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ARTIFICAL POTENTIAL FIELDS ALGORITHM FOR MARS ROVER PATH PLANNING IN AN UNKNOWN ENVIROMENT

In this paper artificial potential fields method applied to autonomous mobile robot - Mars rover is presented. It is assumed that Mars rover operates in an unknown environment. In order to visualize the robot's path in environment Matlab software is used. Inserted by graphic data input interface in top view mode obstacles are deployed in environment area. The method of artificial potential fields is extended by an additional algorithm to avoid a local minimum. The proposed algorithm is implemented as a state machine. In this paper simulations results of the developed algorithm are presented.

KEYWORDS: autonomous mobile robot, Mars rover, path planning, artificial potential fields, bug algorithm

1. CHARACTERISTIC OF MOBILE ROBOT – MARS ROVER

Mars rovers are a kind of mobile robot (Autonomous Mobile Robot – Mars Rover), which are designed for exploration and manual tasks. Mobile robots can be classified into remote controlled and autonomous. Control of mobile platforms on the earth gives a choice of controls between the remote control and autonomy. Mobile platforms - Mars rovers due to destination, impose the use of autonomy [1]. Mars rover control method determines time, which is needed to receive signal from the Earth to the potential planet of exploration – Mars.

In addition, this time is different depending on the distance between the planets arising from position on their own orbits. Mars rovers must be designed for exploration task, which includes moving in the unknown area. The construction of the drive system and suspension is determined through the working area of the mobile platform. For manual tasks manipulators are used. A dedicated mechanical solutions or specially profiled main frame are often used. whose function is make predetermined actions.

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2. MOBILE ROBOT CONTROL

Autonomous mobile platforms can move on in the known or unknown environment. After analysing move methods in terrain, one can distinguish methods dedicated for the known environment as well as for the unknown environment. The research work concerns an unknown environment [2, 3, 4]. Autonomy platform in unknown environment can be realized by designing the robot universal properties to operate in the environment or by using a special control algorithm [5]. The artificial potential fields was chosen. It allows work in unknown area [4, 5]. This method is based on physical nature interaction between static charges to determining the direction of mobile platform movement. For this purpose it is necessary to know the current position in the mobile robot and the destination point. This can be obtained from the GPS navigation system.

The electrostatic interaction force between particles – Coulomb law is define [6]:

$$F_w = \frac{kq_1q_2}{r^2}, \qquad (1)$$

where: k – interactions constant, q_1 – electric charge of the first particle, q_2 – electric charge of the second particle, r – distance between electric charge.

The effect of forces for two positive charges is repel. For different charges Coulomb force causes attracts particles. Assigned negative charge for a mobile robot and obstacles, positive charge for target point. Considering the position of interacting charge we get a mobile robot trajectory (Fig. 1.).

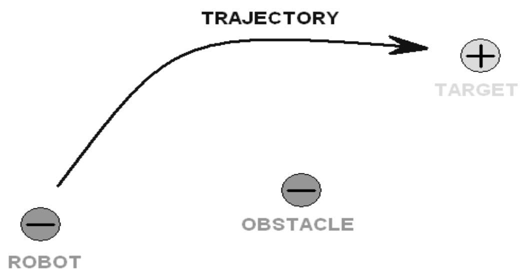

Fig. 1. The principle of artificial potential fields algorithm

The algorithm should take into account an interaction between all obstacles and robot. In such a case the force equation (1) takes the following form:

$$\vec{F}_W = \frac{k_{RT}q_Rq_T}{r_{RT}^2}\frac{\vec{r}_{RT}}{r_{RT}} - \sum_{i=1}^{n}\frac{k_{RO}q_Rq_O}{r_{ROi}^2}\frac{\vec{r}_{ROi}}{r_{ROi}}, \qquad (2)$$

where: R – mobile robot, T – target, O – obstacles, k_{RT} – interactions constant between mobile robots and target, k_{RO} – interactions constant between mobile robots and obstacles, q_R – mobile robot charge, q_O – obstacles charge, q_T – target charge, r_{RT} – distance between mobile robot and target, r_{ROi} – distance between mobile robot and obstacles.

In order to obtain simulation results artificial potential field (APF) algorithm was implemented in Matlab environment. As it was described in [4] an APF method is not resistant to the local minima (i.e. AMRMR can stop for the balanced forces of the obstacles). In order to eliminate described drawback, the "Bug" method was used. The idea of this method has been taken from the real world – for example: move worms at the wall. This method involves bypassing obstacles along the side wall [5].

