Navigation of autonomous mobile robot using ultrasonic and infrared sensors

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Abstract – **The aim of this paper is to briefly describe proposed algorithms for an autonomous mobile robot. These algorithms concern data processing from sensors, description of environment from these data and finally navigation on these data. Results from these processes are based on simulation of real mobile robot system. On proposed algorithms can be showed principle of ultrasonic and infrared sensor, principle of environment mapping and basic navigation of real mobile robot. This knowledge can be used in education to show basic principles of robot motion and navigation.**

Keywords - ultrasonic sensor, infrared sensor, occupancy grid, reactive navigation

I. INTRODUCTION

Collision free mobile robot navigation in the environment is the basic problem of autonomous systems [6]. This problem occurs either when following the path of mobile robot in a known or partially known environments as well as when crossing completely unknown environment. It is also necessary for creating maps or searching task objective.

The robot used for simulations is mobile robot for indoor environment. It is differentially driven robot with three wheels, which two of them are driving wheels and one is a relieving wheel. Model of the robot can be seen at Fig. 1.

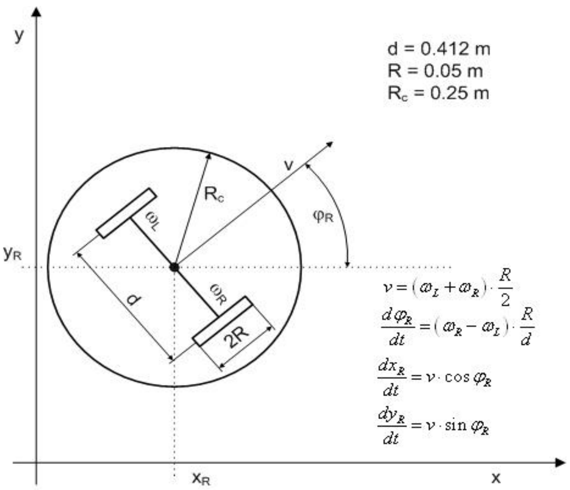

Figure 1. Model of the robot

II. REPRESENTATION OF THE ENVIRONMENT

We will be using occupancy grid for the representation of the environment [1] [2] [3] [5]. Occupancy grid provides an effective platform for fusion of information from multiple sensors and sensing positions. After receiving the information from the sensor, sensor model is applied to the grid and each cell is updated. The value of the cells takes value -1 for the cell, of which we do not have knowledge so far; <0,1> in the case of the cells that are already known to us, where 0 means the cell that is entirely free to cross and 1 stands for a cell where there is definitely an obstacle. Cell size is 10x10 cm.

Mobile robot intended for navigation uses nine ultrasonic rangefinders (Fig. 2).

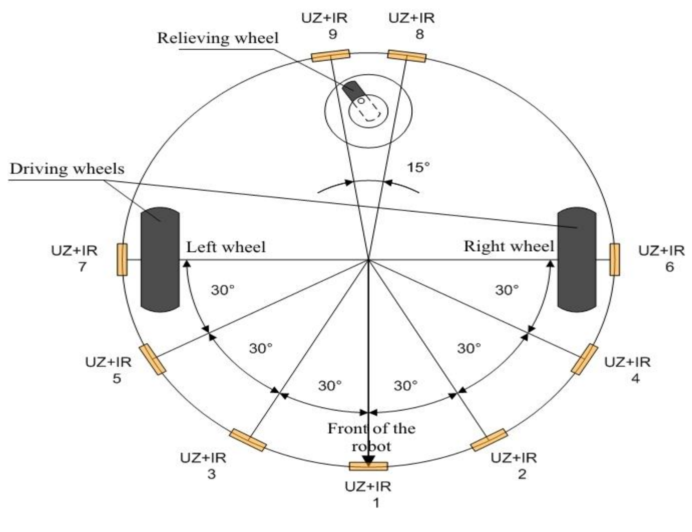

Figure 2. Position of sensors and wheels on the mobile robot.

In order to simplify the calculations, the rotation of the grid regarding the xy axis remains unchanged so that the movement of the robot is represented only by shift of data in the occupancy grid (Fig. 3).

