Swarm Robots Control System based Fuzzy-PSO

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***Abstract*—In this paper describes swarm robots control design using combination Fuzzy logic and Particle swarm optimization algorithm. They can communicate with each other to achieve the target. Fuzzy Logic technique is used for navigating swarm robots in unknown environment and Particle Swarm Optimization (PSO) is used for searching and finding the best position of target. 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 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 Fuzzy-PSO algorithm is able to control swarm robots, achieves the best target position in short time and produce smooth trajectory**

***Keywords*—component; swarm robots; fuzzy-PSO; control**

I. INTRODUCTION

Robots have been used for numerous applications where human intervention is not feasible. In radioactivity detection, environmental monitoring and land mine detection, the robots need to be dispensable. The building of intelligent robot with a number of sensors for various parameters may be able to achieve the tasks but expensive. However, if the robot failure in that task, it's to be costly. A team of small, inexpensive and dispensable robots can be utilized for such areas in lower cost but increase reliability. A large number of robots allow for redundancy and increase the robustness [1]. A swarm of intelligent mobile robots are desirable for target search applications mainly because the remove the need for human intervention in inhospitable areas [1-2].

In recent years, a lot of research is focused on swarm robotic applications [1-5]. Especially in search applications it have some advantages such as, larger coverage of the search space, simplicity of implementation, distribute workload among its member, carry out a large number of tasks simultaneously with simpler robots and greater fault tolerance [3,4,5]. Based on the research [1,2] about target searching, there are at least three stages to find the target, such as (1) searching the target, (2) tracking toward the target, and (3) declare a discovery targets. Currently has a lot of research performed on the swarm robots to achieve the target in dangerous area. Targets are achieved by the swarm robot is a target that cannot be achieved by human. To find the target, robot must be equipped by sensors that can detect a particular target [1].

Before reach the target, the mobile robot will declare its discovery by providing information such as the estimation of target position. Estimation of target position can save travel time of swarm robots movement. Furthermore, the movement of other robots must be able to navigate well in several of unknown environments [2]. This paper proposes an algorithm to solve the problem of designing behavior of the mobile robot for reaching the target by using combination Fuzzy Logic and Particle Swarm Optimization (PSO) algorithm or Fuzzy-PSO.

II. SWARM ROBOTS

Swarm robotics system is a new approach for coordination a 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 leader that moves 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 [3,4,5]. Fuzzy logic control algorithm which consists of linguistic rules is a technique to design controllers based on human expert knowledge and experience [6]. However, only few of existing results have been presented to solve the problem in multi-agent systems use fuzzy logic system [7,8,9].

Furthermore, in order the robot achieve the target, it also need a system that can guide the robot towards the target. One of method that can be applied for robots to search the target is particle swarm optimization (PSO). The advantage of using the PSO approach is that the number of robots is large, accommodating for the failure or destruction of a few robots without compromising the end goal [10]. This method is based on mathematical operations in primitive computational and not complex in terms of speed processing and memory utilization. The algorithm is very simple; it can be implemented in just a few lines of code [10]. This method is imitated the ability of animals looking for food sources. Each individual in PSO will be considered as a particle [11] in the case of a swarm of robot, robot that represents the particles and the target position represents the available food sources.

III. Experimental Set-Up

A. Fuzzy-PSO Agorithm

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. Fuzzy inference system embedded the control rules is applied successfully in several applications areas, especially in solving complex modeling, tracking or control mobile robot problems, while it is very hard to describe the robot plan's mathematic model.

