Algorithm of decision making for autonomous mobile robotic system under indeterminate conditions

Valery SITNIKOV, Artur TROIAN, Oleg STRELTSOV
Odessa National Polytechnic University
troian.ap@gmail.com

***Abstract* — This article discusses possibility to use fuzzy logic to build a complex of route planning movement of autonomous mobile robotic system based obstacle avoidance, as well as fast and power efficient achievement a certain goal. Also consider the collaboration of several robotic systems.**

***Index Terms* — robot, autonomous mobile robotic system, fuzzy control, dynamic planning of movement.**

I. INTRODUCTION

The task of creating a specialized computer system (SCS) is one of the most important problems in a development of autonomous mobile robotic system. In the long term such system can orient itself in space to make decisions in complicated situations, solve problems of pattern recognition, and control their condition and to plan action, based on data from the sensors [1].

Using field of such systems is quite extensive: the performance of work in hazardous areas, research areas using of probe sensors, such as a nuclear power station "Fukushima-1", when examining the "secret room" of the pyramid of Cheops [2].

Environment of an autonomous mobile robotic system (AMRS) action can be classified into [1]:

- structured environment which is already known to AMRS (area map with all the major obstacles for the robot and objects);
- unstructured environment, in which the major obstacles to AMRS, and objects can change their location, new obstacles can appear suddenly, etc.

In addition such environments can be described both stationary and nonstationary. In most cases, even if there maps of the area, there are aspects related to the changes along the route, previously undefined. Thereby AMRS has to operate in nonstationary environments basically with varying degrees of stationarity.

In these conditions SCS has to plan actions to accomplish the goal, based on existing information from the sensors, the status of AMRS and its dynamic properties.

Because of the limited size AMRS can not have as much computing power as well as powerful sources of energy to perform such work. Therefore, planning of actions to be allocated to the coordinating center (hereinafter referred to server) and AMRS.

Server coordinates the activities of a family of AMRS over a communication channel by providing them, target designation, the global route of movement, as well as coordination and correction of AMRS action.

When receiving data from the server, AMRS performs: the environment scanning, making their maps and compare it with the well-known, if it is passed to the server.

Building a new or add to the well-known maps of the area is performed using different navigation systems with binding obstacles to the global and local coordinates. To fix the obstacles video-tools are used and, if necessary, the image recognition.

II. STATEMENT OF THE PROBLEM

SCS for AMRS is essentially a decision-making and management system with artificial intelligence elements based on the collection of environmental data. Conditions of non-stationarity, dynamic situations, the limited computing resources and autonomous on-board power result in a complex system using traditional development methods.

Now intelligent control systems with fuzzy logic are widely used [4, 6]. One of the features of fuzzy logic is functioning under incomplete and imprecise input data.

Thus, it seems appropriate to the development of SCS with elements of fuzzy logic is able to dynamically planning of AMRS and control its facilities.

Due to the limited resources of AMRS, planning is appropriate to split into two parts:

- operational planning unit, which is located directly on the AMRS board, while sensor signals are required for implementation;
- strategic planning unit, which is located on the server, and in operational planning for its messages are directive-advisory for AMRS.

In the event of an unplanned obstacles the operational planning unit decide in which direction it should move and sends to the server location information barriers simultaneously. In turn, strategic planning unit adjusts the path to the new barriers.

In this context it is interesting problem of building a AMRS network, controlled with a server, capable of communicate with each other for clarification of missing information in the decision.

III. BASIC REQUIREMENTS TO FUZZY LOGIC PLANNING SYSTEM

The advantage of an approach based on fuzzy logic is: a smooth transition from one category to another by forming a weighted average result, which can significantly reduce the number of production rules, compared with the expert system, as well as the possibility of explaining the outcome of the process of debugging the system.

In this case, SCS shall meet the following requirements:

- real-time process information from different sensors;
- dynamic action planning for moving to a given point;
- efficiently manage power resources to increase the built-in battery life.

IV. AMRS DESCRIPTION

AMRS is a chassis with six driving wheels (Fig. 1). The maximum speed is 1mps. On the chassis the sensors are located to determine the distance to barriers, IP camera, controller and communication engine (based on the STM32), receiver GPS, inertial navigation system (INS) and power management system (for thumbnail images not shown).

