Particle Swarm Optimization (PSO) for Simulating Robot Movement on Two-Dimensional Space Based on Odor Sensing

K. A. M. Annuar[1,2], Irianto[1], M. H. Harun[1,2], M. F. M. A. Halim[1,2], I. M. Saadon[1,2], N. A. Rahman[1]
[1]*Fakulti Teknologi Kejuruteraan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.*
[2]*Centre of Excellence in Robotic and Industrial Automation, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.*
khalilazha@utem.edu.my

***Abstract*—Nowadays, researches in robotic field have grown increasingly. There are several types of research categories in the field of robotic. Recently, one of the famous research works recently was odor sensing. Within the technology that grows rapidly, this topic has become an interest among researchers. An odor sensing is not only applied in the medical field, but it has also been widely used in the industry. The gradient of concentration of an odor is measured by diluting some amount to reach the threshold of an odor. This paper focused on the implementation of the Particle Swarm Optimization (PSO) method based on odor sensing in two (2) dimensional space. However, it only discusses and focuses on applying in ideal condition. An ideal condition here means that there is no disturbance included in this simulation. The main idea of this paper was to observe how the particle agents make the movement based on concentration by applying the PSO method. The real sensor cannot be implemented in this simulation because the value of concentration is measured due to the distance from the particles agent to the goal of agents. Higher gradient concentration is shown at the shorter distance to the goal. The contributions in this paper are mainly to create an algorithms model by using Particle Swarm Optimization (PSO) to calculate the paths of movement of mobile robot until they reach the goals (source of odor) with respect to the concepts of odor sensing.**

***Index Terms*—Particle Swarm Optimization; Odor Sensing; Simulation Robot Movement.**

I. INTRODUCTION

In the field of robotic engineering, an odor sensing localization becomes increasingly well-known amongst researchers [1-3]. Methods, such as neural network method [4], colony algorithm [5] method and others are adopted in odor sensing localization. In the industry, machine gas technology combined with mobile robot technology is used to search and track the path for odor localization to determine the position of odor source. The role of odor sensing technology has become important, especially in the industry exposed in hazardous workplace.

An odor sensing detects the position of the source odor by making sense of the concentration of material intended to be measured. To run in the mobile robot simulation, numerous algorithms can be applied on it [6]. This paper concentrates on how the simulating mobile robots find their paths to the goal by making sense the concentration of chemical odor. The goal will be set as the cause of the odor. The particle agent will find their paths according to concentration until they reach the goals. Meanwhile, exchange the information will occur among them to reach the goals. Generally, this scenario will happen when the Particle Swarm Optimization (PSO) is applied on it [4].

The objective of this paper is to study and use the Particle Swarm Optimization technique in the simulation on how a mobile robot reaches to its goal, such as the source of odor by gradient concentration in the concept of odor sensing. Then, the simulation of the movement for mobile robots paths using PSO in two-dimensional space in scratch programming software is conducted.

This paper is organized as follows. In Section II, a review of the previous work related to this research is presented. In Section III, the methodology to develop a movement mobile robot simulation based on odor sensing with PSO technique is presented. The results presented in Section IV are drawn from the simulation of the proposed algorithm conducted in three situations. The first situation focuses on the position of mobile robot agent that was arranged in groups to move them to the goal agent. The second situation involves focusing on the individual mobile robot agent arranged randomly to move to the goal agent. The third simulation involves the mobile robot simulation of agent placed in separate position. Finally, our work of this paper is summarized in the last section.

II. PROBLEM BACKGROUND

Several problems concerning mobile robot odor detection in various environments such as diffusion-dominated fluid flow, turbulence dominated fluid flow have been reported.

The motivation of this research is to implement the mobile robot simulation in odor sensing by applying the technique of Particle Swarm Optimization (PSO). This technique has been widely used in robotic research field because it is easy to understand and apply [7-8].

Research on odor sensing has always been increasing nowadays. Odor localization is a behavioral problem that varies from an animal to animal. While some animals exploit fluid information at different layers or several residues on the ground, others can track odors in the air or use a combination of information [9-10].

From the engineering perspective, there are advantages to combining odor tracking with mobile robots, such as detection of chemical leaks and chemical mapping of hazardous waste sites.

As reported in previous research by G.C.H.E. de Croon et al., several algorithms are created for the task of odor source localization with applied evolutionary robotics (SI) approach [11]. The application of this approach was applied in turbulent odor plume in three sub-tasks. By using multi robots, Jianhua Zhang et al. used niching PSO method on localizing multiple odor sources [12]. Based on the simulation, the result showed that the proposed method is effectiveness to simultaneously localize multiple odor sources.