3. APPLICATION

3.1. Sensors system

The considered mobile robot is equipped with 9 distance sensors. The output of the each sensor is a linear distance between AMRMR and the obstacle (or obstacles) seen. The angle between (Fig. 2.b) neighboring sensors is equal to 30 degrees. Designed application contains an overview of the actual status of all sensors. It should noted, that the range of sensors was limited to 3 meters because of the real sensors constraints (Fig. 2.b). Obstacles can also be entered into robot environment by using graphical interface. Sensor system described above identifies the obstacles (i.e. the distance and the orientation with respect to mobile platform (Fig. 2.b).

a) b)

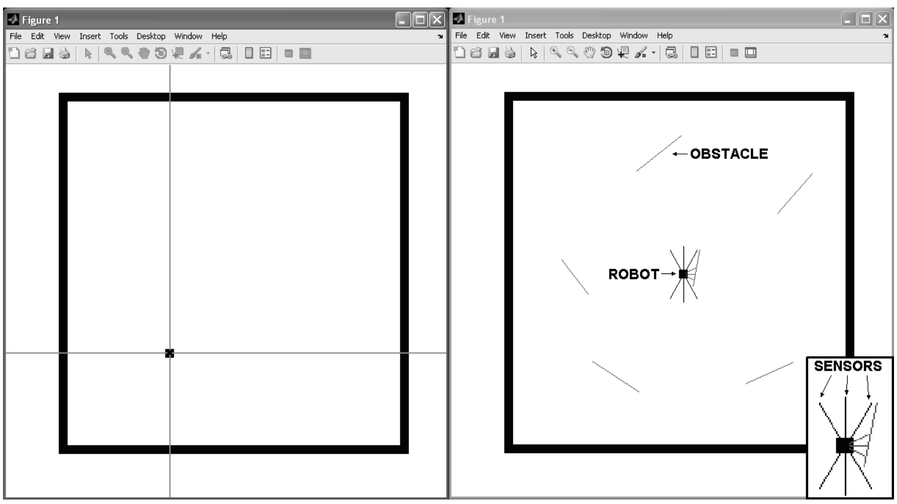

Fig. 2. a.) Entering Data – pre-positioning the mobile robot; b.) sensors system

3.2. Environment and data input interface

Described in a previous section APF was implemented in a Matlab environment. The graphical visualization was introduced in order to present the actual position as well as the previous moves of the AMRMR. Simulated environment of the robot is limited by the sidewall – the main obstacles of the APF. Visualization is performed by using of the Matlab **plot** function. Thanks to the special preparation of the plot function properties, it is possible to watch instantaneous states of the mobile robot. Moreover, the animation was obtained by refreshing the visualization results in the following steps. The destination point (target) is introduced by the cursor. Command **ginput** is used to insert data into graphical interface (Fig. 2.a).

3.3. Proposed Algorithm

The algorithm is performed by the state machine. The basic mode of mobile robot operation is motion based on the artificial potential fields method algorithm. If position of the robot doesn't change (check APF and results is the same as the previous, robot is as the local minima) the state machine is switched to the "Bug" algorithm. This mode is active until robot will bypass an obstacle along the wall. When obstacle is bypassed the state machine will change operation mode to the APF algorithm. Mobile robot moves until the desired position (target) is reached. The flow diagram of the proposed algorithm is presented in Fig. 3.

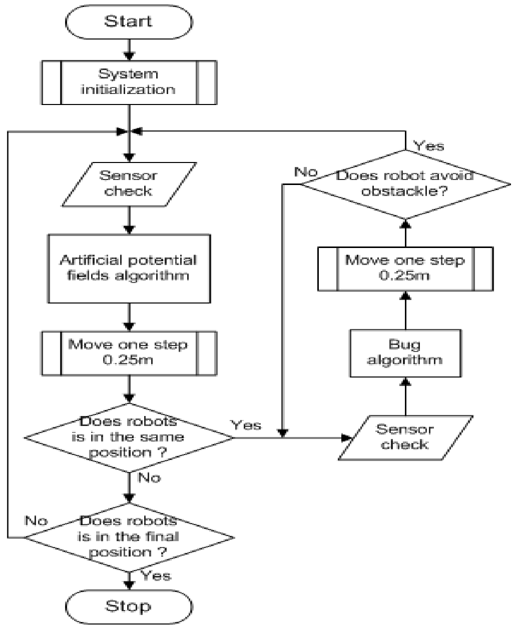

Fig. 3. The flow diagram of the mobile robot algorithm

4. SIMULATION RESULTS

The initial conditions for the simulation is shown in Figure 4a. At the beginning APF algorithm is a mobile robot mode (Fig. 4b.). The obstacles identification on right and left side of robot in APF argorithm is presented in Fig. 5. Switching state machine from APF algorithm to Bug algorithm is shown in Fig. 6a., when robot drove to obstacle, behind which is the target. Bypassed obstacle and driving forward to target is presented in Fig. 6b. Additional simulation with a different set of obstacles in enviroment is shown in Fig. 7. The use of APF algorithm allows work autonomous robot in the unknown environment. In addition, the Bug algorithm immunizes local minima resulting from area arrangement. The simulation results shown the implemented algorithm in action, it works correctly and achieves the target.

