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METHOD OF AUTONOMOUS MOBILE ROBOTIC SYSTEM MOTION CONTROL BASED ON FUZZY LOGIC

Abstract. The different motion modes is proposed to use to the control system of mobile robotic system. The method to control of mobile robotic system that carried out by combining fuzzy logic with linear regression is developed.

Keywords. fuzzy logic, autonomous mobile robotic systems, linear regression, the method of fuzzy inference, rule base.

Problem statement

The branches of application of mobile robotic systems are expanding today. The autonomous motion control of such systems in a complex and uncertain environment is of particular interest now because such systems can be used to implement various tasks in which is no information about the environment or communication with the operator. Such mobile robotic systems can be implemented for liquidations accidents or work at a dangerous environment for human.

The main requirements for the motion control system of autonomous mobile robotic system include: ensuring of rapid response for changing environmental conditions and unexpected events; ensuring of real-time operation in deterministic and non-deterministic environments; achieving all the goals set by the operator or higher control level, adjusting behavior according to the changing conditions of the environment to achieve goals; making decisions based on incomplete and ambiguous input data etc. The intelligent methods for mobile robotic control systems are necessary to use for performing the requirements. The usage of fuzzy logic technology ensures fulfillment of the requirements and effective control of mobile robotic systems because of a result of the mobile robotic control system in many cases is difficult to formalize, but it can be easily described with the usage of common language. Therefore, an effective solution is the usage of fuzzy logic, as this provides the possibility of control even in an uncertain environment with noisy input data that can be obtained from sensors.

Thus, the vital task is to develop a fast and accurate method of mobile robot control system that ensures performing the assigned tasks.

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Analysis of recent research and publications

Analysis of recent research and publications showed [1-4] that there are different methods of fuzzy inference. The most widespread of such methods are: the method of fuzzy inference Mamdani and Sugeno. The disadvantages of aforementioned methods for implementation of mobile robot control systems are the following:

- low accuracy due to the result value of the output variable dependence of method of defuzzification and low speed (Mamdani method);
- complexity of use, if the values of consequents of the rules are represented as fuzzy values and not intuitive approach for a rule base building (Sugeno method).

The antecedents and consequents of rule base which are used for the motion control of mobile robotic systems are fuzzy variables. The usage of Mamdani method does not provide adequate accuracy and speed. Therefore, it’s necessary to develop a method of control that provides the adequate accuracy, speed and takes into account the fuzzy variables of rules for the implementation of mobile robotic control system

The proposed method

In general, the structure of mobile robotic system motion control is shown in Figure 1, that consists of four modes of motion: motion mode to the target, motion mode obstacles avoidance, motion mode along the right wall, motion mode along the left wall and appropriate activation coefficients for each mode of motion. The input data of motion mode obstacles avoidance and motion mode along the walls are the distance to the obstacles that represents by linguistic variables. There are three terms of every linguistic variable which define small, medium and large distance to the obstacles. The input data of motion mode to the target is rotation angle that calculates as difference between the direction of mobile robotic system motion and the direction of the target. The output value of the motion modes is the rotation angle of mobile robotic system that represents by linguistic variables with terms corresponding to the turning to the right, straight motion and turning to the left. The output value of activation coefficients is formed by using the input linguistic variables that represents the distance to obstacles from different sides of robotic system and the value of the rotation angle that calculates as difference between the direction of mobile robotic system motion and the direction of the target. The output value of the linguistic variable of activation coefficients is formed with five terms, which define the value of each motion mode from not activated (which represents as zero) to activated (which represents as one).

Input data coming from sensors of mobile robotic system and the machine vision system. The resulting value of the mobile robotic system rotation angle comes to block for control signals forming, where the rotation angle converts to the corresponding control signals according to the actuators of mobile robotic system.