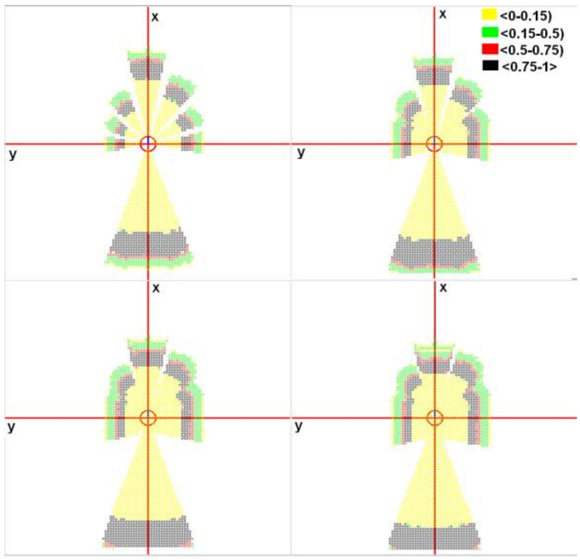

Figure 3. Occupancy grid in the various steps of mobile robot movement in C + + using the OpenCV library. Probabilities of obstacle are expressed by different colours.

A. *Ultrasonic sensor in the occupancy grid*

We used measuring range from 0.5 meter to 5 meter for the ultrasonic sensor [7].

It is written into the grid by the formula:

$$f_k(\upsilon, r) = \begin{cases} \cos(3\upsilon)\left(\dfrac{1-\tanh(r-r_x)}{2}\right) & |\upsilon| \le 12.5^\circ \\ & r \ge r_x \\ 0 & |\upsilon| \le 12.5^\circ \\ & r \le r_x \end{cases} \tag{1}$$

Where the data r_x is measured by the sensor (Fig. 4).

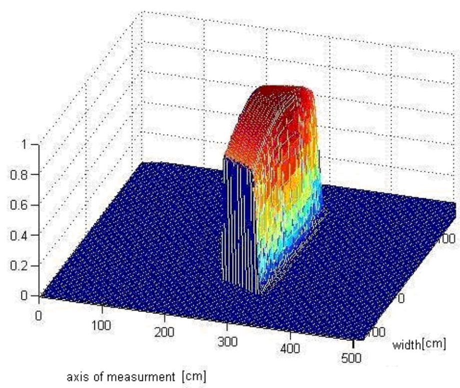

Figure 4. Uncertainty model of the ultrasonic sensor in the occupancy grid.

B. *Infrared sensor in the occupancy grid*

The infrared sensor takes into consideration only one point of an obstacle. Therefore, it is unsuitable for this type of occupancy grids and implementation of the proposed navigation algorithm – it may cause overlooking of the essential data. To prevent this, the infrared sensors are recorded into the grid on larger area.

For infrared sensor we used a measuring range from 2 cm to 40 cm (Fig. 5).

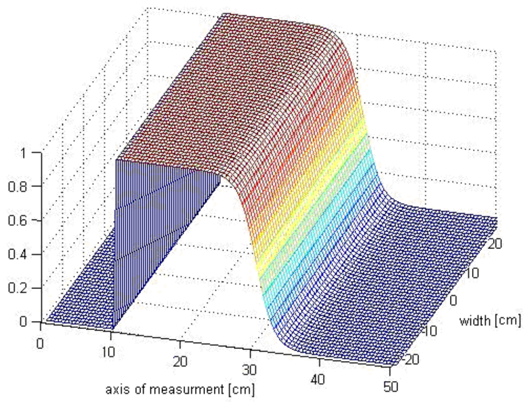

Figure 5. Infrared sensor in the occupation grid.

III. Reactive Navigation

We will use the Wandering standpoint algorithm (Fig. 6) for the reactive navigation because of its simplicity and efficiency [4].

