Motion Control of Wheeled Mobile Robots Using Fuzzy Logic

Ritesh B. Meshram

Abstract*—*In this paper, we propose a fuzzy logic controller for the motion control of a wheeled mobile robot (WMR) in simulation environment. We address the problem of mobile robot tracking and formation control. The leader mobile robot is controlled to reach the desired position, and the follower mobile robot keep constant relative distance and constant angle to the leader robot. Algorithms for controlling robot formations have been inspired by biological and organizational systems. Simulation is conducted in Matlab to investigate the performance of the proposed fuzzy controller.

Keywords*—*Mobile wheeled robot, fuzzy logic controller, leader- follower,formation.

I. INTRODUCTION

In recent years there has been an increasing amount of research on the subject of mobile robotics. Mobile robots are increasingly used in industry, in service robotics, for domestic needs (vacuum cleaners, lawn mowers, pets), in difficult-to access or dangerous areas (space, army, nuclear-waste cleaning) and also for entertainment (robotic wars, robot soccer) [11].There are many robot navigation strategies , and in cases where operating environment map is known, approach with trajectory planning algorithms is commonly used. Here the term trajectory denotes the path that robot should traverse as a function of time. A trajectory can be generated in real-time on the basis of current sensor readings or generated in advance on the basis of operating environment map. In common in practical applications the wheeled mobile robots have the same kinematic model [2],[5],[8]. It is very important to find a control law that produces a smooth control signal. If this is not the case, the implementation on the dynamic model becomes impossible.

One of the important features of multiple mobile agent systems is team formation. It is inspired by swarming behavior of living beings, such as flocks of birds, schools of fish, herds of wildebeest, and colonies of bacteria. Formation control has been studied in robotics within different structures and approaches, such as, Differential Game approach [1],[6],[7], behavior-based structure [6],[17], leader-follower structure [1],[12],[14],[15], and virtual leader structure[10],[11],[16]. Several authors adopt a simple path planning approach which identifies only the target positionof the robot and passes the obstacle avoidance to the motion control using techniques such as model predictive control [3],[9],[13], PID, neural network,fuzzy logic and genetic algorithms[18].

The use of fuzzy logic in the design of navigation behaviors for a mobile robot is nowadays quite popular. Fuzzy logic has been applied to mobile robot and autonomous vehicle control significantly [17]-[27].

Fuzzy control has shown to be a very useful tool in the field of autonomous mobile robotics, characterized by a high uncertainty in the knowledge about the environment where the robot evolves

In this paper, we consider the leader-follower approach for the wheeled mobile robot. Our approach is to develop a control strategy for mobile robots using Fuzzy logic. We propose a motion control strategy based on fuzzy logic control so that WMR reached the desired position/location. We consider the leader-follower control problems revolving around a group of wheeled mobile robots. Here we state the control problem as following

A robot group, comprised of “n” wheeled mobile robots R_i (i=1, 2…n). As soon as leader robot changes it position the follower robots will also changer their position accordingly without colliding with the leaderrobot.

In the following, theoretical information about Fuzzy logic is given in Section II. Fuzzy logic control strategy is presented in Section III. The simulation results are provided in Section IV. Finally, conclusions andfuture work are given in Section V.

II. FUZZY LOGIC

Fuzzy control is one of the intelligent control techniques that pertain to the realization of intelligent control systems. Fuzzy Logic was initiated in 1965 by Lotfi A. Zadeh , professor for computer science at the University of California in Berkeley. Basically, Fuzzy Logic (FL) is a multivalued logic, which allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. [26]. The use of Fuzzy Logic Systems (FLS) for control applications has increased since they became popular from 80's. After Mendel in 90's showed how uncertainty can be computed in order to achieve more robust systems, Type-2 Fuzzy Logic Systems (T2FLS) are in the focus of researchers and recently they became a new research topic [27]. Fuzzy logic poses the ability to mimic the human mind to effectively employ modes of reasoning that are approximate rather than exact. In most applications, an FL solution is a translation of a human solution. Thirdly, FL can model nonlinear functions of arbitrary complexity to a desired degree of accuracy. FL is a convenient way to map an input space to an output space. FL is one of the tools used to model a multi-input, multi-output system.

