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Designing and simulation a motion control system of mobile robot based on fuzzy logic

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***Abstract*— The improved motion control system of autonomous mobile robot is described in this article. We propose to improve control system of mobile robot by adding speed control module which provides speed increasing when there are no obstacles nearby and speed decreasing when some obstacle or target is near. This enhances performance of motion control system of mobile robot. Also we propose to improve control system of mobile robot by taking into account parameters of mobile robot. This enhances the precision of motion control system of mobile robots with different weights.**

***Index Terms*— Mobile robot, motion control system, fuzzy logic, T-Controller, speed control.**

I. INTRODUCTION

Nowadays mobile robotic system is used to implement a variety of tasks, such as: remote research of different objects, execution of military application or tasks in hazardous environments for people, solving some household tasks etc [1]. Performing these tasks provides the ability to automatically achieve the goal by mobile robot in the environment while avoiding collisions with moving or fixed obstacles. It is necessary to use intelligent control for implementation the autonomous control system of mobile robot when there is partial or complete lack of information about the environment. Fuzzy logic is used for motion control system of mobile robot implementation because of sensors of mobile robot can produce uncertain and incomplete information. Fuzzy logic provides the ability to control which are based on qualitative rather than quantitative data since there are often problems with the construction of mathematical models of complex mobile robots. Therefore, the vital task is to implement autonomous control of mobile robot using fuzzy logic.

Analysis of recent research and publications showes [2-7], that at present time effective solution is to use fuzzy logic, since it provides the ability to control of mobile robots even with noisy input data, which can be obtained from sensors. However, the previous developed control systems based on fuzzy logic have such main disadvantages:

- only uniform motion is considered, when mobile robot or group of mobile robots moves at the same speed [6];
- rule base are specialized, that is created specifically for some mobile robots, without taking into account their size or weight [2-7].

Therefore, the vital task is to improve control system of mobile robot by controlling speed for ensuring the fastest achievement of goals and by taking into account the parameters of mobile robot for enhancing the precision of motion control system.

II. STRUCTURE OF THE MOTION CONTROL SYSTEM OF MOBILE ROBOT

The main task of motion control of mobile robot is to achieve the goal while avoiding obstacles. For this purpose we propose to use some multiple motion modes, namely, "to the target", "obstacle avoidance", "along the right wall" and "along the left wall". The implementation of each motion mode is carried out by using a method based on fuzzy logic. Using multiple motion modes provides the possibility of parallel computation values of various motion modes and the ability to easy adapt a mobile robot to perform other tasks which are carried out by adding extra modes that implemented the required behavior. For motion modes "obstacle avoidance", "along the right wall" and "along the left wall" the input linguistic variables are distances to obstacles as measured from the front side, the right side and the left side of a mobile robot. For motion mode "to the target" the input linguistic variable is an angle error that is calculated as the difference between the desired heading required to reach the goal and the actual current heading. The output linguistic variable of each motion mode is rotation angle of a mobile robot. The input signals are received from sensors, which are placed in the front, right and left sides of the mobile robot and a machine vision system. The main problem of using multiple motion modes is to obtain the resulting rotation angle of mobile robot, because the different output data can be received from different motion modes. That is necessary to determine the most effective rotation angle of mobile robot using the obtained rotation angles of different motion modes. We propose to calculate some coefficients which express the degree of activation of each motion mode for the determination of the effective rotation angle of mobile robot. Calculating the activation coefficients is carried out by using method based

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on fuzzy logic. For this purpose the input linguistic variables are distances to obstacles from three sides of mobile robot and an angle error that is calculated as the difference between the desired heading required to reach the goal and the actual current heading. The output linguistic variable is the value of activation coefficient which is in the range from 0 to 1. The calculation of the resulting rotation angle of mobile robot is carried out as linear combination of rotation angles that are obtained at different motion modes and activation coefficients, which represent the degree of activation for each motion mode [8]. We propose to improve the motion control system be adding extra modules of speed control and consideration of mobile robot parameters. This approach reduces the time to achieve the goal and enhances the precision of motion control system while using mobile robots with different parameters.

Figure 1 shows the structure of improved motion control system of mobile robot.

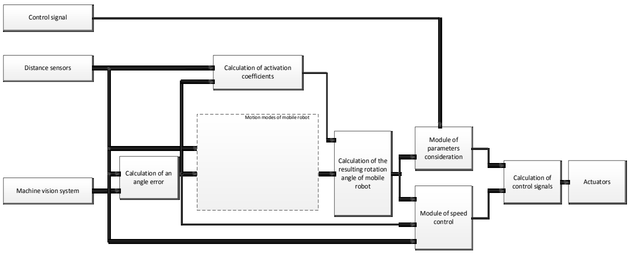
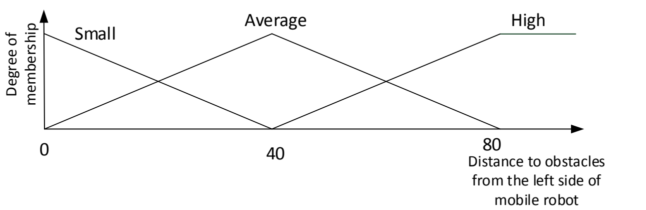


Fig.1. Structure of improved motion control system of mobile robot.