The principle of operation:

1. Go directly to the goal if possible.

2. In case of an encounter with an obstacle, count angle-free path for turning left and right .

3. Choose the smaller angle and follow the path around the obstacle.

4. Go to step 1.

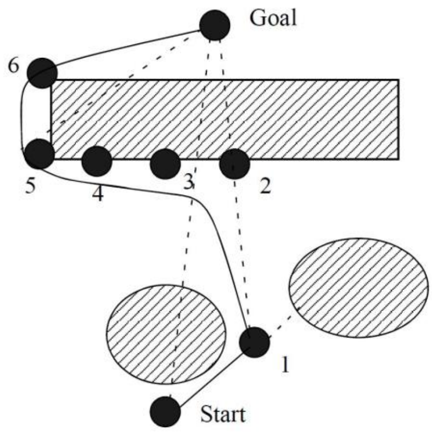

Figure 6. Principle of Wandering standpoint algorithm [4].

The disadvantage of this algorithm is the possibility of loops in some obstacle layouts.

Therefore, we extended this algorithm with the memory of the conflict. The position, in which the robot encounters an obstacle for the first time is called conflict point. If the new trajectory from a place occupied by our robot contains/involves a collision point the trajectory will be affected by this memory. In other words, the algorithm counts the new direction so that the trajectory will eventually avoid this place.

The principle of operation is shown in the following diagram:

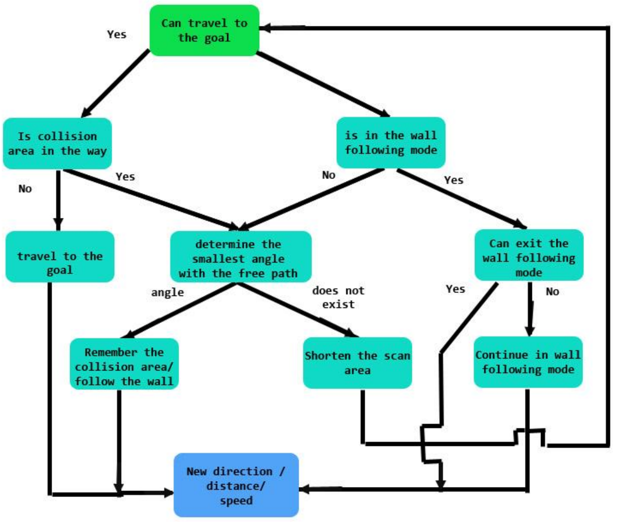

Figure 7. The principle of operation of the reactive navigation.

The direction of free path is designated as a rotation angle, where the area around the robot (Fig. 8) contains no object.

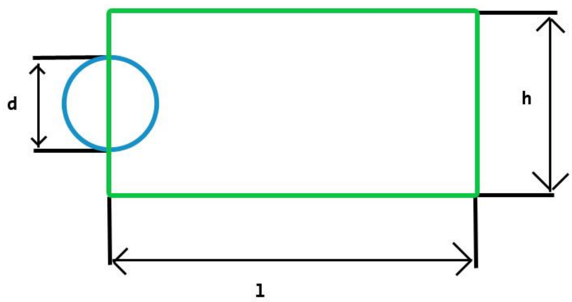

Figure 8. The principle of the safety zone of a mobile robot

Where *d* is the diameter of a mobile robot, *l* is the length of the zone and *h* is the width of the zone.

IV. Experimental Results

In these tests the length of the safety zone *l* is set according to measured distance of the sensors:

Minimal distance>1,3 m *l*=180 cm

0,75< Minimal distance <1,3 m *l*=155 cm

0,3< Minimal distance <0,75 m *l*=130 cm

Minimal distance <0,3 m *l*=105 cm

In order to verify functionality for different types of environments, the proposed algorithm was tested gradually for the cases of three maps. The first environment contained obstacles greater than the size of the robot itself and the distance between the barriers allowed passage of mobile robots (Fig. 9). The second map contained denser distribution of smaller barriers (Fig. 10). The third map contained a classic trap situation (Fig. 11). And finally, the fourth map contained trap situation with some other simple obstacles (Fig. 12).

