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DEVELOPMENT OF MOBILE ROBOT CONTROL ALGORITHM BASED ON THE FUZZIFICATION OF THE LOCAL TERRAIN MAP

Abstract: Based on a review and analysis of the literature for controlling a small light mobile robot based on fuzzy logic, an algorithm was developed based on the fuzzification of the local area and on determining the danger of traffic. The obtained algorithm can be used in the development of control systems for wheeled robots for various purposes, in particular robots designed to operate in confined spaces.

Keywords: fuzzy logic, mobile robot, fuzzification, membership function, linguistic variable

Formulation of the problem

Today, mobile robotics is developing very rapidly and its areas of application are increasing, because they are able to perform many useful functions including danger to human tasks. Now, observed the process of transition from the remote control to the autonomous control of mobile robots. The movement of objects from one place to another is one of the most important tasks facing such systems. The solution of this task is to plan the movement in deterministic or non-deterministic conditions based on a cartographic database, taking into account continuous information from sensory (technical vision systems, tactile, location systems, etc) and navigation systems. Therefore, localization and mapping are important for effective planning and trajectory. Localization tasks are solved with the help of the information obtained in real-time from various sensors (video cameras, ultrasonic rangefinders, laser rangefinders, etc), which are equipped with mobile robots. Using the information obtained from the sensors, the robot must determine the location by comparing the observations with the available map. When mapping, on the contrary, the exact coordinates of the robot's location are known, for example, thanks to a GPS sensor, but nothing is known about the environment, there is no local terrain map. It is necessary to use the same sensors to plot on the map, adhering to the scale in absolute units, the surrounding objects - houses, roads, etc. This is also a difficult task. It is even more difficult when these tasks are combined. There are situations, there is no exact position or map. It turns out that you need to solve the problem of simultaneous localization and mapping (SLAM) [1]. The most relevant now is the setting of SLAM-tasks in the context of video streaming, i.e. when MTS is equipped only with video cameras [1]. However, the proposed information technology is a complex and expensive algorithm that consumes most of the embedded power of the robot. This is not a problem for large robots, but it is becoming vital for small light robots, which are increasingly in demand. For example, small minibusses, about 50 grams and 15 cm in diameter, can be ideal for exploring small and limited spaces. Their onboard computing resources are so limited that they cannot currently use SLAM methods. Thus, the development of fairly simple algorithms that will be effective for small light robots is relevant today.

Analysis of previous research

There are two categories of route planning algorithms: global (offline) route planning and local (online) route planning, [2].

In global route planning, the terrain is static or obstacles are known in advance. Thus, this category of algorithms can make a complete map of the environment from the starting point to the goal before the start of the mobile robot. These planning algorithms require well-known conditions and static terrain. There are such global navigation methods as Voronoi graphs [3], artificial potential field method [4], image graphs, Dijkstra algorithm, cell decomposition method.

On the other hand, in local route planning, the environment is unknown, dynamic, and unstructured, or the obstacles are unknown in advance. In this case, the mobile robot must independently determine or control its movement and orientation, using equipped sensors. There are such local navigation methods as fuzzy logic algorithms [5], neural networks [6], neuro-fuzzy [7], particle swarm optimization algorithm, annealing simulation algorithm, genetic algorithms [8], ant colony optimization algorithm.

Navigation methods based on fuzzy logic algorithms are one of the most effective methods of intelligent control when information about the external environment is the partial or complete lack [9-10]. These methods are used mainly when the management task is difficult to formalize but can be easily described in ordinary language. However, most authors use fuzzy logic to develop an obstacle bypass algorithm [10]. However, when developing a mobile robot traffic control system, there is a problem of introducing a local area map into a fuzzy system. The terrain map, in contrast to scalar quantities, is a large array of data that is quite difficult to process directly.

Formulation of the purpose of the article

Using fuzzy logic methods to develop an efficient and economical algorithm for controlling a small light mobile robot based on the fuzzification of the local terrain map.

Presenting the main material

A class of wheeled autonomous mobile robots was selected for research and testing of the obtained solutions, which are controlled based on inexpensive small-sized microcontrollers with low power consumption and speed. The HC-SR04 ultrasonic sensor with a viewing angle of 180° and a range of 0.8 m is used as a technical vision sensor in this work.

The input parameters for determining the distance to the obstacle are the travel time of the signal (time between transmission and reception of the signal) and the speed of sound.

The speed of sound depends on the temperature and physical state of the environment. When developing the algorithm, the value of the speed of sound in dry air at a temperature of 20°C – 343 m/s is used. The distance to the obstacle (m) is equal multiply the speed of sound (m/s) by the travel time of the signal (s) and divide by 2. It is worth noting that we divide the distance by 2 because the sensor returns the travel time of the signal from the ultrasonic sensor to the interference and from the interference to the ultrasonic sensor.

To build the local terrain map in the work, it is proposed to divide the survey area into 180/15 = 12 sectors. It is assumed that the effective angle of observation of the ultrasonic sensor is 15°. Distance measurement is performed for each sector from 0° to 180°. The example of the results of the calculations are shown in table 1, and the visualization of the local map of the area is shown in Fig.1.