The module of speed control is used for the possibility of changing the speed during mobile robot moving. It leads to increasing the performance of control system by faster movement of the mobile robot in case of absence the obstacle and slower movement of the mobile robot in case of presence the obstacle near mobile robot or in case of small distance between the mobile robot and the goal. Implementation the module of speed control is carried out by using method based on fuzzy logic. For this purpose the input linguistic variables which represent the distances to obstacles, the distance to the goal and the resulting rotation angle of mobile robot are used. For example, the input linguistic variables which represent distances to obstacles can be described by fuzzy sets with such linguistic labels as {"Small", "Average", "High"} which determine a small, middle and large distance to the obstacles. The input linguistic variable which represents the distance to the goal can be described by fuzzy sets with such linguistic labels as {"Small", "Medium", "Far"} which determine a small, middle and large distance to the goal. The input linguistic variable which represents the resulting rotation angle of mobile robot can be described by fuzzy sets with such linguistic labels as {"Right", "Forward", "Left"} which determine a turning to the right, moving straight and turning to the left respectively. The output linguistic variable represents the speed of mobile robot and can be described by fuzzy sets with such linguistic labels as {"Slow", "Average", "Fast"} which determine a slow, medium and fast movement of mobile robot.

The module of parameters consideration is used for the adaptation of the developed control system to a particular mobile robot. We propose to take into account the weight of mobile robot while calculating the rotation angle of mobile robot. At future studies the number of parameters will be increased and the parameters of the environment will be considered. The implementation of the module of parameters consideration is carried out by using a method based on fuzzy logic. For this purpose the input linguistic variables which represent the resulting rotation angle and weight of mobile robot are used. The input linguistic variable which represents the resulting rotation angle of mobile robot can be described by fuzzy sets with such linguistic labels as {"Right", "Forward", "Left"} which determine a turning to the right, moving straight and turning to the left. The input linguistic variable which represents the weight of mobile robot can be described by fuzzy sets with such linguistic labels as {"Ultra-light", "Light", "Average", "Heavy"} which determine a mobile robot with very small, small, medium and large weight. The output linguistic variable is an update resulting rotation angle of mobile robot and can be described by fuzzy sets with nine linguistic labels such as {" Left High", "Left Average", "Left Small", "Left Very Small", "Forward", "Right Very Small", "Right Small", "Right Average", "Right High"} which determine a different rotation angles of mobile robot. A graphical representation of membership functions for input linguistic variables for module of speed control and module of parameters consideration is shown at Fig.2. We propose to use a triangular membership functions, because they are the simplest to implement.



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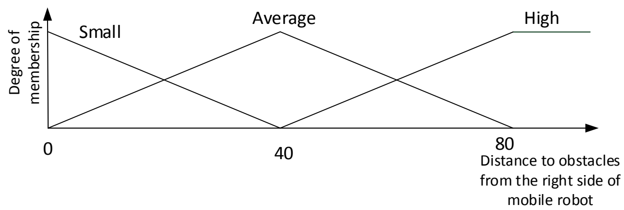

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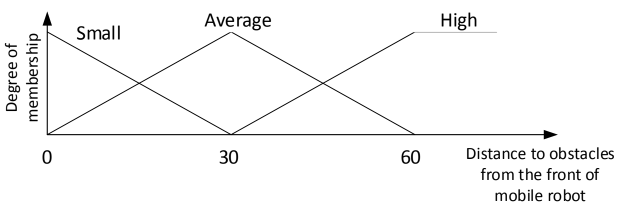

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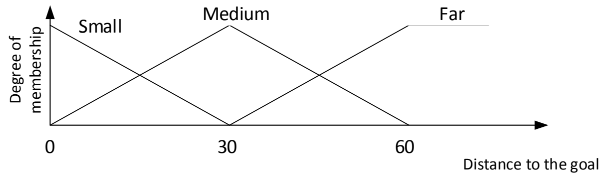

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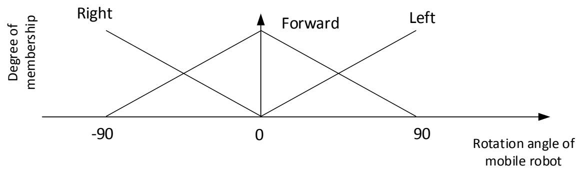

