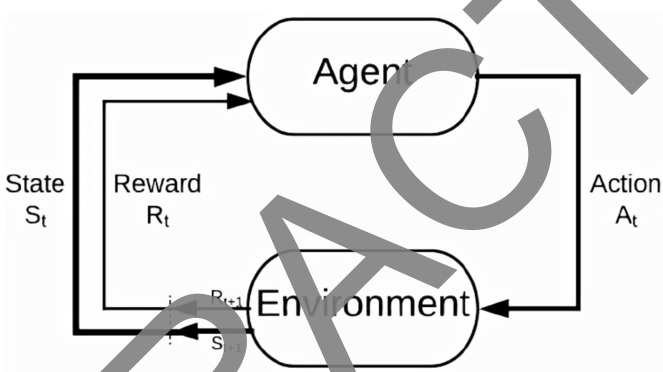

Fig. 1. Learning with reinforcement.

A mobile robot (agent) at time t is in some state S_t it received a reward R_t for a previous action, performs some action A_t, goes to state S_{t+1} and receives feedback from the environment it is in, an evaluation of the action as a reward R_{t+1}

3 Algorithm

1. Specifies the point where the mobile robot needs to get to.
2. The optimal trajectory is calculated using a modified D* algorithm.
3. The robot starts moving, and if it encounters obstacles, it recalculates the trajectory in real time.
4. At each step, we know the point the robot should move to and where it is. At this point we connect the neural network with reinforcement: we give the robot feedback inversely proportional to the distance between the expected and real points (the distance is implied in the sense of Euclidean measure). That is, the more the robot deviates, the less reward it gets and vice versa. Accordingly, the network changes the voltages supplied to the motors to achieve the smallest deviation.
5. As a result of many repetitions of steps (3-4), the influence of external and internal factors that prevent the robot from moving along a given trajectory will be minimized. In Fig.2 schematically demonstrates the learning process. The robot

sequentially performs a movement and remembers the result that leads to the maximum reward.

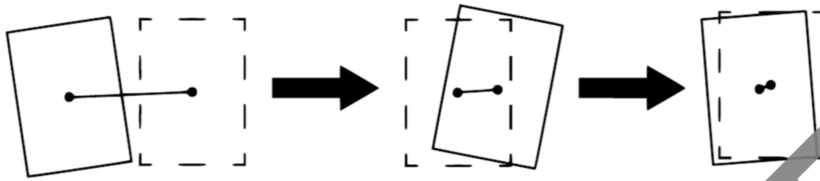

Fig. 2. Rotation of the robot.

The modified D* algorithm assumes robot movements in 8 directions, given that the turn is made by circular motion, that is, it does not stop to turn (Fig. 3), so the MR needs to be trained to move in 4 directions and 4 turns.

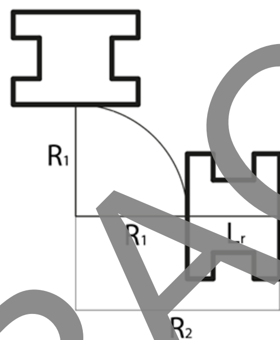

Fig. 3. Rotation of the robot.

4 Conclusion

The proposed method solves the problems that arise in the practical implementation of the navigation network construction method. It is a more efficient method for certain categories of problems. In addition, the algorithm reduces the cost of the robot equipment, because it is less demanding on computing systems, which is also not unimportant. The robot will be able to move both in the open terrain and indoors. This is an advantage over methods based on the use of GPS navigators.

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