SWARM ROBOT IMPLEMENTATION IN GAS SEARCHING USING PARTICLE SWARM OPTIMIZATION ALGORITHM

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SWARM ROBOT IMPLEMENTATION IN GAS SEARCHING USING PARTICLE SWARM OPTIMIZATION ALGORITHM

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ABSTRACT

In this reseach, a PSO method is impelemented in searching a gas leakage. A swarm robot consisted of 3 agents, yelow, blue, and green, was used. The research was done in 2 type of experiments, i.e. in simulation and real expeiment. A Matlab is used as a simulation validation while for the real experiment, a 2 x 2 m arena is used. From the experiment, it can be concluded that a good performance of a swam can be achieved using PSO method.

Keywords: *Swarm Robot, Gas Leakage, Particle Swarm Optimization (PSO)*

1. INTRODUCTION

The use of various types of gases in everyday life contributes to the increasing of the comfort in human life. However, the increasing is also followed by the hazardous enhancement due to carelessness in using them [1]. Gas will be useful if it is controllable and used properly. Nugraha in [2] stated that besides giving some advantages, the use of the gas will also cause a negative impact to humans and the surrounding [2]. The gas is very susceptible to fire hazards; therefore, to get a high level of safety, it should be noticed carefully. For an industrial one, the safety should be paid attention starting from the production until the delivery process to the customers.

Commonly, gas leakage handling consists of two stages, i.e., detecting and looking for the sources of leakage [3]. In practical situation, gas leakage can be detected conventionally by using the eyes, nose, or ears. However, the conventional techniques are not always reliable. It is due to the sensitivity level of person senses is different. Moreover, not all gases have odor or color. In addition, only high-pressure leakage can produce sound within the human auditory range [4].

Along with the development of science, various efforts have been developed to solve the problems of gas leakage. Utilization of robots to sniff out gas leakage is one of studies that were conducted since 1990s. Robots implementation doesn't take risk to the human life [5]. Researchers created the "sense of smell' in robots, such as the sense of smell in organism to know whether there was a gas leakage or not [6]. Some researchers was successful developed the prototype of the robot in detecting the source of gas leakage [7].

In recent years, some researchers used swarm robots as gas leakage searchers. Swarm robot is a relatively new field. Most of the researchers focused in controlling a number of homogeneous systems of robots. This system was used to develop robotic behavior with small and simple modules size. Swarm robots have several advantages compared to individual robots that have comparable capabilities. The simplicity of each individual in swarm robots offers an easier and cheaper implementation. Another advantage of swarm robots is larger coverage area than individual robots, due to distributive intelligence [8][9][10]. The concept of swarm intelligence is the main target that is implemented in the final result with generic application domains. Therefore, the method of Particle Swarm Optimization (PSO) algorithm is really suitable in controlling swarm robot.

Particle Swarm Optimization (PSO) algorithm is one of the algorithms which has been tested and successful in searching gas sources with the restrictions of the algorithm. PSO was adapted from the animal habits that move in its colony to look for foods. In its development, the PSO algorithm has been modified into various methods to solve the problem of gas leakage that was closer to reality such as an unstable wind direction and more than one gas leakage source [11][12].

Jatmiko [13] in his research, managed to create a single gas source detection system through PSO modifications. He added the detection and response methods, used charge robot and applied wind in his research. However, in real world case, the amount of gas leakage that occurs in one region is not only comes from one hole, so that the research results are still needed to be developed by the next researcher.

In this research, Particle Swarm Optimization will be implemented in two experiments, i.e. i. Simulation and ii. real experiment. In simulation, a MATLAB program will be used while in real experiment, a conditioned room will be occupied. In this research, the robots and the agents have the same meaning, therefore, the term robots and agents are used interchangeably.