III. FUZZY CONTROLLER DESIGN

The simulation environmental model is expressed in a two-dimensional area,with x and y axis. The center position of the vehicle (x, y, θ) is expressed in the inertial coordinate frame. Here x and are position of the robot and θ is orientation of the robot with respect to inertial frame.As said above the robot group, comprised of “n” mobile robots R_i (i=1, 2…n).

So the state of n robots is denoted as $R_i(x_i, y_i, \theta_i)$.

Manuscript Received July, 2013.

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The state of leader and follower robots will be (x_l, y_l, θ_l), (x_f, y_f, θ_f) respectively. Therobot can go Forward, Backward, Left or Right. The robots will do point to point tracking to reach the desired position.When the require number of robots is entered.The user will be asked to select the leader from the entered number of robots. Once the leader is selected user will select the required motion for the leader robot, whether it want the leader to move forward, backward,Left or Right. If forward or backward motion is selected then the following equation will be used for the distance(y_d) it has to move;

$$y_l = y_l \pm y_d \quad (1)$$

Here +ve signis used for forward motion & -ve sign is used for backward motion.

If Left or Right motion is selected then, theprogrammer will enter the required angle. Now the new angle for leader is calculated as;

$$\theta_l = \theta_l \pm \theta_d \quad (2)$$

Here +ve sign is used for right motion & - ve sign is used for left motion.

Distance(d_{12}) and angle12(θ_{12}) between leader and followers is calculated using equation given below;

$$\theta_{12} = \theta_f - \theta_d \quad (3)$$

If $\theta_{12} < 0$,then $\theta_{12} = 180 + \theta_{12}$ (4)

Else $\theta_{12} = 180 + (\theta_{12} / 2)$ (5)

$$d_{12} = \sqrt{(x_f - x_l)^2 + (y_f - y_l)^2} \quad (6)$$

For forming the formation between leader robot and follower robots we will use following equations.

$$x_f = \sin(t) + x_l \quad (7)$$

$$y_f = \cos(t) + y_l \quad (8)$$

Where,

$$t = ((1/(2(n-1))) + (i-1)/(n-1)) \times 2\pi \quad (9)$$

A. Fuzzy Controller

The application of fuzzy logic control in robotics is to produce an intelligent robot with the ability of autonomous behaviour and decision. In this section, the problem of how to set the control parameter values for desired robot behaviour is solved.

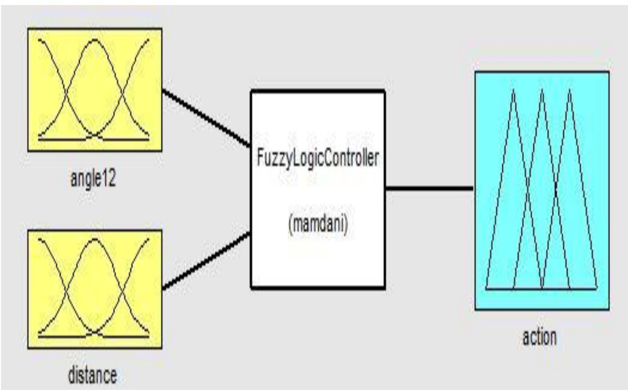

Figure 1.Fuzzy Controller design.

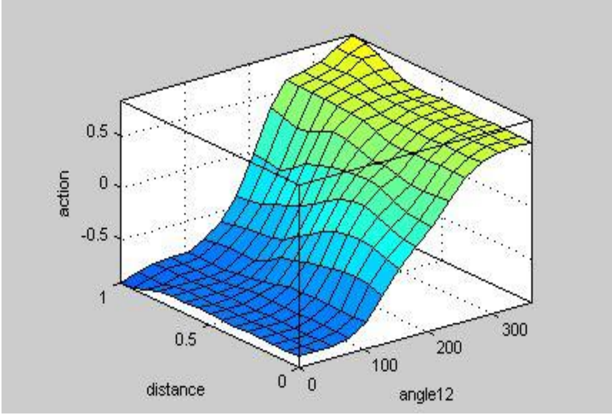

Figure 2.The control surface

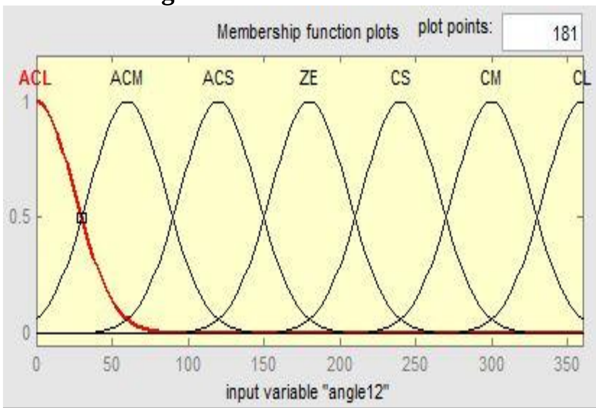

Figure 3.input membership function of angle12.

