Application of Fuzzy Methods in Designing the Motion Control System of Industrial Mobile Agent in a Non-Deterministic Environment

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***Abstract*— With the development of the field of industrial Internet of things, the use of mobile agents in solving more problems became the focus of many researchers. Applicable agents should be completely autonomous, the equipment and drives must be managed by the on-board system, and the agent should not pose a hazard to people. This article offers a system for managing the autonomous movement of an agent, developed on the basis of the Arduino platform and equipped with various distance and obstacle sensors. To control such a system, the use of a fuzzy logic apparatus is proposed.**

***Keywords*— mobile agent; autonomous movement; managing; Arduino; sensors; fuzzy logic**

I. Introduction

A mobile agent is understood as a mechanism that is able to make a movement in space with a certain degree of autonomy, which is connected with external sensors that provide information about the environment.

Modern agents can move autonomously in the environment and perform the necessary actions. They are equipped with vision systems and information sensors that can give an integrated presentation of the current situation. The knowledge base of the agent allows him to navigate the environment and make decisions about the actions necessary to perform the task [1–2].

The aim of the study is to develop the structure of the navigation control system (NCS) of a mobile agent, which ensures its movement to the target without colliding with obstacles, based on the principles of fuzzy control.

The essence of fuzzy agent control consists in the development of fuzzy control models for each sensor, which provide sufficient information and necessary data when moving and solving problems in an unknown environment [3]. To do this, you need to know the principles of movement sensors, which are equipped with a mobile agent.

II. The general structure of the platform

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Managed mobile agent is built on the basis of the platform structure, which allows by a combination of modules to achieve the desired functionality for specific experience, without modifying the platform. The following groups of modules were identified (Fig. 1) [1]:

1. Control module
2. Communications module
3. Computation module
4. Sensor modules.

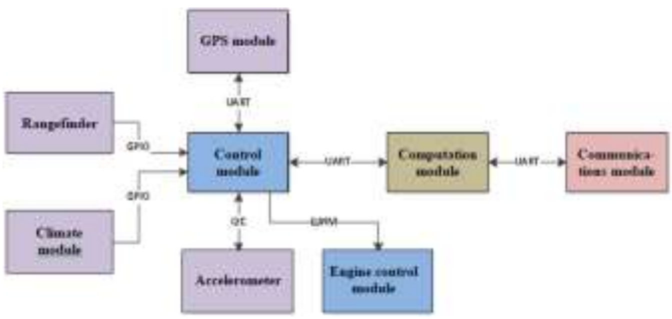

Fig. 1. The general scheme of the connection module

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Sensor systems of mobile agents are the main part of their information-measuring systems, the purpose of which is to generate and issue information about the state of objects and processes in the environment and the robot itself, for the operation of which this information is required [2].

In other words, the main task of sensor modules is to provide the agent with the most detailed information about the environment. That is why there can be a huge number of them. But for the purposes of scientific work was chosen the following set:

- GPS-module.
- Module range finder.
- Obstacle detection module.
- Climate module.
- Module of the accelerometer and gyroscope.

The study uses local positioning modules [2]. These include:

- Ultrasonic rangefinder HC SR04 to determine the distance to the obstacle.
- IR sensor TCRT5000 obstacle to determine obstacles when driving in the blind spots.
- Accelerometer MPU6050 to determine the slope of the surface.

A. *Working principle of ultrasonic rangefinder*

The ultrasonic rangefinder generates an ultrasonic pulse during the measurement (usually 40 kHz), the sound is reflected from the obstacle and received by the microphone (Fig. 2).

The electronic device of the rangefinder registers Δt time between the moment of formation of the signal by the speaker and its reception by the microphone (at a certain threshold level). The distance to the obstacle is determined by the formula:

$\Delta t = (D1+D2)/c \approx 2D/c \approx 58[\text{мкс/с}]\ .D[\text{см}]$

$D=(\Delta t.c)/2$, where: c is the speed of sound in air (343 m/s).

