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I. TSMOTS, V. TESLYUK, A. ROMANYUK, I. VAVRUK
Lviv Polytechnic National University

A FUZZY LOGIC BASED NAVIGATION SYSTEM FOR A MOBILE ROBOT IN UNCERTAIN ENVIRONMENT

The control system based on fuzzy logic that enables achieving goals by mobile robotic system in an uncertain environment with obstacles is proposed. We suggest to apply some additional behaviors such as "movement along the right wall" and "movement along the left wall" for implementation of mobile robot motion control. Fuzzy rules for each of behaviors units and speed control unit are realized. A method for coordination conflicts among behaviors is developed.The velocity control unit, which provides more accurate and rapid goal achievement by decreasing speed when obstacles or goal is near robotic system and increasing speed otherwise. References 9, tables 3, figures 2.

***Keywords*:** mobile robotic system, fuzzy logic, uncertain environment, behavior-based control.

Introduction

Today, mobile robotic systems (MRS) can be used to implement a lot of tasks. It is important to ensure the autonomous motion of MRS at the environment with dynamically varying conditions or inaccurate information. Because of such systems can be applied for work in hazardous environments for people; for some objects investigation or transportation at warehouses and more. Different requirements are imposed to MRS depending on the task [5]. However, the basic requirements, applied to the operation of the robots, is to provide real-time operation, solving the tasks for the optimal number of steps, taking into account restrictions on size, power consumption and costs. It imposed certain requirements to the control algorithms of mobile robotic system motion and to the technical tools.

There are different approaches to the control of MRS motion. The selecting of the control method was defined basing upon the conditions of robotic systems operation: deterministic or nondeterministic, static or dynamic. The main raised problems were the necessary to ensure the operation of autonomous mobile robotic system in an uncertain environment. The intelligent control methods, such as: fuzzy logic, genetic algorithms and neural networks [2] are used for implementation of the motion control system of mobile robot, which operates in unknown and dynamic environments. The fuzzy logic control has some advantages. For example, it does not need the mathematical model of the controlled process [7] and can be used in development of a multi agent systems [10]. Therefore, the vital task is to provide autonomous movement to the goal of mobile robotic systems in uncertain environments with unknown parameters by using methods based on fuzzy logic.

Fuzzy logic control

There are several implementation approaches of mobile robot control system: reactive control, deliberative control, hybrid control and behavior-based control [6]. We suggest to use a behavior-based control system for the implementation of MRS motion control. Such approach integrates several behaviors of mobile robots that can be implemented simultaneously and can enable the robotic system adaption for any tasks performing by adding extra behaviour. Compared to other approaches, this one provides developing more complex and fast control systems.

In many cases, for implementation of mobile robot motion control only two behaviors are used: "movement to the goal" and "obstacle avoidance" [1, 8]. We suggest to apply some additional behaviors such as "movement along the right wall" and "movement along the left wall". The motion behaviors of mobile robotic system "movement along the right wall" and "movement along the left wall" are mostly used when it is necessary to move indoor along the wall or along some corridors. The implementation of these behaviors provides smoothing motion trajectory of MRS in the environment with many obstacles. Moreover, these behaviours ensure the passage U-shaped obstacles by mobile robotic system, which is difficult or impossible by using only the behavior "obstacle avoidance". Moreover, the motion control system of mobile robot must take into account the velocity and parameters changing. Velocity control unit operates in the following way: if the distance to the goal of MRS is large and there are no obstacles near, the mobile robot is moving fast, otherwise the velocity of mobile robotic system is slow. This provides accuracy and performance increasing while achieving goal. The implementation of each behaviour is fulfilled by separate method based on the fuzzy logic.

To achieve the proposed task, which is moving to the goal while avoiding obstacles, it is necessary to define what obstacle and goal are. In particular, in [9] the goal and obstacles definition are determined by using the camera only without additional sensors. In [3] is the input variables: the angle between the robot's current heading and the location of the goal and the distance to any nearby obstacles by using sensors. In [4] the integrating ultrasonic sensors and the vision system is proposed. The ultrasonic sensors provide distance information between the robot and obstacles for behavior control of the mobile robot. While the vision system identifies some subgoals for determining a good motion direction to reach the goal.

We propose to use, as input variables, the distance to obstacles which is derived from ultrasonic sensors while robotic system motion. The distance to the goal from MRS and rotation angle relative to mobile robotic system are used for goal determination. At each step during the movement of MRS the distances to the obstacles are received by distance sensors and the new value of the rotation angle to the goal is calculated. These three sensors that determine the distance to obstacles which locate at the front of MRS, at the right and at the left is proposed to use.