Linguistic variables for inputs membership function angle12 are denoted as, Anticlockwise Large (ACL), Anticlockwise Middle (ACM), Anticlockwise Small(ACS), Zero (ZE), Clockwise Small(CS), Clockwise Middle(CM), Clockwise Large(CL).

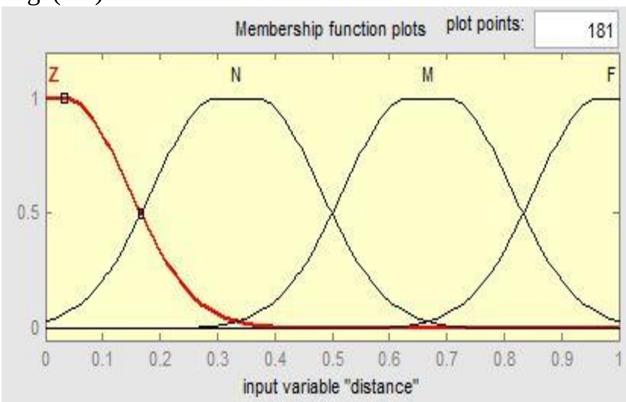

Figure 4.Input membership function of distance.

Linguistic variables for inputs membership function distance are denoted as, Zero (Z), Near (N), Medium (M), Far (F).

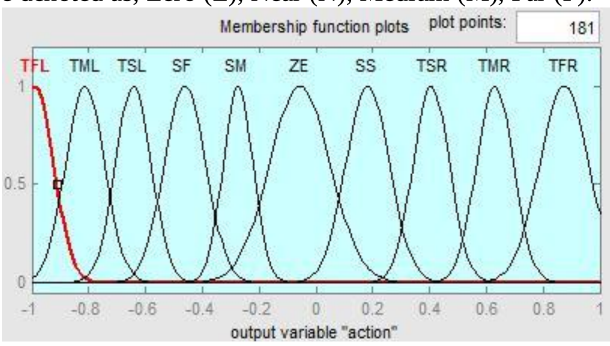

Figure 5.Output membership function action

Linguistic variables for output membership function action are denoted as, Turn medium

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left(TML), Turn medium right (TMR), Turn fast left (TFL), Turn fast right (TFR), Turn slow left (TSL), Turn, Slow right (TSR), Straight slow(SS), Straight medium (SM), Straight fast (SF).

B. Fuzzy Rules

The robot will be controlled by total 28 rules.

TABLE I.Rules table of Fuzzy logic controller.

θ_{12} / d_{12}	ACL	ACM	ACS	ZE	CS	CM	CL
Z	TML	TML	TSL	ZE	TSR	TMR	TMR
N	TML	TML	TSL	SS	TSR	TMR	TMR
M	TML	TML	TML	SM	TMR	TMR	TMR
F	TMF	TML	TML	SF	TMR	TMR	TFR

IV. SIMULATION RESULT

The effectiveness of the fuzzy controller is demonstrated by selecting 9 robots out of which one is selected as leader. The overall system is designed and implemented within Matlab environment. At first user will be asked to enter the number of robots, then out of those one will be selected as leader robot. Initially the robot will at any random position. The system output is shown as below.In the output the leader is shown in red color while the followers are shown in green color.