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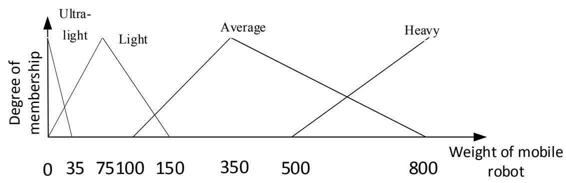


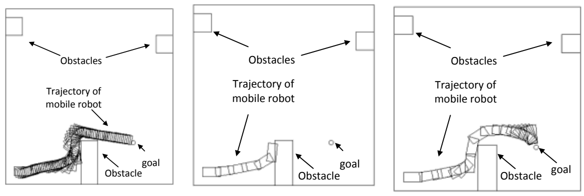
f)

Fig.2. Graphical representation of membership functions for input linguistic variables for module of speed control and module of parameters consideration: a) the input linguistic variable which represents distances to obstacles from the right side of mobile robot; b) the input linguistic variable which represents distances to obstacles from the left side of mobile robot; c) the input linguistic variable which represents distances to obstacles from the front of mobile robot; d) the input linguistic variable which represents distance to the goal; e) the input linguistic variable which represents the rotation angle of mobile robot; f) the input linguistic variable which represents the weight of mobile robot.

The calculation values of output variables for the module of speed control, the module of parameters consideration, motion modes and the activation coefficients are carried out by using method based on fuzzy logic. We propose to replace some operations of fuzzy control system which require a large amount of time by the calculation the value of the linear regression model. To determine the coefficients of linear regression models we propose to use a fuzzy-neural T-controller, which provides a high precision of operation. Crisp values are calculated for entire domain of output linguistic variables by using T-controller. Software T-Controller Workshop is used for implementing fuzzy-neural T-controller [9-10].

III. SIMULATION MOVEMENT OF MOBILE ROBOTIC SYSTEM

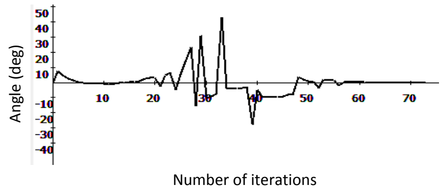
Software for simulation a trajectory of mobile robot is developed. Comparison of the motion control system without using modules of speed control and parameters consideration and proposed motion control system is presented. Comparison is carried out under the same conditions. The trajectory of mobile robot to fixed goal, which are located behind the obstacle is showed at Fig.3. There you can see trajectory of mobile robot movement with consistently low speed and consistently high speed for motion control system without using modules of speed control, parameters consideration and trajectory of mobile robot movement with changeable speed for proposed motion control system.



a) b) c)

Fig.3. The trajectory of mobile robot to fixed goal which are located behind the obstacle: a) trajectory of mobile robot with motion control system with consistently low speed; b) trajectory of mobile robot with motion control system with consistently high speed; c) trajectory of mobile robot with the proposed motion control system.

Values of resulting rotation angles of mobile robot are showed at Fig.4.



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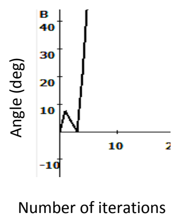
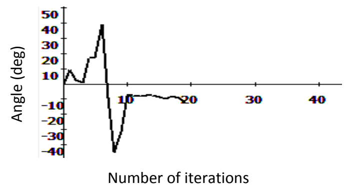


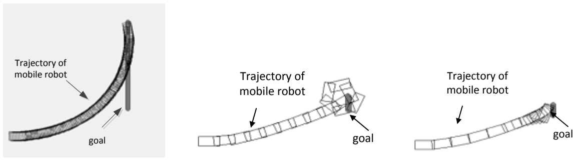


b) c)

Fig.4. Values of resulting rotation angles of mobile robot: a) mobile robot with motion control system with consistently low speed; b) mobile robot with motion control system with consistently high speed; c) mobile robot with the proposed motion control system.

As it shown at Fig. 3 and Fig. 4, the usage of mobile robot with proposed motion control system provides achieving goal in fewer steps in comparison with the usage of mobile robot with motion control system with consistently low speed. As it shown at Fig. 3b) and Fig. 4b), the usage of mobile robot with motion control system with consistently high speed does not ensure the achievement of goals, because there is a collision with an obstacle. The mobile robot with proposed motion control system can provide obstacle avoidance by decreasing a speed near an obstacle.

