

Motion Coordination for Swarm Robots

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Abstract—In this paper describes motion coordination of swarm robots using Interval Type-2 Fuzzy Logic Controller (IT2FLC). In this experiment utilize three identical robots with different color. Every robot has three infrared sensors, two gas sensors, 1 compass sensor and one X-Bee. A camera CCD in the roof of robot arena is utilized to determine the position of each robot with color detection methods. Swarm robots and camera are connected to a computer which serves as an information center. From the experimental results the IT2FL algorithm is able to control swarm robots coordination, produce smooth trajectory without collision.

Keywords; swarm robots; IT2FLC; motion control

I. INTRODUCTION

An extensive literature exists that describes the results concerning the motion coordination problem. In [1] presents different *behaviors* of each robot for finding different solutions. Based on local sensing, each robot moves according to three different terms and their stability analysis is discussed. The work of [2] describes mobile agent networks with an algorithmic coordination approach for making the agents converge without losing the connection with their neighbors. In [3,4] describe surveys recent developments in distributed motion coordination algorithms in terms of modeling, analysis, and design of for multi-robot systems. In [5] presents only using local interactions, a team of robots converge to the boundary of regular shapes by using decentralized control strategy. In [6] propose flocking for multi robots system via the Null-space-base behavioral control, flocking behavior is analyzed in a variety of conditions.

Distributed motion coordination behavior can be achieved using three simple behaviors: namely *collision avoidance* to keeps the individuals away from each other avoiding collisions, *velocity matching* to match the velocity of an individual with its neighbors and *flock centering* to stay close to its neighbors [1]. It is assumed that the initial distribution of robots is arbitrary and distinct.

Lately, the many type-1 fuzzy logic control controller (T1FLC) which consists of linguistic control rules is a technique to design motion coordination controller based on human expert knowledge and experience [7-9]. However, only few of existing results have been presented to solve the problem of this behavior in multi-agent systems based on interval type-2 fuzzy logic controller (IT2FLC) [10-12]. This paper aims to investigate the motion coordination control base

on IT2FLC, where the problem of collision avoidance and flock centering are considered.

II. SWARM ROBOTS

Swarm robotics system is a new approach of the coordination of large numbers of relatively simple robots. Basically, these systems try to employ a large number of simpler agents to perform different types of tasks, oftentimes inspired by their biological counterparts. The swarm shares information about the environment and individual members interact with each other, therefore a distinction between the sensing and the communication network is made.

In the swarm, one or a few robots act as leaders which move along predetermined trajectories and other robots in the group follow while maintaining the desired relative position with respect to the leader, the ability of a robot depends on its task [13-16]. Generally leader-follower-based robot systems are implemented as centralized systems.

However, most leader-follower approaches are not complete algorithms because the safe path, that which gives a robot sufficient distance from obstacles and other robots, is difficult to derive. In order to obtain a safe path for all robots in unknown environment, IT2FLC algorithm is developed to maintain the swarm formation and avoid collision in complex environment.

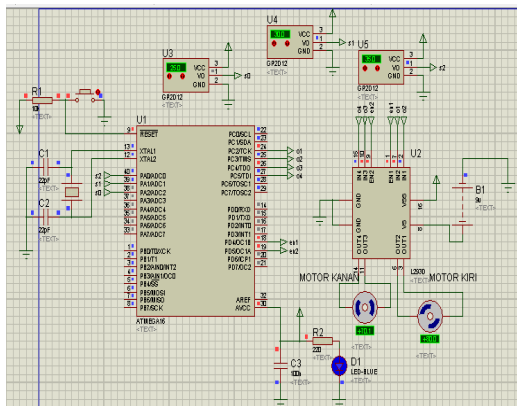
Swarm robots must manage a large array of sensory information to determine environmental situation. Fuzzy systems are known the popular linguistic rules based knowledge acquisition machine, it is highly desirable to represent the human thinking to utilize the domain knowledge to create autonomous strategies for controlling the mobile robot plan. By using fuzzy logic, each sensor provides some input about the world around the robot; that input being incorporated into a membership functions (MFs). From this MFs, appropriate rules about output actions taken in response to input are generated. These rules allow the robot, to interact with its surroundings in a way that hopefully achieves some goal.