Enter number of Robots:9
Enter the Leader Number(1-9):2
Follower Robot 1, X:372, Y:140, Angle:20.62
Leader Robot 2, X:79, Y:100, Angle:51.69
Follower Robot 3, X:246, Y:189, Angle:37.53
Follower Robot 4, X:141, Y:332, Angle:66.99
Follower Robot 5, X:234, Y:220, Angle:43.23
Follower Robot 6, X:367, Y:114, Angle:17.26
Follower Robot 7, X:303, Y:301, Angle:44.81
Follower Robot 8, X:152, Y:227, Angle:56.19
Follower Robot 9, X:30, Y:22, Angle:36.25

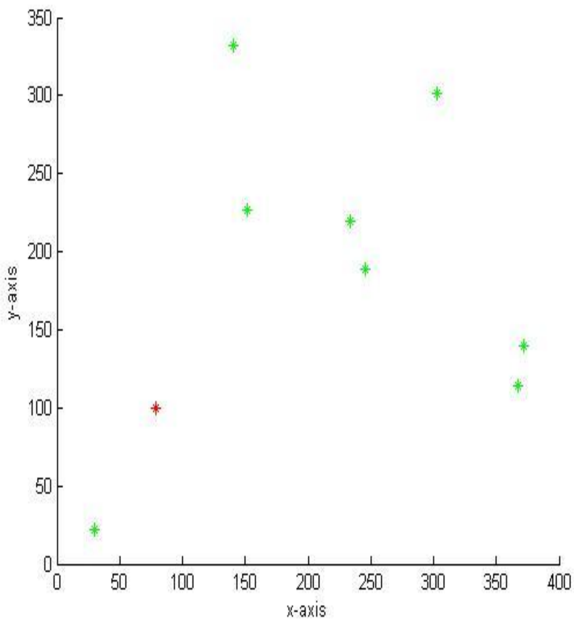

Figure 6. Initial position of robots with leader shown in red and followers are shown in green color.

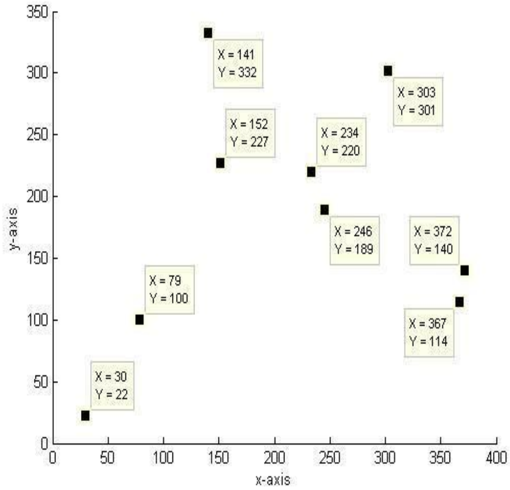

Figure 7. Initial position of robots with X,Y co-ordinates of leader and followers.

Figure 8.menu for selecting the desired motion for leader robot.

We have selected random motion for the leader robot. For random motion we will also tell the robot number of motion/moves it has to make. In our case we selected 5 moves for the leader robot. The result is shown as below.

Enter number of motions:5
Left
Follower Robot 1, X:393.70, Y:-54.64, Angle:20.62
Leader Robot 2, X:91.83, Y:88.37, Angle:43.90
Follower Robot 3, X:257.10, Y:173.59, Angle:37.53
Follower Robot 4, X:146.06, Y:329.81, Angle:66.99
Follower Robot 5, X:238.35, Y:215.28, Angle:43.23
Follower Robot 6, X:375.33, Y:-82.54, Angle:17.26
Follower Robot 7, X:371.79, Y:210.20, Angle:44.81
Follower Robot 8, X:119.43, Y:245.70, Angle:56.19
Follower Robot 9, X:29.87, Y:22.18, Angle:36.25

Right
Follower Robot 1, X:270.67, Y:-291.07, Angle:20.62
Leader Robot 2, X:89.80, Y:90.43, Angle:45.20
Follower Robot 3, X:276.85, Y:139.97, Angle:37.53
Follower Robot 4, X:153.51, Y:326.40, Angle:66.99
Follower Robot 5, X:248.80, Y:203.11, Angle:43.23
Follower Robot 6, X:231.02, Y:-307.11, Angle:17.26

Follower Robot 7, X:426.02, Y:30.32, Angle:44.81
Follower Robot 8, X:78.19, Y:261.76, Angle:56.19
Follower Robot 9, X:29.87, Y:22.18, Angle:36.25