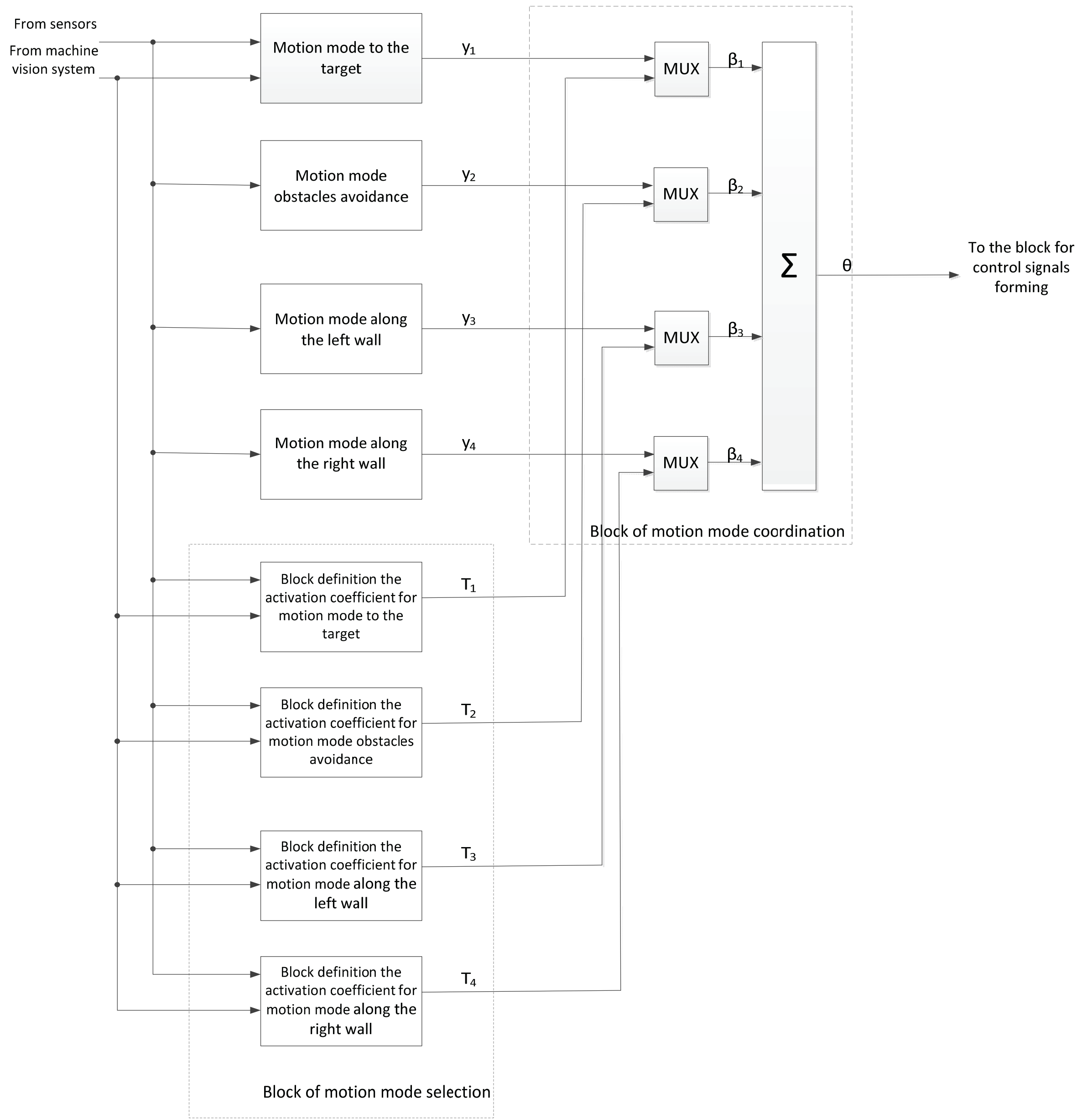

Figure 1 – Structure of mobile robotic system motion control.