To implement such behaviors as “obstacle avoidance”, “movement along the right wall” and “movement along the left wall” the input linguistic variables “distance to obstacles at front”, “distance to obstacles from the right” and distance to obstacles from the left ” that determine the distance to obstacles are used. The set of linguistic variables values is given as {«Small», «Average», «High»}, denoting small, medium and large distance to the obstacle respectively. To implement the behavior “movement to the goal” the input linguistic variable “angle error” that defines the angle, calculated as the difference between the desired heading required to reach the goal and the actual current heading of MRS, is used. The set of linguistic variable values is given as {«Negative», «Zero», «Positive»}, denoting, respectively, the goal location on the right, directly in front and on the left of the mobile platform. The output linguistic variable of each of behaviors determines the angle of rotation of the MRS.

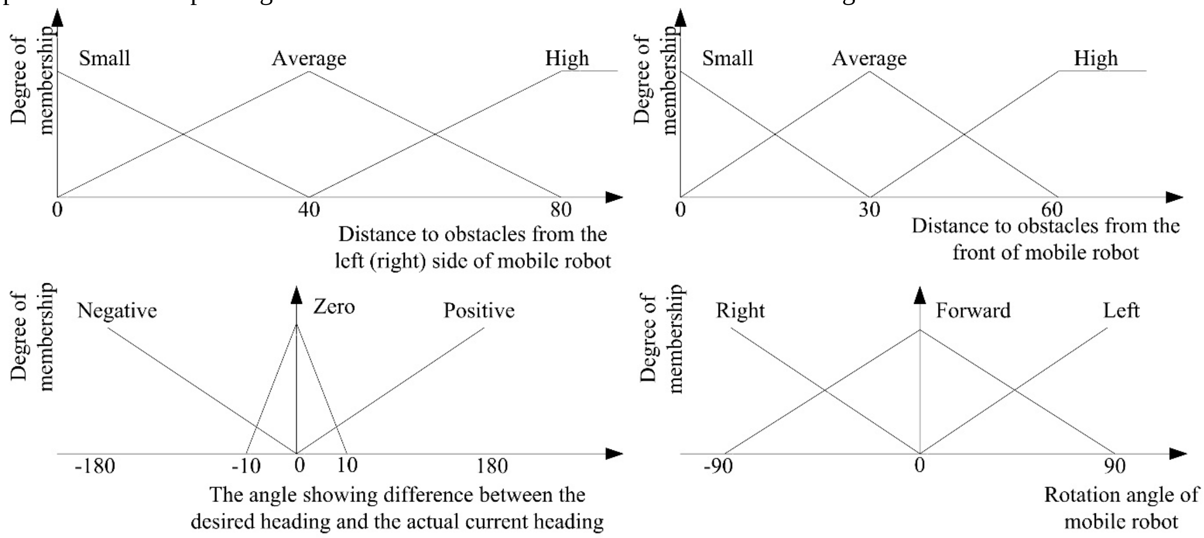

Fig.1. Graphical representation of membership functions for input and output linguistic variables

The set of linguistic variable values is presented as {«Left», «Forward», «Right»}, denoting respectively turn to the left, move forward and turn to the right. To represent linguistic variables we propose to use the triangular membership functions. Figure 1 views the graphical representation of membership functions of input and output linguistic variables.Databases of fuzzy rules, which represent behaviors of mobile robotic system motion, are shown at tables 1-2.

A key issue in behavior of based control is how to coordinate conflicts among behaviors efficiently. The selection of only one behavior at each step has such disadvantage as the trajectory of MRS, which is not optimized. For example, when there is any obstacle during movement to the goal, MRS can pass it as from the right side or from the left. In this case the behavior with the highest priority is chosen among all other behaviors. When “obstacle avoidance” behavior is selected, than the goal position is not considered. Therefore, in some cases, this leads to the inefficient outcome.

We propose to use a method to determine the effective rotation angle of MRS, which is a linear combination of rotation angles that are obtained at different behaviors and activation coefficients, which represent the degree of activation for each behavior.

The implementation of activation coefficients is developed with the method use, based on fuzzy logic. The input linguistic variables, which are used to define the activation coefficients, are the same as for behaviors as "distance to obstacles at front", "distance to obstacles from the right", "distance to obstacles from the left" and "angle error". The activation coefficients values are ranges from zero to one.