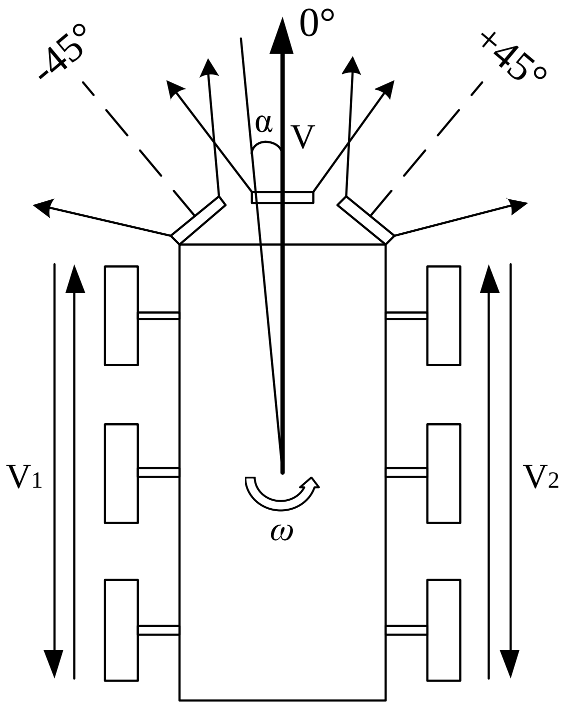


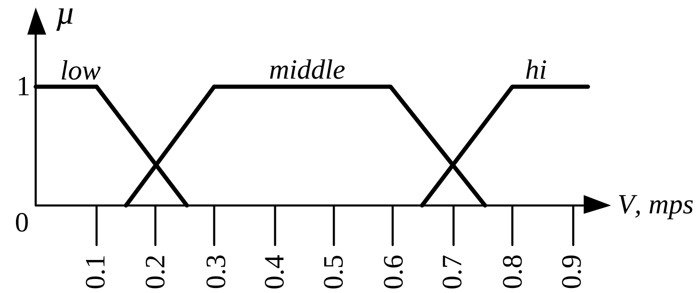
Figure 1. AMRS thumbnail

Definition of the distance to the barrier and relative position angle of AMRS carried out with ultrasonic sensors on the front of the AMRS. Direction and speed of AMRS is defined using INS based on a gyroscope, an accelerometer, a compass and odometer.

V. OPERATIONAL PLANNING OF ACTIVITIES

Suppose there is an input speed signal received by the odometer. We define for logical-linguistic variable three values: "small", "medium" and "large" (fuzzyfication [4]). Correspondence between the actual values of speed and variable values are defined by their membership functions (Fig. 2).

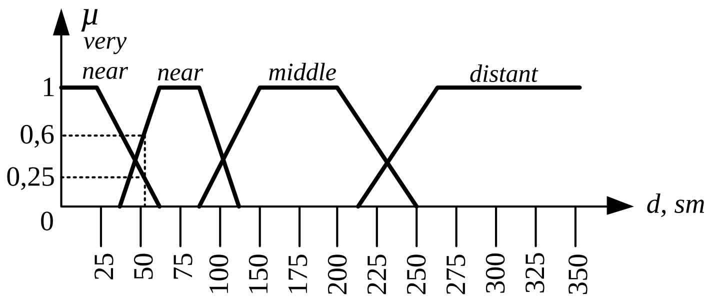
Speed range from 0.25 to 0.6 mps with reliability of value 1 belong to the concept of an "average". Speed of 0.2 mps and 0.7 mps belong to the concept of "average" with the reliability of value 0.5. Speed of 0.15 mps and



below, as well as 0.75 mps and above, does not include the concept of "average", and reliability is zero.

Figure 2. Membership function of the input variable (speed).

Well as for the logical-linguistic variable, which



denotes the distance from the robot to a barrier, we define the values shown in Figure 3.

Figure 3. Membership function of the input variable (distance).

Variable that is takes values of directions set terms of "left", "direct", "right".

As output variables, limit one - includes the following terms of: "sharply left", "left", "direct", "right", "sharply right." Since the robot has not the steering wheel, a reversal is carried out with engine braking on the side toward which to turn. Then you can also add terms of " clockwise U-turn on the spot ", " counter-clockwise U-turn on the spot." If in the case of unstructured environment barrier appears in front of AMRS in too close when you can not even turn on the spot. It is advisable to add terms of "pass back left", "take back", "pass back right."

The relationship between input and output is determined by a table of fuzzy rules.

TABLE 1. EXAMPLE OF FUZZY RULES FOR THE AMRS.

		Distance			
		Very close	*close*	*average*	*far*
Direction	*left*	sharply left	sharply left	left	direct
	direct	sharply left	left	left	direct
	right	sharply right	sharply right	right	direct

Featured fuzzy logic controller model for an operational planning block is some conventional, since the real model will contain a significant amount of input variables and rules. Also seems to be perspective and possible to implement adaptive fuzzy logic controller, which will be able to change form of membership and output functions, a set of rules and their priority.