a) b)

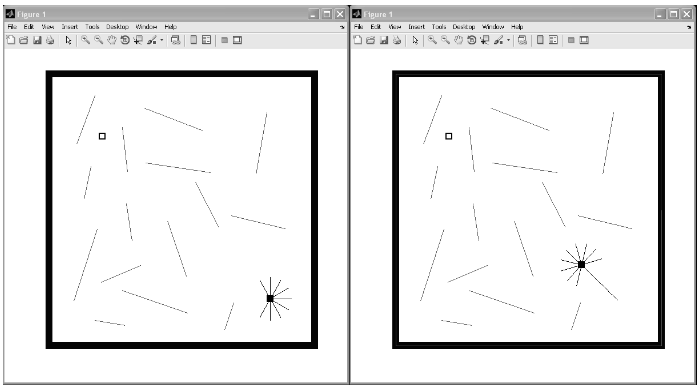

Fig. 4. a.) The initial state of simulation; b.) Mobile robots starting

a) b)

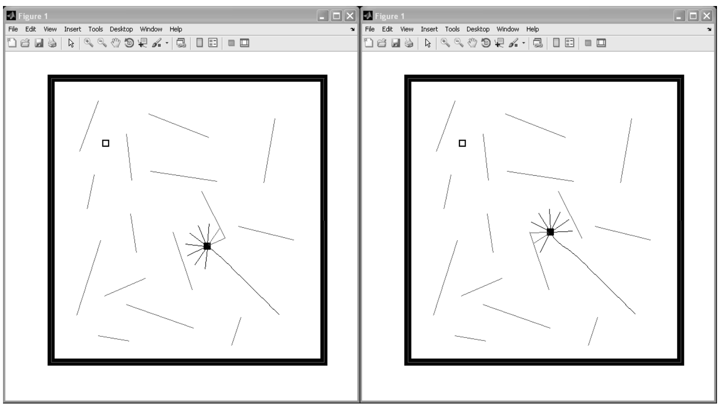

Fig. 5. a.) and b.) Obstacles identification

a) b)

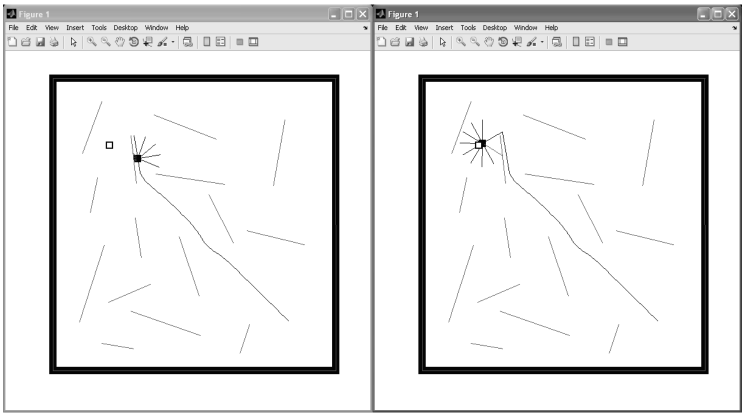

Fig. 6. a.) Bug algorithm: avoidance obstacle b.) Move forward to target

a) b)

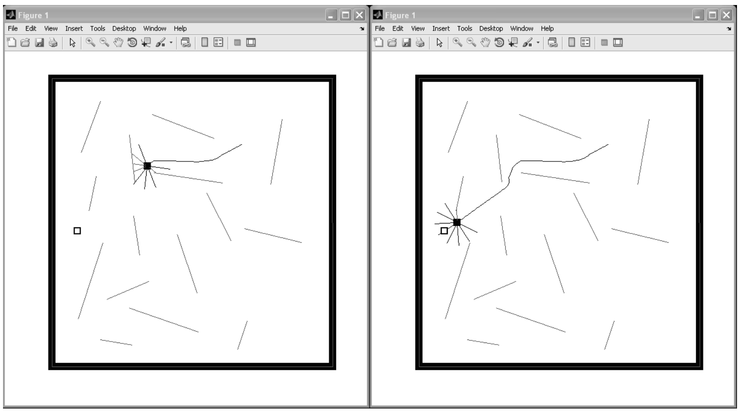

Fig. 7. a.) and b.) Another simulation

5. SUMMARY

In this paper an implementation of artificial potential field method for autonomous mobile robot is presented. The algorithm was extended by the "Bug" method [5] in order to avoid the local minima. Simulation test results obtained in a Matlab environment confirm proper operation of the proposed algorithm. An implementation of the described algorithm on the Mars rover is planned in the future. The algorithm will be tested on the ground, so it is possible application communication based on TCP/IP protocol [7].

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