Table 1

Fuzzy rules for the obstacle avoidance behavior

Input			Output
Distance to obstacles from the right	Distance to obstacles at front	Distance to obstacles from the left	Rotation Angle
Small	Small		Left
Small	Average	Small	Forward
Small	Average	Average	Left
Small	Average	High	Left
	High		Forward
Average	Small	Small	Right
Average	Average	Small	Right
Average	Small	Average	Left
Average	Small	High	Left
Average	Average	Average	Forward
Average	Average	High	Left
High	Small	Small	Right
High	Small	Average	Right
High	Small	High	Left
High	Average	Small	Right
High	Average	Average	Right
High	Average	High	Forward

Table 2

Fuzzy rules for movement along the right wall behavior

Input			Output
Distance to obstacles from the right	Distance to obstacles at front	Distance to obstacles from the left	Rotation Angle
Small	Small		Left
Small	Average		Forward
Small	High		Forward
Average			Right
High			Right

Fuzzy rules for movement along the left wall behavior

Input			Output
Distance to obstacles from the right	Distance to obstacles at front	Distance to obstacles from the left	Rotation Angle
	Small	Small	Right
	Average	Small	Forward
	High	Small	Forward
		Average	Left
		High	Left

Table 3

Input					Output
Rotation Angle	Distance to obstacles from the right	Distance to obstacles at front	Distance to obstacles from the left	Distance to goal	Velocity
				Small	Slow
Right	Small				Slow
Forward		Small			Slow
Left			Small		Slow
Right	Average			Medium	Average
Right	High			Medium	Average
Forward		Average		Medium	Average
Forward		High		Medium	Average
Left			Average	Medium	Average
Left			High	Medium	Average
Right	High			Far	Fast
Forward		High		Far	Fast
Left			High	Far	Fast

To implement the velocity control unit, the following input linguistic variables were used: "distance to goal" with the set of values wich is given as {«Small», «Medium», «Far»}. They describe the small, medium and large distance to the goal, distance to obstacles, which are received from sensors and effective rotation angle of mobile robotic system, which is received with the usage of proposed method. The output linguistic variable is a variable that determines the velocity of mobile robot with the set of values, {«Slow», «Average», «Fast»}, denoting respectively low, medium and high speed. Databases of fuzzy rules, which represents velocity control unit, is shown in Table 3. The empty cells mean that linguistic variables can take any of their values.

We provide the simulation of motion control system of mobile robot with the usage of software Visual Studio 2010. In Fig. 2 the trajectory of mobile robot to fixed goal at different environments is represented.

The figure confirms the fact that in both cases goal is achieved. If there is too short distance to the obstacle or to the goal, the velocity of robotic system decreases. If there is the long distance the goal or to the obstacles velocity increases. This provides increasing the performance and accuracy of MRS.

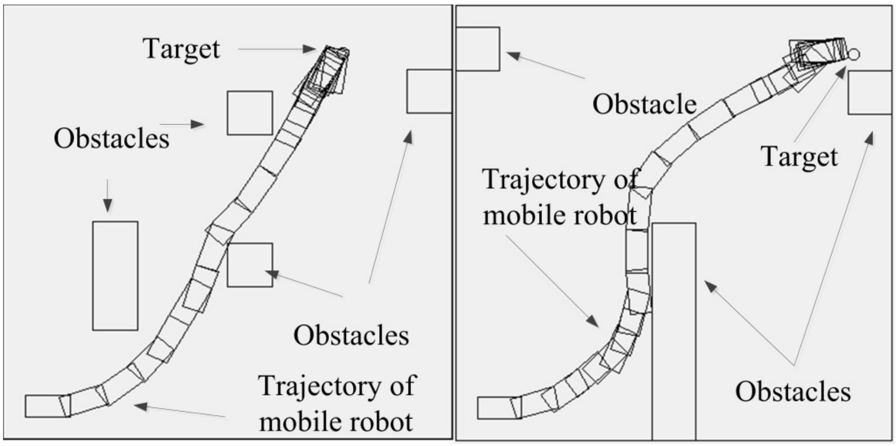

Fig.2. The trajectory of mobile robot to a fixed goal

Conclusion

In this paper the implementation of a mobile robotic system motion control, that enables achieving goal in an uncertain environment with obstacles, is examined. For this purpose, the implementations of the four behaviors are developed. The velocity control unit, which provides more accurate and rapid goal achievement by decreasing speed when obstacles or goal is near robotic system and increasing speed otherwiseare developedtoo.