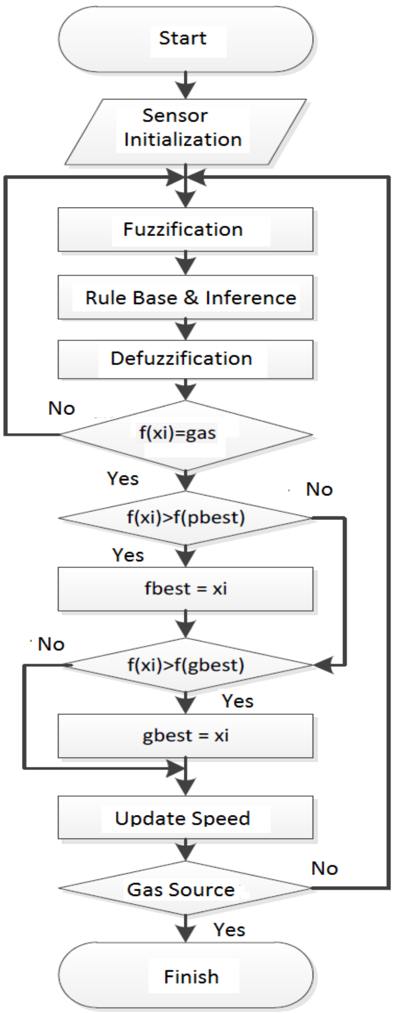


Fig. 1. Flowchart of Fuzzy-PSO algorithm

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. They will search for the best position that can be achieved with different circumstances. In this situation they need search system for finding the best target position. PSO is used with Fuzzy logic to achieve the target in unknown environment. Fig. 1 shows the general flowchart of the fuzzy-PSO algorithm is applied to the swarm robots. Mobile robot speed changes in each time iterations based on sensor detection. In this work fuzzy logic algorithm is used when the gas sensor not active and robot moves in unknown environment. If the gas sensor is active then swarm robot move utilize fuzzy-PSO algorithm.

In this situation, it needs the modification of the fuzzy-PSO algorithm for swarm robots with target position [12,13]. The process of PSO algorithm is initialized with a group of random particles (solutions), *N*. The i_{th} particle is represented by its position as a point in an S-dimensional space, where *S* is the number of variables. Throughout the process, each particle i monitors three values: its current position (x_i), the best position it reached in previous cycles (p_i), its flying velocity (v_i). These three values are represented as follows,

Current position $x_i = (x_{i1}, x_{i2}, ... , x_{is})$
Best previous position $p_i = (p_{i1}, p_{i2},...., p_{is})$ (1)
Flying velocity $v_i = (v_{i1}, v_{i2},...., v_{is})$

In each time interval (cycle), the position (p_g) of the best particle (*g*) is calculated as the best fitness of all particles. Accordingly, each particle updates its velocity v_i to catch up with the best particle *g*, as follows,

$$v_i^{k+1} = w_i * v_i^k + c_1 * rand * (p_i^k - x_i^k) + c_2 * (p_g^k - x_i^k) \quad (2)$$
$$x(k+1) = x(k) + v(k+1) \quad (3)$$

As such, using the new velocity v_i, the particles updated position becomes, where c_1 and c_2 are two positive constants named learning factors. rand() and Rand() are two random functions in the range [0, 1], v_{max} is an upper limit on the maximum change of particle velocity, and *w* is an inertia weight employed as an improvement proposed by Shi and Eberhart to control the impact of the previous history of velocities on the current velocity. From equation (2), it can be stated that the speed of the robot will continue to decrease in all iteration and eventually reach the condition where the robot stops moving. The simple pseudo code of equation (2) and (3) is described in Fig. 2.

```
for each particle i
if f(xi) >f(pbest) then
pbest ←xi
end if
if f(xi) >f(gbest) then
gbest ←xi
```

end if
end for
For each particle i

$$v_i^{k+1} \leftarrow w_i * v_i^k + c_1 * rand * (p_i^k - x_i^k) + c_2 * rand * (p_g^k - x_i^k)$$

end for
finish

Fig. 2. Pseudo code of PSO Algorithm

B. *Swarm Robots Design*

Block diagram control of a single robot can be seen in Fig. 3, each robot has 3 infrared sensors, 2 gas sensors and 1 compass sensor. Communication betwen robot using X-Bee with 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. Fuzzy-PSO controller is designed using C ++ language and compiled with code vision AVR software.

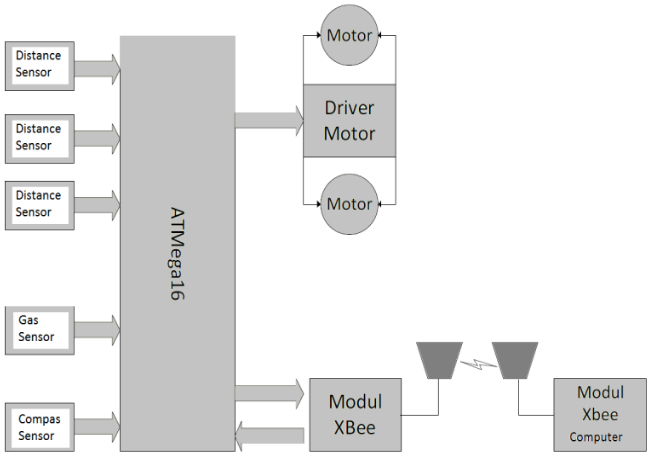


Fig. 3. Swarm robot design

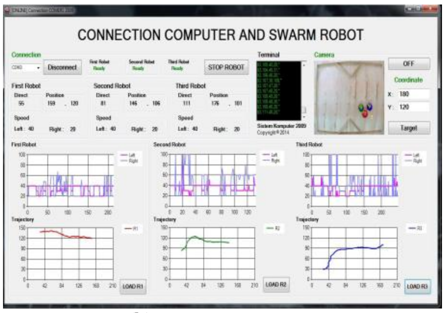
Swarm robots have the ability to move in the real environment. In this experiment the swarm robots with circular shape have diameter is 15 cm and height is 17 cm. The robot uses three wheels which two behind wheels of robot functions are as a controller which one wheel that can move freely. Both robot's wheel is connected with dc motor an as well as connected with a motor driver that can be controlled using pulse width modulation (PWM). In the swarm robots design, Li-Po battery is used with a capacity of 1300mA 12V. Fig. 4 shows the real swarm robots are used in the experiment.