2. PARTICLE SWARM OPTIMIZATION (PSO)

Particle Swarm Optimization (PSO) was first introduced by R.C. Eberhart and J. Kennedy in 1995 [14]. This algorithm is made by imitating animal techniques in finding food sources in groups. In PSO concept, any animals or agents would be considered as a particle. According to its creator, the PSO algorithm is a very simple algorithm because it requires only primitive mathematical operations and it is not computationally 'expensive', either in memory usage or processing. In addition, the PSO paradigm can be implemented in just a few lines of codes. In searching gas sources, robots will be considered as PSO particles [15]. For updating the velocity and position, PSO will use Equation (1) and (2). The new position was got by summing the current particle position with its velocity.

$$X_i(t) = X_1(t), X_2(t), \ldots, X_N(t) \quad (1)$$
$$V_i(t) = V_1(t), V_2(t), \ldots, (t) \quad (2)$$

Where:
X : Particle position
V : Particle velocity
i : Particle index
t : Iteration (t)

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N : Space of dimension

PSO is one of evolutionary computing techniques, in which the population in PSO is based on algorithmic search. It begins with a random population that is called a particle [16]. Unlike other evolutionary computing techniques, every particle in the PSO is also associated with a velocity. These particles move through space searching with a dynamic velocity adapted according to their historical behavior. Therefore, the particles have a tendency to move to a better searching area after passing through the searching process [17].

Although, PSO searching has similarities to the Genetic Algorithm (GA) that starts with a random population in matrix form, however, the PSO does not have an evolutionary operator, such as a crossover and a mutation in GA. The line in the matrix that is occupied by PSO is called a particle or in a GA as a chromosome that consists of the value of a variable. Each particle in PSO moves from its original position to a better position with a velocity [18].

In PSO algorithm, the velocity vector is updated for each particle and then adds the velocity vector to the particle position. The velocity update is influenced by the two solutions, namely: 1. Global best that is associated with the lowest value obtained from a particle, and 2. Local best solution that is associated with the lowest value in the initial population. If a local best solution has a value that is less than the value of an existing global solution, then the local best solution replaces the global best solution.

TABLE 1.
Comparison of some PSO methods

No.	Techniques	Advantages	References
1.	Particle Swarm Optimization (PSO)	Easy to implement	[5], [8], [14]
2.	Modifcation Particle Swarm Optimization (MPSO)	Have a better response than PSO	[2], [3], 9]
3.	Fuzzy-PSO	Efficient in its use	[15], [19], [20], [21]

There were a lot of researchers have investigated PSO that was applied in searching gas leakage. Table 1 shows the comparison performance of several PSO methods. As stated before, PSO technique is easy to implement. It is due to in the concept of this technique; each agent shares information about best position to other agents and adjusts their position and speed based on information received.

Table 1 also shows that the response in Modified Particle Swarm Optimization (MPSO) was better from PSO method. Modified Particle Swarm Optimization was good in searching many sources. Compared to PSO, it was more reliable in searching multiple sources. However, it was implemented only in simulation.

In fuzzy-PSO technique, the fuzzy logic method was used to control agent movement [19][20]. There were also some studies that used fuzzy logic methods as decision makers in classifying and identifying gas leakage [21]. Meanwhile, to determine the position of the robot and regulate the movement of robots during gas sources localization, a PSO algorithm was used.

The simplicity of the algorithm and its good performance makes the PSO has attracted a lot of attention among researchers and has been applied in various optimization issues [22]. PSO has become a popular global optimization in solving problems that has real number variable [23]. Some common terms that are used in PSO can be defined as follows:

1. Swarm: population of particles.
2. Particle: member or individual of a swarm. Each particle represents a potential solution for the completed problem. The position of a particle is determined by the representation of the solution at that time.
3. Personal best: personal best position of a particle that shows the position of the particle prepared to get the best solution.
4. Global best: best position of particle in swarm or best position among existing personal best.
5. Velocity: a vector that drives an optimization process that determines the direction in which a particle is required to move to improve its original position or speed.
6. Inertia weight: this parameter is used to control the impact of velocity given by a particle.
7. Learning rates (c1 and c2): a constant for assessing the ability of particle (c1) and social swarm capabilities (c2) that indicate the weight of the particle on its memory.

3. EXPERIMENTAL SETUP

3.1 BLOCK DIAGRAM

From the block diagram shown in Figure 1, it can be explained that the gas-searching robot has several important parts, including the inputs, the outputs, the controller, and the driving parts. In the input section, gas detection robot works using 12V input supplied from a 1000 Mah battery. The battery will give voltage to motor driver, so that it can activate the DC motor. Before supplying voltage to Arduino MEGA 2560, firstly, the voltage should be lowered to 5V through DC to DC Converter. It is due to the input voltage of Arduino MEGA 2560 is 5V.