Table 1. **Determining the distance to the obstacle**

Sector	Distance (cm)	Sector	Distance (cm)
0-15	20	90-105	45
15-30	20	105-120	40
30-45	80	120-135	30
45-60	80	135-150	40
60-75	80	150-165	40
75-90	35	165-180	45

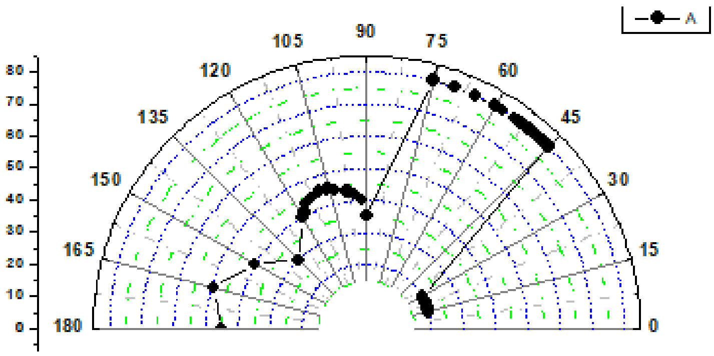

Figure 1. Visualization of the local map of the area

After receiving the initial information about the environment, the obtained results were fuzzified. For this purpose, the linguistic variable DISTANCE (distance from the mobile robot to obstacle) was introduced, which has the terms NEAR, MEDIUM, FAR and the exact physical meanings of the terms of this variable are determined. For the linguistic variable DISTANCE, the algorithm for determining the affiliation of the input clear value of the variable to the term is described. It has been suggested that such a variable can take any value from 0 to ∞. According to the theory of fuzzy sets, each value of the variable can be assigned a number from 0 to 1, which is determined by the membership function of a term μ (x), where x is the distance to the obstacle. Three trapezoidal membership functions were created.

The accessory function for the term CLOSE looks like this:

$$\mu Near(x) = \begin{cases} 1 & 0 \le x < a \\ \frac{b-x}{b-a} & a \le x \le b \\ 0 & b < x \end{cases} \quad (1)$$

The function of belonging to the term AVERAGE:

$$\mu \mathrm{Far}(\mathrm{x}) = \begin{cases} 0 & 0 \le \mathrm{x} < \mathrm{a} \\ \frac{\mathrm{x-a}}{\mathrm{b-a}} & \mathrm{a} \le \mathrm{x} \le \mathrm{b} \\ 1 & \mathrm{b} < \mathrm{x} \le \mathrm{c} \\ \frac{\mathrm{b-x}}{\mathrm{b-a}} & \mathrm{c} \le \mathrm{x} \le \mathrm{d} \\ 0 & \mathrm{d} < \mathrm{x} \end{cases} \quad (2)$$

The function of belonging to the term FAR:

$$\mu Far(x) = \begin{cases} 0 & 0 \le x < c \\ \frac{x-a}{b-a} & c \le x \le d \\ 1 & d < x \end{cases} \quad (3)$$

where $a = 30$, $b = 35$, $c = 40$, $d = 45$.

Graphs of the corresponding membership functions are shown in Fig. 2.

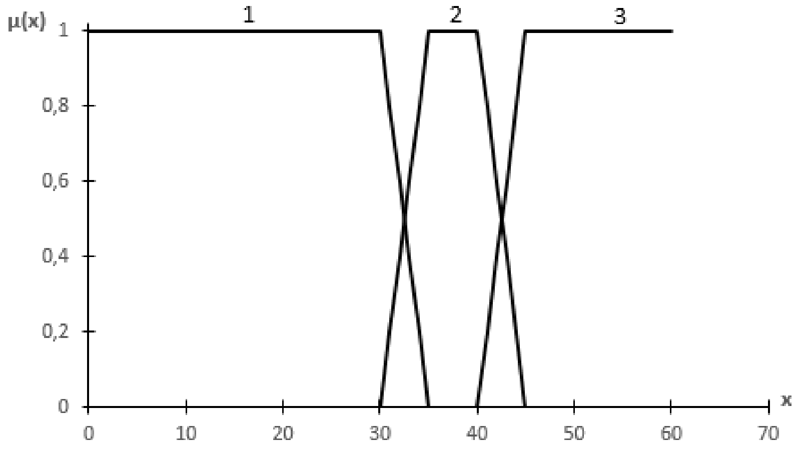

Figure 2. Function of belonging to the terms NEAR (1), MEDIUM (2), and FAR (3)

After fuzzification, the data were stored as shown in table.2.

Table 2. **Fuzzification of the obtained measurements**

Sector	Distance (cm)	Sector	Distance (cm)
0-15	CLOSE	90-105	FAR
15-30	CLOSE	105-120	AVERAGE
30-45	FAR	120-135	CLOSE
45-60	FAR	135-150	AVERAGE
60-75	FAR	150-165	AVERAGE
75-90	AVERAGE	165-180	FAR

After receiving 12 phased sectors, they are grouped by linguistic variables NEAR, MEDIUM, FAR. Due to this, at the output of the algorithm, the mobile robot control system will receive three classes of sectors.

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Let’s consider the decision-maker block. If there are one or more sectors in the FAR group, the control mobile robotic system decides to use one of these sectors for building the route. Otherwise, the AVERAGE group is checked and if there are one or more sectors in this group, the control mobile robotic system decides to drive slowly by one of these sectors until it gets close to the obstacle. And if all sectors are part of the CLOSE group, the control mobile robotic system decides to turn right or left at 90° and build a new local terrain map.

Conclusions

The result of the work presented above was the development of an efficient and economical algorithm for controlling a small light mobile robot based on the fuzzification of the local terrain map. The resulting algorithm based on fuzzy logic can be used in the development of control systems for wheeled robots for various purposes, in particular robots designed to operate in confined spaces.

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