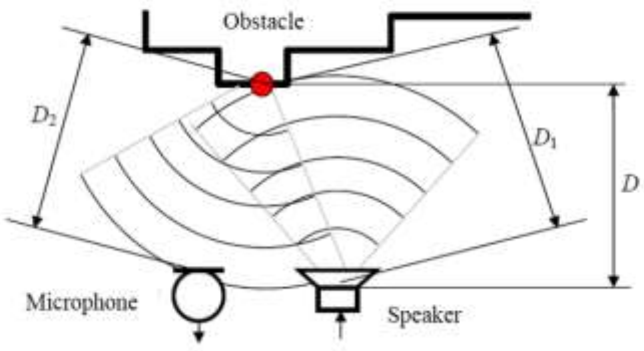

Fig. 2. Illustration of the principle of operation of ultrasonic rangefinder

A piezoelectric microphone and speaker are usually used to generate an ultrasonic signal, since conventional electromagnetic microphones and speakers are not designed for this audio range. Also in the ultrasonic rangefinder there is a band filter for this audio frequency to filter out alien sounds [6].

An important feature of ultrasonic rangefinder is the presence of a relatively wide scanning angle, usually from 20 to 60 degrees. The rangefinder generates a range mark, if any, even a small obstacle appears in the scanning zone.

Another feature is the orientation of the surface of the obstacle relative to the rangefinder. An obstacle is not detected if the angle between the rangefinder axis and the normal to the surface is more than 70–80 degrees (depending on the smoothness of the surface), because the reflected sound wave goes into the void. When installing the rangefinder on the robot, it should be understood that the signal can be reflected from the floor if it falls into the cone of the rangefinder scanning.

It should be noted that structurally both the microphone and the speaker are arranged in the same way. Almost any speaker can be used as a microphone. Therefore, in some rangefinder microphone and speaker are combined into one device: at the time of radiation, the device operates in speaker mode, and then switches to microphone mode.

B. *Infrared obstacle sensor module*

Every agent capable of driving, flying or swimming must see the obstacles in his way. For the agent to be able to do this, it needs appropriate sensors.

The IR sensor contains a directional light source and a light detector. The source is often an infrared led with a lens, and the detector-photodiode or phototransistor [5–6].

Fig. 3. Ir-sensor

IR receiver and transmitter to detect obstacles on the reflected signal at a given distance, the working distance from 2 to 30 cm, the angle of operation of 35°, the supply voltage 3.3–5 V, the sensing distance is set by the string resistor.

III. FUZZY MOTION CONTROL SYSTEM OF A MOBILE AUTONOMOUS ROBOT

Fuzzy logic provides an opportunity to describe complex behavior through a set of simple linguistic rules, which makes it an appropriate tool for modeling and managing complex systems.

In this paper, two fuzzy logic controllers have been developed that are used to navigate the mobile agent from the start point to the target:

1. The first one gives the speed of the agent depending on the received sensor signals and their rate of change,

2. When an obstacle is detected, the second allows a detour depending on the distance to the obstacle and its position. Gives the output values of the rotation angle and steering direction.

These fuzzy algorithms are combined to allow the mobile agent to move to the target on the way without colliding with an obstacle. If sensors detect any obstacles along the way, then the control algorithm switches to detour.

MATLAB environment was chosen in the study. In MATLAB fuzzy modeling is performed using the fuzzy logic Toolbox extension package, in which the user can perform the necessary actions to develop and use fuzzy models [4].

The input and output parameters shown in table 1 were determined in the course of the development of the speed control model.

The success of fuzzy control systems is determined by the quality of the knowledge base, which consists of the production rules database and the rules parameters database. The system contains 15 of the rules of fuzzy productions (Table 2).

TABLE I. BATHS LINGUISTIC VARIABLES

input variables		The output variable
Sensor signal (Signal)	*Rate of change*	*Speed*
Very weak (VW)	Negative (N)	Very fast (VF)
Weak (W)	Zero (Z)	Fast (F)
Medium (M)	Positive (P)	Medium (M)
Strong (S)		Slow (S)
Very strong (VS)		Very slow (VS)