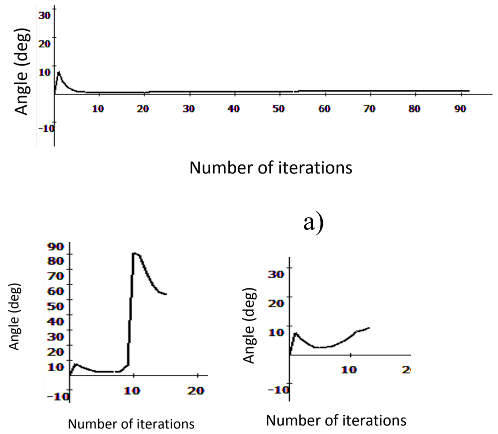
The trajectory of mobile robot to moving goal is showed at Fig.5. There you can see trajectory of mobile robot movement with consistently low speed and consistently high speed for motion control system without using modules of speed control and parameters consideration and trajectory of mobile robot movement with changeable speed for proposed motion control system.



a) b) c)

Fig. 5. The trajectory of mobile robot to moving goal: a) trajectory of mobile robot with motion control system with consistently low speed; b) trajectory of mobile robot with motion control system with consistently high speed; c) trajectory of mobile robot with the proposed motion control system.

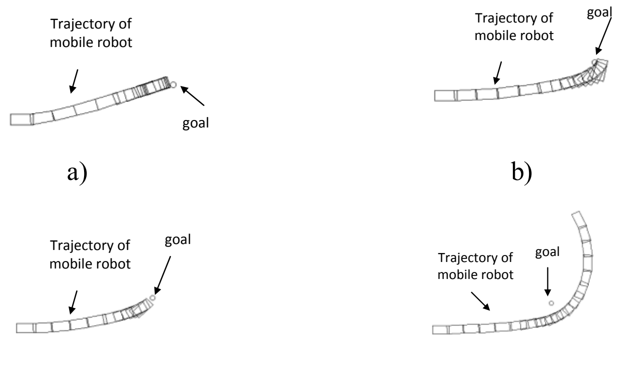
As it shown at Fig. 5 the mobile robot with motion control system with consistently low speed and mobile robot with the proposed motion control system achieve a goal. The movement of mobile robot is much slower in comparison with the mobile robot with the proposed motion control system, where speed is increased at the beginning of movement and is decreased when the goal is near. A mobile robot with motion control system with consistently high speed (Fig.4b) do not achieve the goal because of mobile robot passing a goal and then moving around it, trying to reach it. Values of resulting rotation angles of mobile robot are showed at Fig.6.



b) c)

Fig. 6. Values of resulting rotation angles of mobile robot: a) mobile robot with motion control system with consistently low speed; b) mobile robot with motion control system with consistently high speed; c) mobile robot with the proposed motion control system.

As you can see at Fig. 6a, the adjustment of rotation angle is provided at the initial stage of moving of the mobile robot with motion control system with consistently low speed, and then this rotation angle changes very slowly over the entire movement of mobile robot. At the initial stage, rotation angles of mobile robot with motion control system with consistently high speed and rotation angles of mobile robot with the proposed motion control system are similar due to the rapid movement of mobile robot to the goal when there are no obstacles near mobile robot (Fig.6.b,c). The rotation angle of mobile robot with the proposed motion control system slowly changes when mobile robot is near the goal, due to the decreasing of speed of mobile robot. The rotation angle of mobile robot with motion control system with consistently high speed changes dramatically when mobile robot is near the goal. It happens because of passing the goal by mobile robot because it moves with high speed and rotation angles is changed in order to return to the goal. The trajectory of mobile robot movement with different weights to fixed goals at the environment without obstacles is shown at Fig.7.



c) d)

Fig.7. The trajectory of mobile robot to fixed goal at the environment without obstacles: a) trajectory of mobile robot with very small weight (less 35 kg); b) trajectory of mobile robot with small weight (less 150 kg); c) trajectory of mobile robot with medium weight (less 800 kg); d) trajectory of mobile robot with large weight (over 800 kg).

The speed of mobile robot with the proposed motion control system is high at the beginning of movement and it decreases when distance to the goal is small.

The mobile robot with a very small weight immediately turns to the target as is shown at Fig. 7a. The changing of rotation angle of mobile robot with small weight and mobile robot with medium weight is small at the beginning of movement and when distance to the goal is small the rotation angle increases. The rotation angle of mobile robot with large weight is small at each step movement. If the target is at short distance from mobile robot with large weight, it is impossible to achieve the goal (Fig.7d).

IV. Conclusion

1. We propose to improve control system of mobile robot by speed control, which provides the increasing of speed when there are no obstacles nearby and decreasing pf speed when some obstacle or target is near. This enhances the accuracy and performance of motion control system of mobile robot.

2. We propose to improve control system of mobile robot by taking into account parameters of mobile robot. This enhances the precision of motion control system of mobile robots with different weights.

3 Software for building the trajectory of mobile robot is created.

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