For controling the movement, the gas-searching robot uses Arduino MEGA 2560 and raspberry PI 3 type B as controllers. In this research, the usage of 2 different controllers was intended to speed up the searching process. In this case, the Arduino MEGA 2560 works to control the sensors, such as ultrasonic sensors, TGS sensors, rotary endoder, and compass HMC5883. Raspberry PI 3 type B has function to process the data from gas sensors, TGS 2600, TGS 2602, and TGS 2620.

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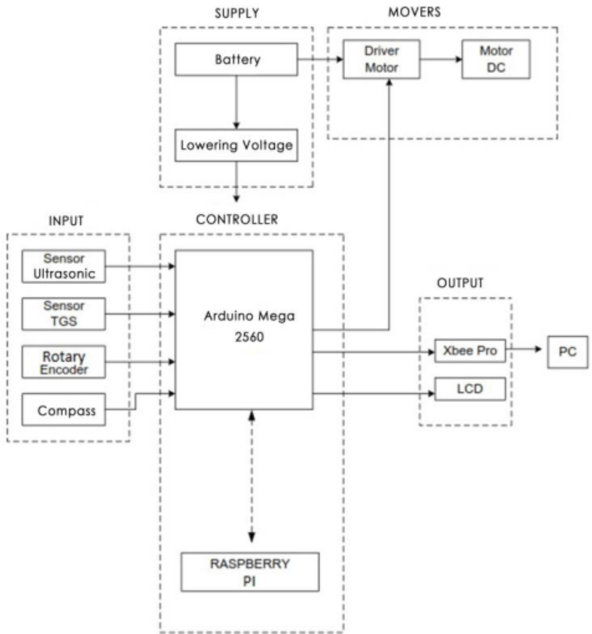

FIGURE 1. Block Diagram of gas searching robot

In the output part, there are 2 components, i.e. Xbee Pro S2 and LCD 16x2. Xbee Pro is a serial wireless interface that connects one microcontroller with other microcontrollers through wireless communication. This serial communication can reach 1.6 km outdoors. The main reason why Xbee Pro was chosen as wireless serial communication in this research was because it has low power consumption, which is only 3.3V. Xbee Pro was used to deliver the predicted results performed by the gas-searching robot to the server. The LCD was used as a display on the gas-searching robot.

3.2 FLOWCHART OF PARTICLE SWARM OPTIMIZATION (PSO) ALGORITHM

The PSO method in this research was started by a ‘start’ command. When the robot was turned on, the robot will observe the surrounding in order to monitor the existence of a gas leakage. When there was a gas leakage, the robot will start to search the gas source. However, when the robot did not find any gas leakages, the robot would still observe the surrounding until it found the gas leakage.

When one of the robots has detected the existence of gas, it would go to the gas source, and the other robot would follow it until the gas leakage source was found. This is the point why the Particle Swarm Optimization (PSO) algorithm was used,

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i.e. the robot communicated one another and notified the position of the gas leakage. The flowchart of PSO Algorithm can be seen in Figure 2.

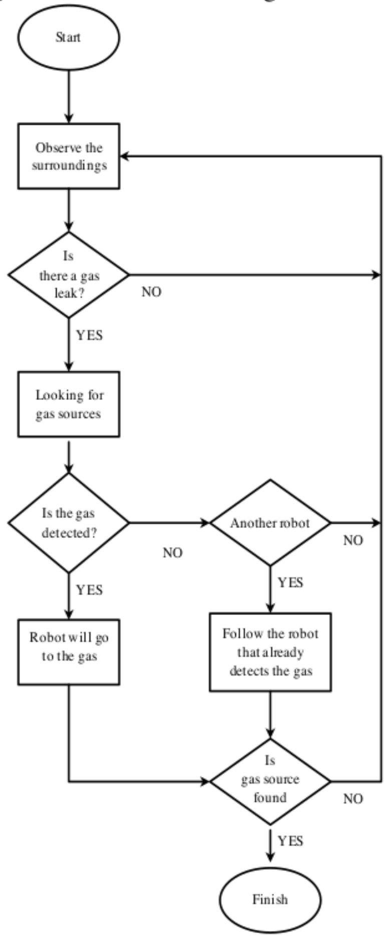

FIGURE 2. Flowchart Particle Swarm Optimization (PSO) Algorithm

4. RESULT AND DISCUSSION

4.1 SIMULATION ANALYSIS

One of the advantages of PSO algorithm is its convergence; it means that all particles will move toward a certain point after some times. This feature is the searching benchmark that indicates the particle has finished their task.

