Target Localization With Fuzzy-Swarm Behavior

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***Abstract*—In this paper describes target localization using deliberates fuzzy and swarm behavior. Localization is the process of determining the positions of robots or targets in whole swarms environment. To localize the target in real environment, experiment is conducted 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 in the roof of robot arena is utilized to determine the position of each robot with color detection methods. Swarm robots are connected to a computer which serves as an information center. Fuzzy and swarm behavior are keeping the swarm robots position and direction with a certain distance to the target position. From the experimental results the proposed algorithm is able to control swarm robots, produce smooth trajectory without collision and have the ability to localize the target in unknown environment.**

Keywords— swarm robot, IT2FLC, motion control

I. Introduction

Swarm robotic system first introduced in [1]. This is a novel approach for coordination of large numbers of robots. It is inspired from the observation of social insects such as ants, termites, wasps and bees, which stand as fascinating examples of how a large number of simple individuals can interact to create collectively intelligent systems [2-4]. The concept of swarm behavior is based on local sensing of neighborhood. They emerges in the system even if no group leadership, hierarchical control and global information are present [5-7].

Single operation of intelligent robot commonly used expensive autonomous mobile robots [8]. On the other hand, swarm robots consists of a large number of homogenous autonomous relatively incapable or inefficient robots [9]. 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. The main advantages of swarm robotics are robustness, flexibility and scalability of the system [10].

This system can be applied in areas, where the use of a single robot is insufficient. The specific applications can be search and rescue operations, dangerous environment exploration or surveillance. For instance, during a search and rescue operation the robotic swarm is deployed in the target environment.

II. Swarm Robots Localization

Swarm robotics system need a 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 to reach the target. In this situation, swarm robot localization should be conducted to support efficient goal directed performance. It can facilitate navigation between points of interest without having to introduce additional nodes.

Localization is the process of determining the positions of robots or targets in models of the environment and aids in the navigation of both individual robots and whole swarms [11]. However, a difficulty associated with conducting localization processes with swarm robots systems is that these systems usually are highly decentralized which makes it hard to synthesis and access global maps, which in turn decreases its flexibility. Unless some centralized mechanisms also are integrated into the system [12].

Some localization technique using vision based self-localization technique that can be used by individual robots in swarm robots systems is described in [13], include the particle swarm optimization (PSO) based techniques that are presented in [14], and neural network [15]. However, this approach does not ensure efficient goal directed behaviour. Centralized mechanishm must be use to syntesise and accest global map to support goal directed navigation. To overcome that drawback, in this paper fuzzy behavior navigation strategies deliberates with swarm behavior. It's facilitate the centralized mechanisms that are necessary for conducting flexible localization tasks to ensure that swarm robotic system is robust towards failure of any one individual.

The proposed algorithm deliberates the fuzzy control from low-level navigation tasks such as formation keeping, obstacle avoidance and reaching the target. At the same time the swarm behavior is covering a large area of the searched environment, thus leading to a faster localization of possible target. The controller works as an adaptive intelligent mechanism and improves the maneuvering performance of the swarm robots.

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.

Lately, many of 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 [16-18]. 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) [19-21]. This paper aims to investigate the swarm robot localization problem base on IT2FLC, where the problem of collision avoidance and target seeking are considered.

III. EXPERIMENTAL SET-UP

A. *Swarm Robot Design*

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. Swarm robot experimental situation shown in Fig. 1.

Fig. 1 Swarm robots experiment

Camera is used for tracking and detecting swarm robot position or their orientation. Its resolution is largely determined by the resolution of the camera and the optical system. The 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. In the experiment, the 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. The center of each circle can be calculated through the image processing hardware and software. Coordinates of the centers of the the color circles is used to calculate the position of the robot's center and its orientation as well.

The hardware for multi-robot as shown in Figure 2. Communication sytem betwen swarm robots using X-Bee, 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.

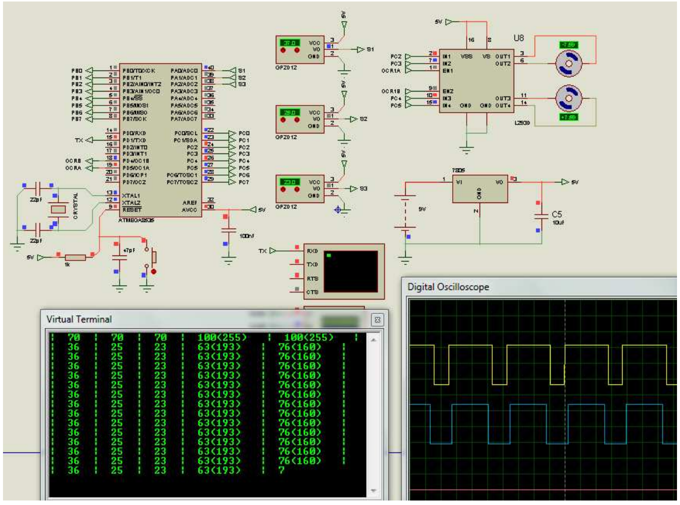
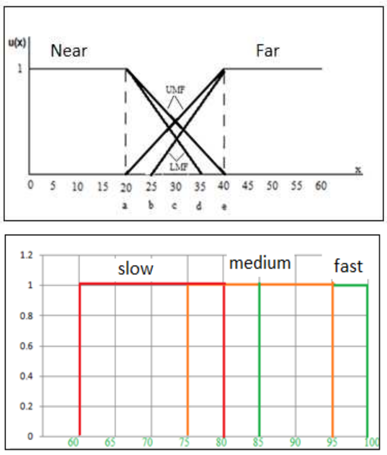