III. EXPERIMENTAL SET-UP

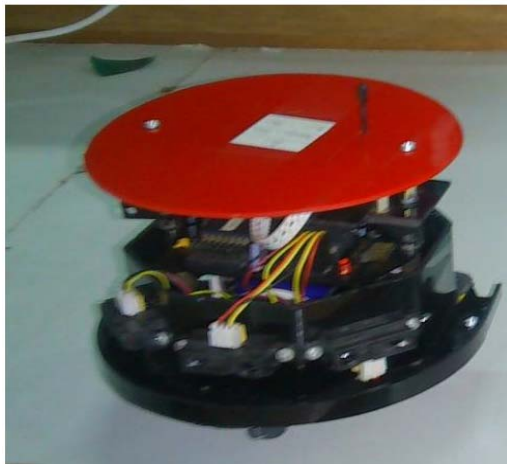
A. Swarm Robot Design

Single robot design shows in Figs 1 (a) and (b). The robot simulation is conducted using Proteus Simulator software with three inputs from infra red sensor. On the real

robot infra red sensor 1 is set at 25 cm, sensor 2 is set at 30 cm, and sensor 3 is set at 35 cm. While pulse width modulation (PWM) to control motor output is calculated for producing stable movement. In this work, left motor PWM is set only 80% and right motor PWM is set only 70 %.



(a) Single robot design



(b) robot with on-board collar
Fig. 1. Robot platform

Swarm robots have the ability to move in the real environment. In this experiment the swarm robots with circular shape have diameter is 15 cm and height is 17 cm. The robot uses three wheels which two behind wheels of robot functions are as a controller which one wheel that can move freely. Both robot's wheel is connected with dc motor an as well as connected with a motor driver that can be controlled using PWM. In the swarm robots design, Li-Po battery is used with a capacity of 1300 mA 12V.

Block diagram control of swarm robot connection can be seen in Fig. 2. CCD camera is developed for tracking and detecting swarm robot position or their orientation. Its resolution is largely determined by the resolution of the CCD camera and the optical system. In the experiment, the CCD camera is mounted on a bracket fixed on the ceiling. Due to the limitation of ceiling's height, the viewable area on the test bed is of 2 m by 3 m. To identify the robot's position and orientation, a color pad is attached on the top of a robot as shown in Fig. 1(b). The center of each circle can be calculated

through the image processing hardware and software. Coordinates of the the color circles is used to calculate the position of the centers of the robot's center and its orientation as well. The hardware connection for multi-robot communication as shown in Figure 2. The CCD camera has a resolution of 480 by 360 pixels. The x and y coordinate to the vision system is designed for calculating the real resolution.

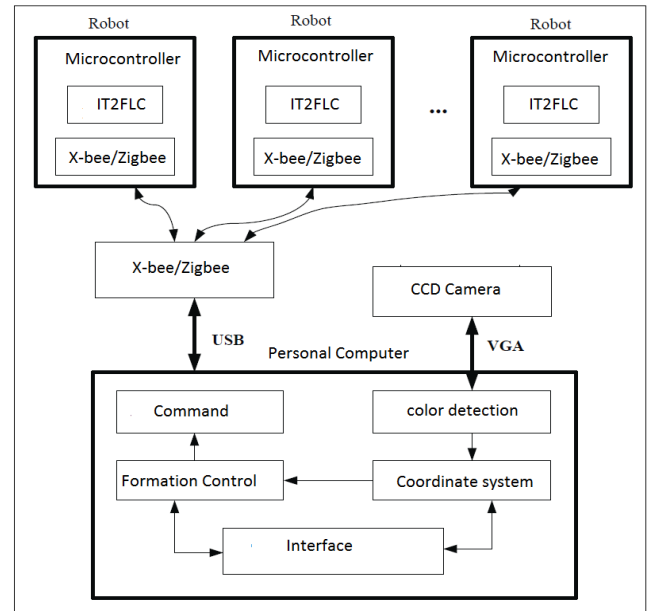


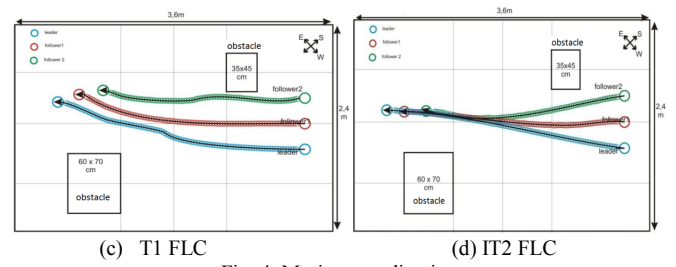
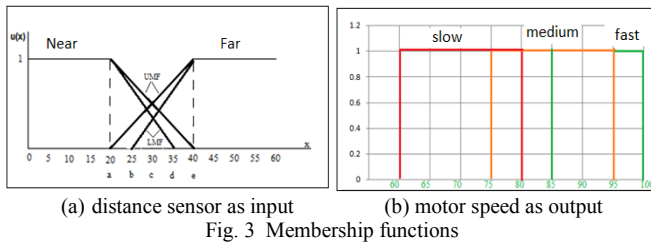
Fig. 2. Swarm robot design

Communication between robot using X-Bee/Zigbee protocol, they also connected to the central computer for collecting the experimental data. For controlling all the existing systems on the real robot platform, microcontroller ATmega16 is used as embedded controller. IT2FLC is designed using C ++ language and compiled with code vision AVR software.