If all the particles are convergent, then there are no existence possibilities of other gas sources in the searching area. Another advantageous feature of this convergence is the PSO can employ many agents in searching. The more agents, the more areas can be monitored; this leads to the sooner of gas finding. The convergence feature of PSO tends to make the searching agents move closer to a particular area and reduce the agent to run oversight area.

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Each agent has its own ability to find the best value (gbest) and the best solution (pbest). Agents can move on their own, based on speed, position, and distance. The Particle Swarm Optimization algorithm is shown in Equation (3) and (4).

$$V_i(t) = V_i(t-1) + \underbrace{C_1 r_1 (P_{best,i} - X_i(t-1))}_{\text{Individual}} + \underbrace{C_2 r_2 (G_{best} - X_i(t-1))}_{\text{Global}} \quad (3)$$

$$X_i(t) = V_i(t) + X_i(t-1) \quad (4)$$

Where
X= Particle's position
V = Path direction
i = Particle index
t = Iteration (t)
C_1 = Weight of local information
C_2 = Weight of global information
P_{best} = Best position of particle (Global best)
G_{best} = Best position of swarm (Personal best)
r1, r2 = Random variable

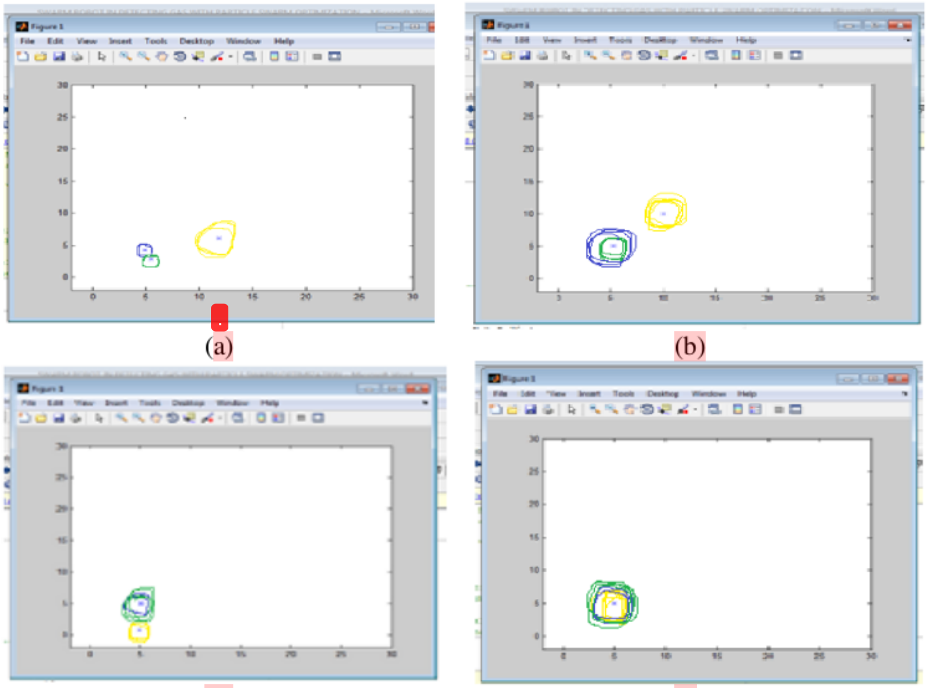
In MATLAB simulation, 3 agents, namely: green, yellow, and blue, were required as identifiers. Each of them was given 1000 times interaction in order to make efficient the gas searching. The positions of gas source, i.e. the value of horizontal axis, X, and the vertical axis, Y, were set as 5. By using the concept of the PSO, agents communicated one another to know the best value and position in their respective positions.

In the 1st second of the particles spreading, the blue agent was at coordinate (4.5), the green agent was at (4.4), and the yellow agent was at (7.13). The simulations in this second can be seen in Figure 3.a.

In the 2nd second, the green and blue agents have reached the minimum source at coordinate (5.5), while the yellow agent was at (10.10) and was still looking for the minimum coordinate of the source. Simulation at this 2nd second can be seen in Figure 3.b

In the 3rd second, the green and blue agents were still at the minimum position of the source, i.e. at the coordinate (5.5), while the yellow agent was near to the source, at (0.5). Figure 3.c shows the simulations of the 3rd seconds

In the 4th second, each agent has reached the minimum source coordinate, at (5.5). The testing results of this second can be seen in Fig. 3.d



(a) (b) (c) (d)

FIGURE 3. Simulation of the 3 agents using PSO method. (a) T=1s, (b) T= 2s, (c) T= 3s, (d) T= 4s

4.2 REAL EXPERIMENT

In this research, a room 6x6 meters were used as searching area. An area of 2x2 meters was set up in this room. 1 gas source was placed in one of the arena's corner. 3 agents (yellow, green, and blue) were used as the particles of the PSO algorithm. These 3 agents can be seen in Figure 4.