In general, a fuzzy inference system consists of the following main steps: fuzzification , aggregation , activation , accumulation and defuzz-

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ification. The large number of operations is required for implementation of these steps [5]. We propose to replace the operations that take a long computation time to the linear regression model. This method would reduce the number of operations and improve performance of control. In the general case the structure of the algorithm of developed fuzzy method of mobile robotic system motion control consists of two blocks: the block of fuzzy inference (BFI) and block of linear regression (BLR). The membership functions of each term for output linguistic variable is calculated with the usage of a given input data and the rules of the rule base at BFI. The output value of control variable is calculated using linear regression models at the BLR as [6]:

$$y = a_0 + a_1 Fy_1 + ... + a_q Fy_q , \qquad (1)$$

where $a_0,...a_q$ - linear regression model coefficient; $Fy_1...Fy_q$ - the value of membership functions of each term for output linguistic variable; y - output control variable. The main problem in the implementation of this method is to find the coefficients of the linear regression model.

As can be seen from Figure 1, which shows the structure of mobile robotic system motion control, it is necessary to use this method for finding the rotation angle of each of the four motion modes and each of the four activation coefficients.

Three terms of result output linguistic variable is used to calculate the rotation angle of each of the four motion modes of mobile robotic system. Thus equation (1) takes such form for this purpose:

$$y_i = a_{0i} + a_{1i} Fy_{1i} + a_{2i} Fy_{2i} + a_{3i} Fy_{3i} , \qquad (2)$$

where $a_{0i},...a_{3i}$ - linear regression model coefficients of an appropriate motion mode; $Fy_{1i}...Fy_{3i}$ - the value of membership functions of each term for output linguistic variable of appropriate motion mode, y_i - output control variable, $i = \overline{1,4}$.

Five terms of result output linguistic variable is used to calculate the activation coefficients of each motion modes of mobile robotic system. Thus equation (1) takes such form for this purpose:

$$T_i = b_{0i} + b_{1i} Ft_{1i} + b_{2i} Ft_{2i} + b_{3i} Ft_{3i} + b_{4i} Ft_{4i} + b_{5i} Ft_{5i} , \qquad (3)$$

where $b_{0i},...b_{5i}$ -linear regression model coefficients of appropriate activation coefficient; $Ft_{1i}...Ft_{5i}$ - the value of membership functions of each term for output linguistic variable of appropriate activation coefficient; T_i - output variable of activation coefficient of appropriate motion mode; $i=\overline{1,4}$.

At first, the crisp values of the rotation angles and activation coefficients of appropriate motion modes as output variables must be calculated to determine the linear regression model coefficients. We propose to use fuzzy-neural T-Controller for this purpose which is based on fuzzy geometrical transformation model.

T-Controller provides higher accuracy than methods of fuzzy inference by usage of zero methodological error of defuzzification and higher performance, due to lack of accumulation of fuzzy rules consequents. T - Controller Workshop is software where T- controller is implemented. [7-9].

The same input data are sent to the BFI. So values of membership functions of each term for output linguistic variable of appropriate activation coefficients and rotation angles of each motion modes are calculated for all data base. A fuzzification (receiving fuzzy values from crisp values with the usage of triangular membership function), determining the degree of fulfillment antecedents of individual linguistic statements of rules from fuzzy inference system, determining the degree of fulfillment consequents of individual linguistic statements for each rule from rule base, determining the membership function of each output linguistic variable are implemented at BFI.

The method of least squares is proposed to use for calculating the linear regression model coefficients. The resulting rotation angle of mobile robotic system is the sum of the products of the rotation angles values and activation coefficients of the appropriate motion modes.

Conclusion

1. The combination of different motion modes and corresponding activation coefficients is used for implementation the autonomous mobile robotic system motion control. Such approach enhances adaptation to the requirements of the particular application by developing and adding new motion modes to system of motion control.
2. A new method to control of mobile robotic system is proposed, which is the combination of fuzzy logic and linear regression

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model. The usage of this method provides increasing performance due to reduction of the number of computational operations.

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