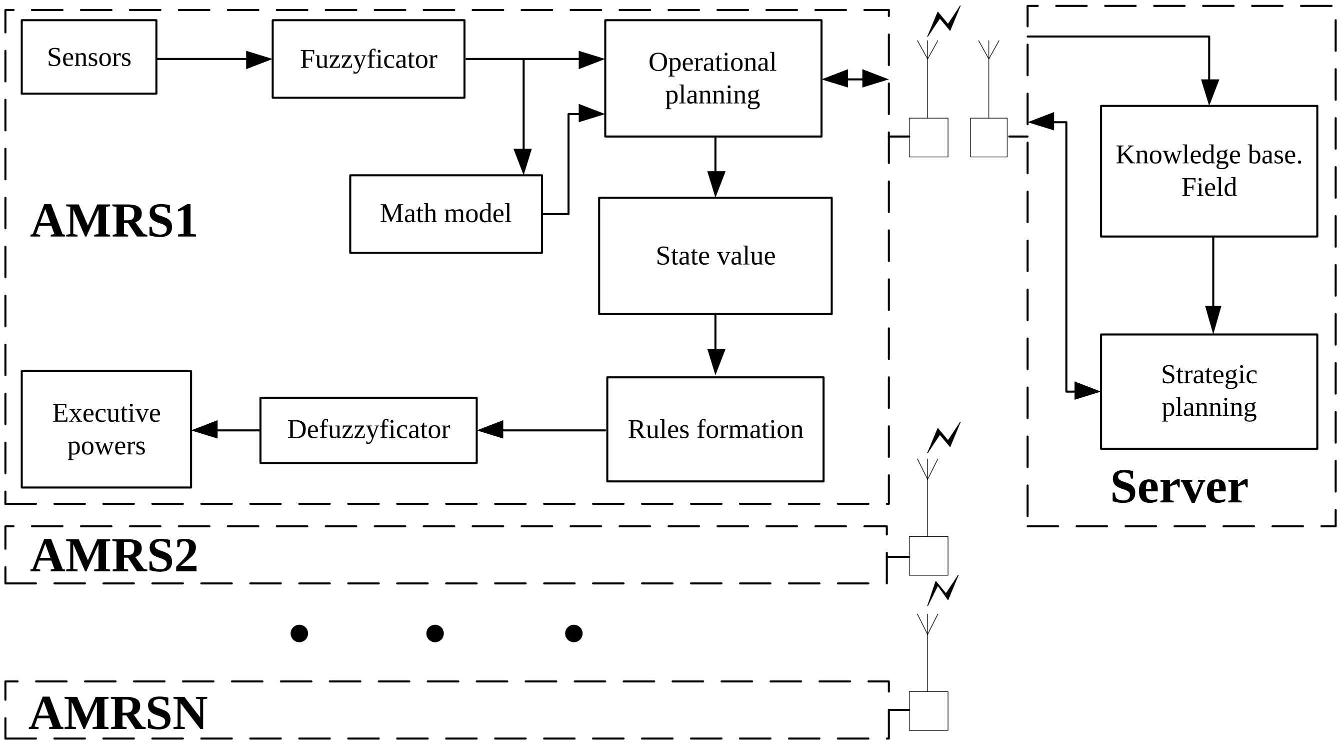


Figure 4. Block's of system.

Based on sensors data, the operational planning unit transmits the information for strategic planning to create a correct map of obstacles and objects. If the map correction, traffic may re-route. GPS-receiver data used as coordinates, and INS is used to define the local coordinate.

The proposed method can work in the case of structured and unstructured environments. In the first case positions of obstacles are specified, and in the second - their definition.

To speed up paving the way, except for management systems, should be developed a mathematical model (MM) of AMRS. MM as well as the control system receives data from sensors. Simulated behavior of AMPS is send to the input fuzzy logic controller and is an advisory. Using this model will more accurately analyze the state of AMRS and pave the way, if an obstacle is detected, but it is at a distance. Using this model will also help more precise entry in turns where the planned route.

Because that the wheels are connected to the engines via gearboxes with high gear ratio and the mass of AMRS is not great, its inertial properties in the kinematics model of MM can be neglected in some cases.

Block diagram of the system which includes coordinating center (the server) and a family of AMRS, which are interrelated and the server is shown in Figure 4. AMRS includes the following main blocks:

- sensor unit;
- images recognition and formation unit (fuzzyficator);
- operational planning unit;
- AMRS assessment unit;
- fuzzy rules formation unit;
- decision-making unit (defuzzyficator);
- actuators.

Such a structure of AMRS allows dynamic plan and coordinate actions with the neighboring AMRS and the coordinating center.

Given the fact that for more rapid and effective research robots can be networked together if necessary, we need to develop an action plan for strategic planning unit for managing multiple AMRS. To implement this task, strategic planning system should have the following basic properties:

- to distribute of AMRS evenly over investigated area (eg with Voronoi diagrams);
- to ensure of impossibility AMRS collisions;
- in case of a new object, re-pave the way to AMRS which should pass through this point;
- to reconfigure the network, taking into account AMRS movement;
- if the coordination center is located far away from investigated area or a permanent moves, each AMRS may be configured to temporarily broadcasting center;
- to redistribute uncharted territory among neighbors in case of failure of one of AMRS;
- in case of failure or server loss connection with one or more AMRS temporarily serve as storage media followed by its transfer server.

VI. CONCLUSION

At the first stage the task of building SCS for AMRS is proposed to solve due to fuzzy logic control loop actions and resources, as well as dynamic planning action (decision) in real-time data from sensors and the server.

Thus, this SCS with fuzzy logic is an intelligent SCS (ISCS) and is able to perform tasks of research and analysis area, finding objects and mapping.

The interaction of AMRS with each other improves the operations efficiency of separate AMRS, and in their entirety.

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