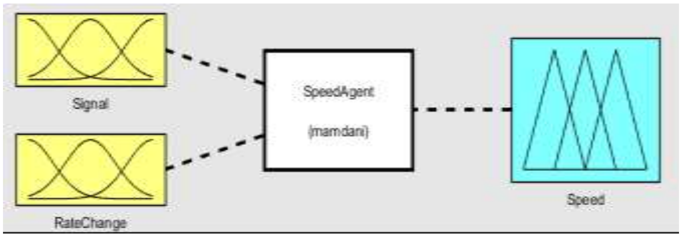

Fig. 4. FIS-structure model

TABLE II. PRODUCT FUZZY RULES

IF	Input 1 Signal	Condition	Input 2 (RateChange)	Condition	Output (Speed)
1	VW	AND	N	THEN	VF
2	VW	AND	Z	THEN	F
3	VW	AND	P	THEN	M
4	W	AND	N	THEN	VF
5	W	AND	Z	THEN	F
6	W	AND	P	THEN	M
7	M	AND	N	THEN	F
8	M	AND	Z	THEN	M
9	M	AND	P	THEN	S
10	S	AND	N	THEN	M
11	S	AND	Z	THEN	S
12	S	AND	P	THEN	VS
13	VS	AND	N	THEN	S
14	VS	AND	Z	THEN	VS
15	VS	AND	P	THEN	Stop

If the sensors do not show the presence of obstacles, the mobile agent moves in a straight line-the target direction. The target direction in the absence of an obstacle is called allowed, and if there is a prohibited one.

For registration of occurrence of an obstacle and to securely introduce the detour 2 input and 2 output linguistic variables: distance (Distance), Regulation obstacles (Obstacle), steering direction (Steering) and rotation angle (AngleRotation).

To detour the control system prevents the fuzzy inference device constructed rule base, production rules which are listed in Table 3.

TABLE III. THE RULE BASE FOR FUZZY CONTROLLER

Rules	Input		Output	
	Distance	*Obstacle*	*Steering*	*AngleRotation*
R1	Big	Right	Forward	Small
R2	Big	Ahead	Forward	Small
R3	Big	Left	Forward	Small
R4	Medium	Right	Left	Medium
R5	Medium	Ahead	Right	Medium
R6	Medium	Left	Right	Medium
R7	Small	Right	Left	Large
R8	Small	Ahead	Right	Large
R9	Small	Left	Right	Large

To check the system in action you need to open the rules viewing window and set the values of variables. The rules viewer does not allow you to edit the rules and functions of belonging terms of variables and is used after the development of fuzzy inference system at the stage of its analysis and evaluation.

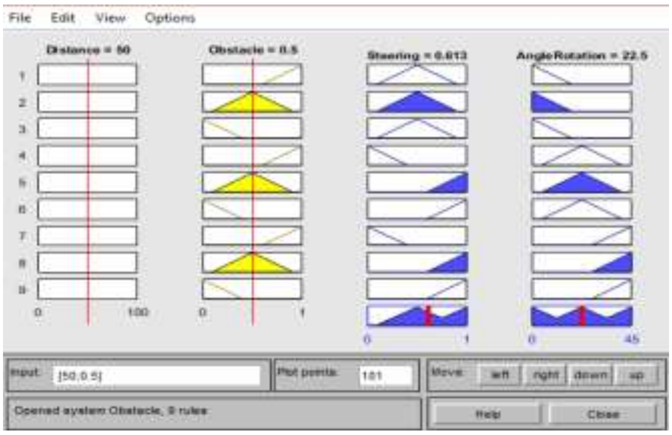

Fig. 5. Window Rules Viewer

The graphical interface of the surface viewer is shown in Fig. 6. The output surface viewer has a main menu that allows the user to call other graphical tools to work with the FIS fuzzy output system, load and save the FIS structure in external files.

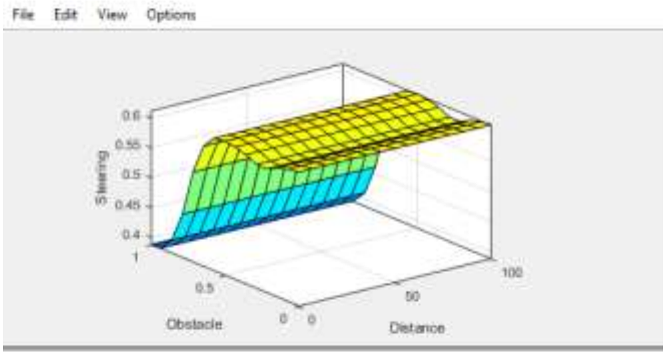

Fig. 6. Output surface viewer

IV. Conclusion

As a result of the study, the mobile agent is able to independently move along a certain trajectory, determine the distance to the obstacle and carry out its detour.

The work performed is relevant, and its results will be used for a series of different experiments in the fields of: automotive technology, agricultural machinery, robotics, etc., as well as the organization of interaction devices in the platforms of the industrial Internet of things.

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