At the initial time of deployment, each agents and source were placed in different positions. The situation of the deployment can be seen in Figure 5.a.

In the first of 5 seconds, each agent began to move to search the gas source. Each agent moved randomly and sought the best position (see Figure 5.b and Figure 5.c).

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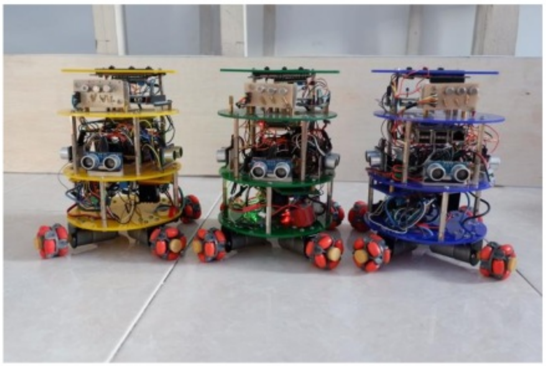


FIGURE 4. The swarm robots; yellow, green, and blue agents

In the 6th to 10th second, the blue agent was in the maximum position to the source, while the green agent and yellow agent were still looking for the source location (Figure 5.d).

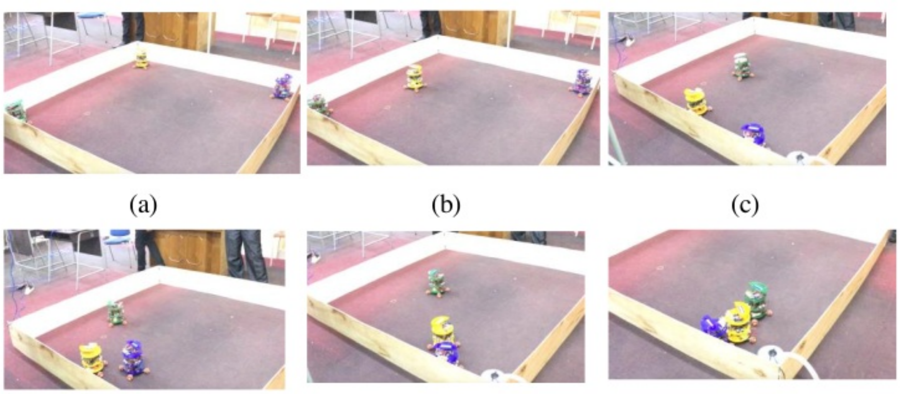
At the initial time of deployment, each agents and source were placed in different positions. The situation of the deployment can be seen in Figure 5.a.

In the first of 5 seconds, each agent began to move to search the gas source. Each agent moved randomly and sought the best position (see Figure 5.b and Figure 5.c).

In the 6th to 10th second, the blue agent was in the maximum position to the source, while the green agent and yellow agent were still looking for the source location (Figure 5.d)

In the 11th to 15th second, the blue and the yellow agent have reached the maximum point of the source, while the green agent was still looking for the source position. Figure 5.e shows the situation of 11th to 15th second of searching.

In the 16th to the 20th seconds, the green agent position has also reached its maximum point. Thus, each agent has found the maximum point of the gas source (Figure 5.f)



(a) (b) (c)

(d) (e) (f)

FIGURE 5. Real Experiment

5. CONCLUSION

Based on the final result obtained in this research, it can be concluded that swarm robot optimization with Particle Swarm Oprimization (PSO) method showed good performnace in searching the gas leakage. The swarm robot was successful finding the source of leakage by utilizing the communication among the individuals robots of the swarm. The experimental results also showed that each agent could be a leader interchangeably. The Particle Swarm Optimization (PSO) algorithm was capable to lead the agents to approach the predetermined target positions. The speed control using this algorithm produced smooth and dynamic movement changes. In the real experiment process in searching the gas target, the swarm robot has managed to perform a stable group behavior without any collision among robots

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