Left
Follower Robot 1, X:-23.30, Y:-396.79, Angle:20.62
Leader Robot 2, X:96.90, Y:82.77, Angle:40.50
Follower Robot 3, X:295.60, Y:94.12, Angle:37.53
Follower Robot 4, X:157.05, Y:324.72, Angle:66.99
Follower Robot 5, X:254.26, Y:196.23, Angle:43.23
Follower Robot 6, X:-63.39, Y:-379.03, Angle:17.26
Follower Robot 7, X:374.77, Y:-204.84, Angle:44.81
Follower Robot 8, X:26.13, Y:271.94, Angle:56.19
Follower Robot 9, X:29.21, Y:23.04, Angle:36.25

Forward
Follower Robot 1, X:-308.96, Y:-250.05, Angle:20.62
Leader Robot 2, X:96.90, Y:86.15, Angle:41.64
Follower Robot 3, X:310.18, Y:5.17, Angle:37.53
Follower Robot 4, X:161.21, Y:322.67, Angle:66.99
Follower Robot 5, X:264.53, Y:182.15, Angle:43.23
Follower Robot 6, X:-323.55, Y:-207.37, Angle:17.26
Follower Robot 7, X:120.16, Y:-409.84, Angle:44.81
Follower Robot 8, X:-26.65, Y:271.89, Angle:56.19
Follower Robot 9, X:28.36, Y:24.07, Angle:36.25

Forward
Follower Robot 1, X:97.24, Y:95.03, Angle:20.62
Leader Robot 2, X:96.90, Y:94.09, Angle:44.16
Follower Robot 3, X:97.88, Y:93.91, Angle:37.53
Follower Robot 4, X:97.54, Y:93.32, Angle:66.99
Follower Robot 5, X:96.90, Y:93.09, Angle:43.23
Follower Robot 6, X:96.26, Y:93.32, Angle:17.26
Follower Robot 7, X:95.91, Y:93.91, Angle:44.81
Follower Robot 8, X:96.03, Y:94.59, Angle:56.19
Follower Robot 9, X:96.56, Y:95.03, Angle:36.25

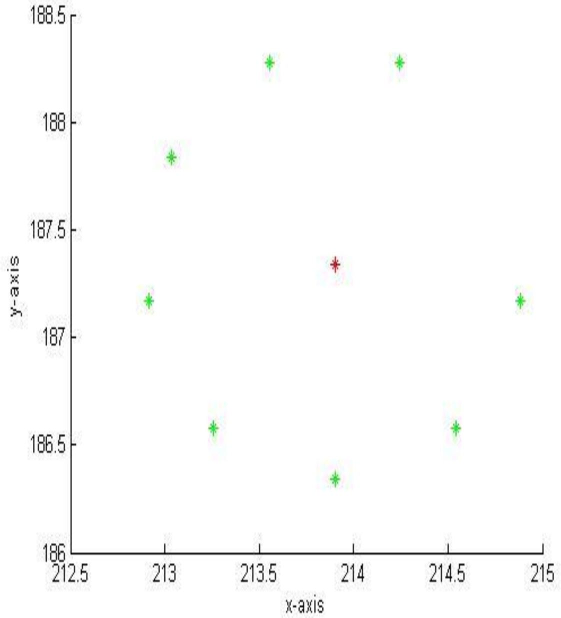

Figure 9. Final position of robots with leader shown in red and followers are shown in green color.

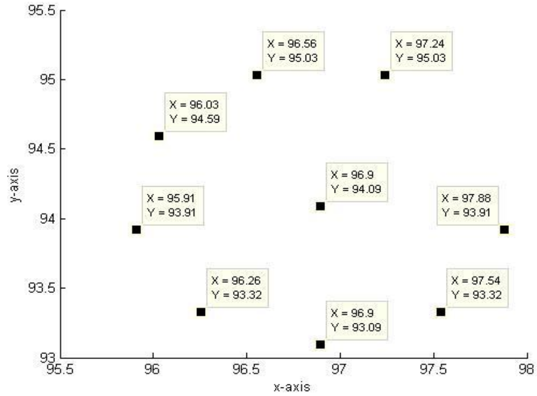

Figure 10. Final position of robots with X,Y co-ordinates of leaders and followers.

V. CONCLUSION AND FUTURE WORK

In this paper, we show the effectiveness of fuzzy controller on tasks like point to point tracking and forming a formation between leader and follower robots verified by simulation results. The controller is based on simple *if* and *then* rules.
The future research work will focus on extending the simulation results to more general applications such as employing real time continuous path tracking and maintaining formation between leader and follower robots taking into consideration of robot dynamics, model uncertainties and noise.

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