Fig. 4. Real swarm robots

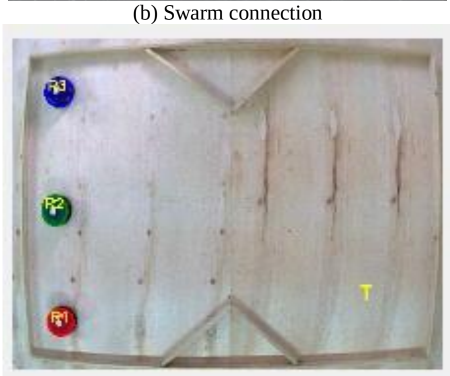
IV. Experimental Results

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.

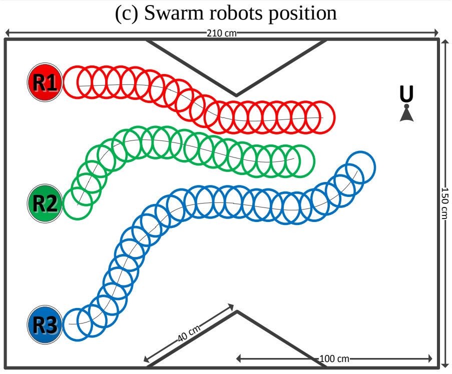
(a)Camera Control



(b) Swarm connection



(c) Swarm robots position



(d) Swarm robots trajectory

Fig. 5. Swarm robots experimental results

In Figs. 5 (a), (b), (c), and (d) respectivelly, shows swarm robots control experimental results. There are three identical robots with different color that communication each other use X-Bee/Zigbee. The camera on the roof is used to control the movement of the three robots and to determine the leader robot by using color identification as shown in Fig 5 (a). From Fig. 5 (b), shows swarm robots connection and communication. The mobile robot speeds in the form of a percentage of PWM value. If one robot detects a target, then the control system will send a signal in the form of color and positions of robot. For example, in this experiment first robot become a leader because it find the source target fast, at point 214 data compared with two other robots. From experimental data base, second robot find the target at point 226 amount of data and third robot find the target at point 248 amount of data. Fig 5 (c) and (d) describes that swarm robots movement reached a predetermined target position at coordinates x = 180 and y = 120.

Another result shows in Fig. 6, presents the starting locations of the swarm robots to achieve the gas source. By using PSO, a number of robots are randomly move into specific area, one new position of swarm robots is calculated for each particle per iteration. When the coordinates of the target are known the swarm robots use a coordinates as a fitness function to analyze the status of their current position. While Fuzzy logic only use when the target not detect. From the result, the swarm robots move in the group without collision, keeping safe distance each other and the pathways taken to converge at the target locations.

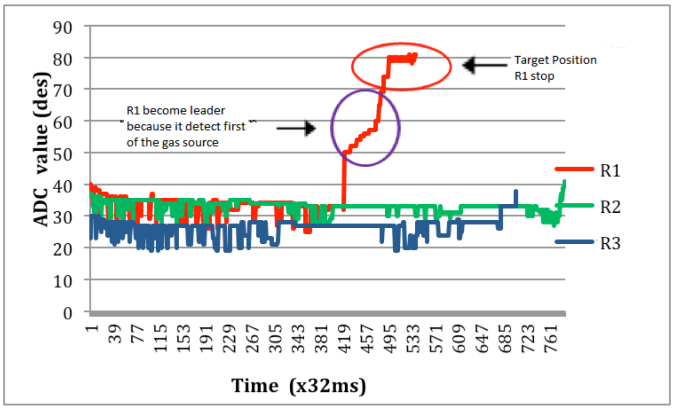


Figure 6 Swarm robots action with Fuzzy-PSO

V. Conclusion

This paper presents swarm robots design with Fuzzy-PSO algorithm as the navigation control. The experimental results show that this proposed algorithm is able to move closer to the target position, produce smooth trajectory and they capable keep the robots movement in the group without collision. In the future works, we want to apply this system with several sensors gas as target and the swarm robots will be implement in unknown environment with some source as a target.

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