Fig. 2 Swarm robot design

B. *Fuzzy behavior Design*

Fuzzy system employ a mode of approximate reasoning that makes them a suitable tool to implement a robust robot behavior tolerating noisy and unreliable sensor information [16]. The fuzzy rules describe the relation between the external and internal states of the robot and the set of possible actions. To date all the fuzzy logic system (FLS) implementation in robot control are based on the traditional type-1 fuzzy logic sytem (T1FLS). The most common way is to construct the FLS by eliciting the fuzzy rules and the membership functions based on expert knowledge or through the observation of the actions of a human operator controlling the mobile robot.

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 [22]. To simplify the computation of T2FLS then become the Interval Type-2 Fuzzy Logic System (IT2FLS) which can easily to determine [23]. 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.



(a) distance sensor as input (b) motor speed as output
Fig. 3 Membership functions

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 perfomance. The MFs is made from sensor detection relation to motor output of swarm robots. The fuzzy 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.

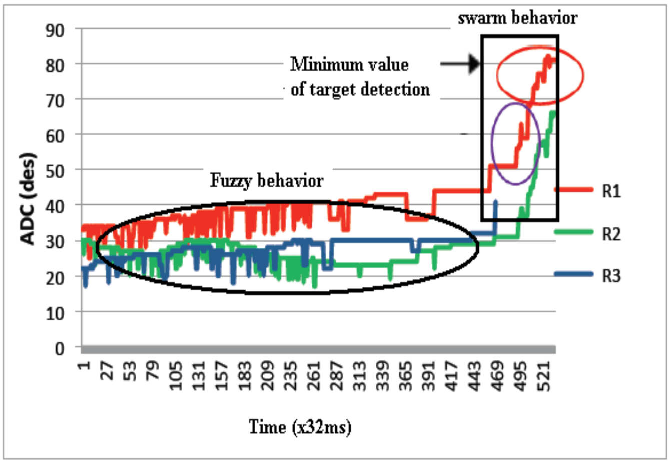
TABLE 1
RULE'S TABLE

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

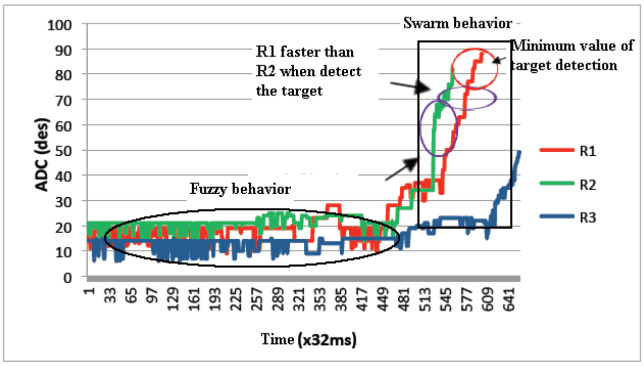
Before defuzzification stage, the IT2FL sets resulted from the previous step has to be reduced first called "type-reduction". Type-reduction (TR) represents a mapping of a IT2FSs into a ITFSs. The type-reduced set is always an interval set and is determined by its left end points $y_l(x)$ and right end 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 [22]. 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.

IV. EXPERIMENTAL RESULTS

The experiments are conducted in our robotic laboratory with environmental space about 1.5 x 2.1 m. 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.



(a) Target localization in experiment 1



(b) Target localization in experiment 2
Fig. 4 Target Localization use deliberates fuzzy swarm behavior

In Figs. 4 (a) and (b) respectivelly, shows experimental results of swarm robots motion in two environment with obstacle and without obstacle. In such environment the swarm robots are keeping the position and direction with a certain distance to the target position. In this work deliberate centralize control with swarm behavior and fuzzy behavior, it means the swarm behavior active if one robot detects a target, then the control system will send a signal in the form of color and positions of robot. When the target source not in range swarm robots move with fuzzy behavior. From the result, the target localization using fuzzy-swarm behavior algorithms generate a satisfactory performance, 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 deliberates fuzzy and swarm behavior for target localization. The experimental results show that the proposed algorithm produce smooth trajectory, it capable keep the robots movement in the group without collision and have the ability to localize the target in simple algoritm. 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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