B. IT2FLC Design

Unlike Type-1 Fuzzy Sets (T1FSs) where the membership grade is a crisp number in [0,1], Type-2 Fuzzy Sets (T2FSs) are characterized by fuzzy MFs. However, in general, T2FLS produce computationally overhead [17]. To simplify the computation of T2FLS then become the Interval Type-2 Fuzzy Logic System (IT2FLS) which can easily to determine [18].

In this work the implementation of IT2FLS design, each antecedents have two membership functions (MFs), that is far and near. Both are trapezoid formed of MFs, as depicted on Fig 3 (a). The number and form of each MFs of antecedents cannot be changed, but the parameter for each set can be modified. The data paramteres of input MFs and output MFs as shown in Figs 3(a) and (b). The MFs and rule base parameters are the basic criteria of mobile robot performance. The MFs is made from sensor detection relation to motor output of swarm robots.



The IT2FL rule bases are determined by the number of the fuzzy MFs. The rule bases are used to control the motor speed as shown in table 1.

TABLE 1. RULE'S TABLE

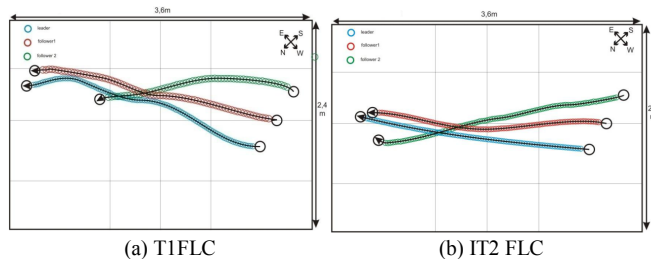
| Rule | Sensor | | | Speed Reference | |
|------|-----------|------------|------------|--------------------|----------------|
| | Left (S1) | Front (S2) | Right (S3) | Motor 1 | Motor 2 |
| 1 | Near | Near | Near | slow* condition | fast*condition |
| 2 | Near | Near | Far | Fast | Slow |
| 3 | Near | Far | Near | Slow | Slow |
| 4 | Near | Far | Far | Medium | Slow |
| 5 | Far | Near | Near | Slow | Fast |
| 6 | Far | Near | Far | Fast | Slow |
| 7 | Far | Far | Near | Slow | Medium |
| 8 | Far | Far | Far | Fast | Fast |

Before defuzzification stage, the IT2FL sets resulted from the previous step has to be reduced first called "type-reduction". Type-reduction (TR) represents a mapping of a IT2FSs into a ITFSs. The type-reduced set is always an interval set and is determined by its left end points $y_l(x)$ and right end points $y_r(x)$. In this works, the type reduction is center of sets (CoS), where reduced set value is comprises of y_l and y_r , which is the approach of inferencing result midpoint. Karnik-mendel iterative algorithm is utilized to determine y_l and y_r [17]. Finally, the output of defuzzification step of IT2FLS is obtained by averaging the values of y_l and y_r obtained from type reduction step,

$$y = \frac{y_l + y_r}{2} \quad (1)$$

IV. EXPERIMENTAL RESULTS

The experiments are conducted in our robotic laboratory with environmental space about 1.5 x 2.1 m. There are several obstacles in the environment. In this experiment, three identical robots with different color move together towards a predetermined to find target position. The target position is gas source from artificial source in the environment.



In Figs. 4 (a), (b), (c), and (d) respectively, shows swarm robots control experimental results in two environment with obstacle and without obstacle. From Fig. 4 There are stable and smooth movement by using IT2FLC compare to T1FLC. Robot follower have the ability to follow the leader in small distance without collision eachother. The trajectory of three robots as shown in Figs. 4 (a), (b), (c) and (d) with IT2FLC are keeping the position and direction with a certain distance to the leader but with T1FLC leader position far to follower position. The motion coordination formation using IT2FLC algorithms generate a satisfactory performance compared to algorithm T1FLC. If follower detects out one obstacle in this protected, it will turn a small angle to avoid the direction of this obstacle and then it will turn an angle which is necessary to keep the formation as shown in Fig 4 (c) and (d).

In this work no centralize control if one robot detects a target, then the control system will send a signal in the form of color and positions of robot. From the result, the swarm robots move in the group without collision, keeping safe distance each other and the pathways taken to convergen at the target locations.

V. CONCLUSION

This paper presents swarm robots design with IT2FLS algorithm as the navigation control. The experimental results show that the proposed IT2FLS algorithm produce smooth trajectory and they capable keep the robots movement in the group without collision. In the future works, we want to combine this technique with particle swarm optimization and will apply this platform with several sensors gas as target. The swarm robots will be implement in unknown environment with some source target and complex obstacle.

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