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І. ЦМОЦЬ, д-р техн. наук, проф., **В. ТЕСЛЮК,** д-р техн. наук, проф.,
А. РОМАНЮК, канд. техн. наук, доц., **І. ВАВРУК,** асп.
Національний університет "Львівська політехніка"

СИСТЕМА УПРАВЛІННЯ НА ОСНОВІ НЕЧІТКОЇ ЛОГІКИ ДЛЯ МОБІЛЬНОГО РОБОТОТЕХНІЧНОГО КОМПЛЕКСУ В СЕРЕДОВИЩІ, ЩО СПОСТЕРІГАЄТЬСЯ ЧАСТКОВО

Пропонується система управління на основі нечіткої логіки, яка дозволяє мобільному робототехнічному коплексу досягати поставлених цілей в середовищі, яке спостерігається частково. В системі управліня базові поведінки запропоновано розширити поведінками "рух вздовж стіни справа" та "рух вздовж стіни зліва",які використовуються при оминанні перешкод.Для кожної з поведінок та для контролю швидкості розроблені набори нечітких правил та реалізовано метод уникнення конфліктів при координації поведінок.Блок керування швидкістю реалізовує більш точне і швидке досягнення цілей шляхом зменшення швидкості при наближенні до перешкоди або цілі та збільшення швидкості в іншому випадку. Бібл. 10, табл. 3, рис. 2.

Ключові слова: мобільний робототехнічний комплекс,нечітка логіка, середовище що спостерігається частково, управління на основі поведінок.

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И. ЦМОЦЬ, д-р техн. наук, проф., **В. ТЕСЛЮК,** д-р техн. наук, проф.,
А. РОМАНЮК, канд. техн. наук, доц.,**И. ВАВРУК,** асп.
Национальный университет "Львовская политехника"

СИСТЕМА УПРАВЛЕНИЯ НА ОСНОВЕ НЕЧЕТКОЙ ЛОГИКИ ДЛЯ МОБИЛЬНОГО РОБОТОТЕХНИЧЕСКОГО КОМПЛЕКСА В ЧАСТИЧНО НАБЛЮДАЕМОЙ СРЕДЕ

Представляется система управления на основе нечеткой логики для достижения целей мобильным робототехническим комплексом в частично наблюдаемой среде. Базовые поведения в системе управления расширены дополнительными поведениями "движение вдоль стены справа" и "движение вдоль стены слева", которые будуть использоватся для обхода препятствий. Для каждого из поведений и для контроля скорости разработаны наборы нечетких правил. Также разработан метод избежания конфликтов при координации поведений. Блок управления скоростью реализовывает более точное и быстрое достижение целей с помощью уменшения скорости при приближении к препятствию или цели и увеличения скорости в противном случае. Библ. 10, табл. 3, рис. 2.

Ключевые слова: мобильный робототехнический комплекс, нечеткая логика, частично наблюдаемая среда, поведенческое управление.

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Б.Р. РАКИШЕВ[1], акад. НАН РК, д-р техн. наук, проф., **А.А. КОПЕСБАЕВА**[2]**,** канд. техн. наук, доц.,
А.М. АУЭЗОВА[2], канд. техн. наук, **А.Е. КУТТЫБАЕВ**[1], канд. техн. наук
[1] **Казахский национальный технический университет имени К.И. Сатпаева**
[2] **Алматинский университет энергетики и связи,**

ИНТЕЛЛЕКТУАЛЬНЫЕ СИСТЕМЫ ТЕХНОЛОГИЙ ВЗРЫВНОЙ ПОДГОТОВКИ ГОРНЫХ ПОРОД

Подготовка высококвалифицированных кадров в технических ВУЗах будет неполной, если обучающиеся (бакалавры, магистранты и докторанты) не имеют возможности тестировать модели технологических и производственных процессов, так как они не в состоянии определить структуру и параметры данных процессов по каналам управления и оценить уравнение взаимосвязи входных и выходных координат наглядно, в связи с этим, такой специалист не может грамотно эксплуатировать (управлять) функционирующим производством, а тем более создавать и проектировать новые более эффективные технологии и системы управления ими. Современные SCADA – системы (Supervisory Control and Data Acquisition) – позволяют разрабатывать виртуальные модели различной сложности, максимально приближенные к реальным технологическим и производственным процессам, контроллерное управление данными процессами, визуализацию и возможность тестировать изменения параметров технологического процесса в режиме реального времени для использования в соответствующих учебных работах по профилирующим дисциплинам технических специальностей ВУЗов. В данной статье рассматривается исследование сложноструктурных блоков в условиях карьера, разработка программно-технических комплексов для определения внутренней структуры развала пород и их горно-технологических характеристик, параметров буровзрывных работ, визуализация в режиме реального времени массива пород при различных параметрах взрывания на основе современных SCADA – систем.