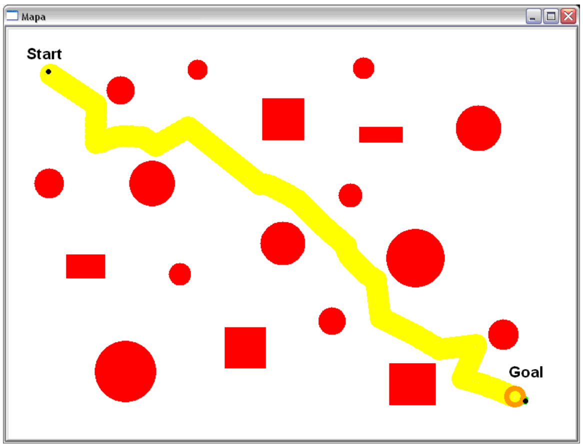

Figure 9. First testing map

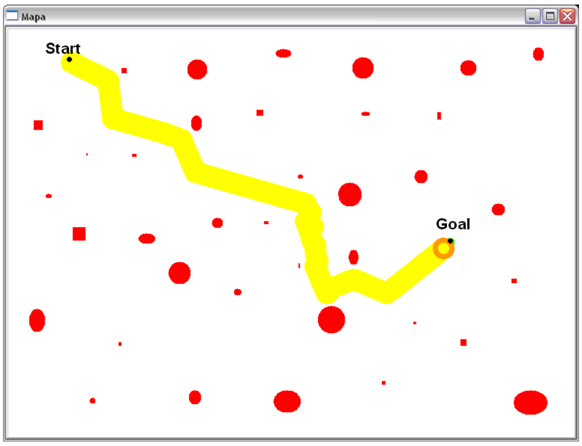

Figure 10. Second testing map

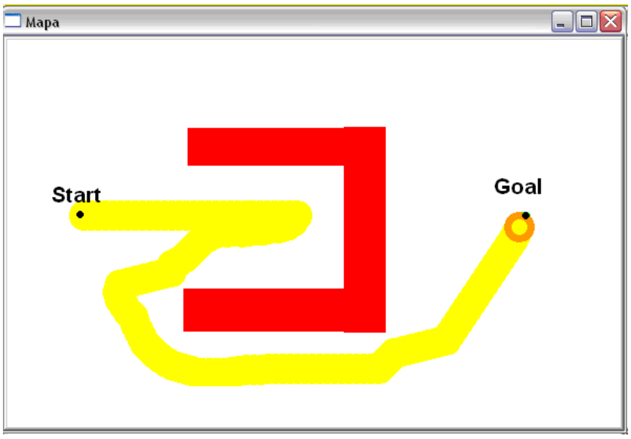

Figure 11. Third testing map

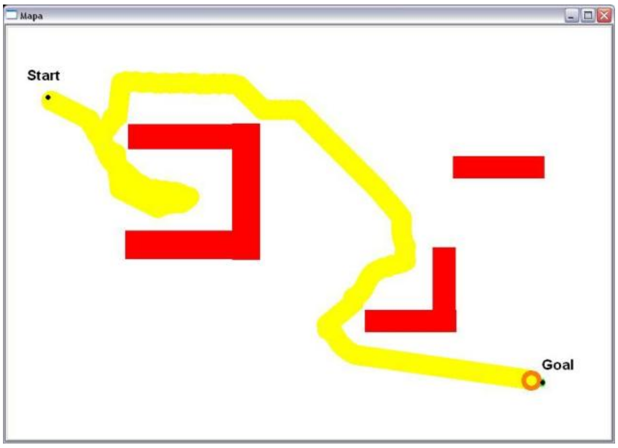

Figure 12. Fourth testing map

As shown in four figures, with use of proposed algorithm, mobile robot has found path from start to goal in all testing environments.

V. Conclusion

The aim of this paper was to present and verify by experiment the algorithm for an autonomous mobile robot. As algorithm for data processing from sensors was presented uncertainty model of ultrasonic rangefinder, which takes into account the width of the scanning angle. As description of the environment was proposed occupancy grid, whose main advantage is its simplicity and efficiency. And finally, navigation on the basis of these data was realized through modification of the wandering standpoint algorithm.

Acknowledgment

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