There is an increased number of research in odor sensing in the field of robotic application. A well-known subject of research, biological odor localization and tracking have been made in moths, rats and other animals. They used the olfaction sense to finding other species, searching for the food, avoiding predators, and communicating among them. Odor localization is generally presented in the behavior of animals. Usually, an odor sensing is applied to security, food quality control, gas leakages and others [13].

This analogy can be applied in robotics field application. From the field of engineering, an odor localization concept can be applied to sense any chemical in work environment [14]. It involves risk, which is the source of dangerous substances and detecting the chemical that can be harmful for human health.

This project aimed to implement the Particle Swarm Optimization (PSO) into the mobile robot movement simulation based on odor sensing. Because the implementation cannot be done with real environment, the gradient of concentration will be assumed in terms of the distance of agent. The gradient of concentration becomes lower when it is near to the goal agents in term of distance. In this case, the higher the concentration, the lower the distance to the goal of agent.

The source of odor is detected by the gradient of concentration of the molecules in the air. In the simulation, an algorithm model is used to calculate the concentration movement of mobile robot to the goal (source of odor) in the environment for two-dimensional space. The agents (mobile robot) will continuously make a movement until they meet the source of odor that has higher concentration of molecules.

III. METHODOLOGY

To develop the movement of mobile robot simulation based an odor sensing with PSO method, there are several software that can be used to design the agent (mobile robot simulation), such as Matlab, R programming, Scicos Lab and Scratch software. After that, the PSO method is used to analyse the mobile robot simulation denoted as agent to find their goal denoted as the source of odor used for getting the results.

A. Designing the Mobile Robot Agents and Goal Of Agent

In this stage, about 10 mobile robot agents simulation and 1 goal of agent were designed in a scratch programming software, as shown in Figure 1. In the scratch programming software, all agents are choosen directly from the given sprite.

B. Coding Development

After designing the mobile robot that is denoted as an agent (sprite) and source of odor denoted as the goal in Scratch, the algorithm of PSO is applied in it. There are several steps of algorithm PSO that must be followed to implement it into this simulation. The steps in PSO method are as followed:

1. Initialize the random position and velocity and local best position, p_best and global best position g_best.
2. The next step is to update the fitness function of the particle velocity by using Equation (1).

$$v_{i+1} = \omega v_i + c_1 r_1 (p_{best} - x_i) + c_2 r_2 (g_{best} - x_i) \quad (1)$$

3. Next, the particle position is updated using Equation (2).

$$x_{i+1} = v_{i+1} + x_i \quad (2)$$

4. If the current fitness value is better than the previous value, the value will be updated.
5. The step in (b) will be repeated until it finds the objective function. The objective function in this project research is the highest concentration of odor.

In this simulation, the concentration is defined by the distance of mobile robot agents from the goal of agent. This is because the real sensor cannot be synchronized in this simulation. In the concept of odor sensing, the higher concentration is detected when the agents are closer to the source of an odor.

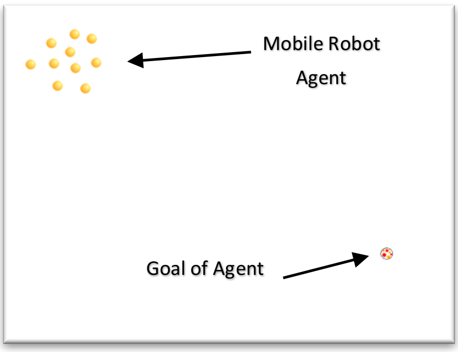

Figure 1: Designing of agents in Scratch

IV. SIMULATION RESULTS & DISCUSSION

This section discusses the result of the simulation. It has several data including the value of the positions of agents, and the concentrations of odor. The nearest agents to the goals has the higher gradient of concentrations.

The result of data were drawn from three (3) situations. First, the position of the mobile robot agent was arranged by grouping them to move to the goal agent. In the second situation, the position of mobile robot agent was arranged randomly without any group as they move to the goal agent. The third situation is the simulation of mobile robot agent is placed in separate position.

A. Position of mobile robot agent was arranged by grouping

For the first situation, the goal of agent has been set in one position to observe the movement of 10 mobile robot agents that have been initialized and arranged in groups. After the simulation is conducted, the result shows that about 32 iteration of mobile robot made a random movement to find their path to the goal of agent.

Based on Figure 1 and Figure 2, the data were taken based on the position of agents and the concentration of agents. From the value of the concentration of agents, the gbest is denoted by the lowest value among the agents. The data are shown in the table below as initial position and final position in Table 2 and Table 3 respectively. The bold value in the table shows the value of the gbest in each iteration.

Figure 2: Initial condition of agents

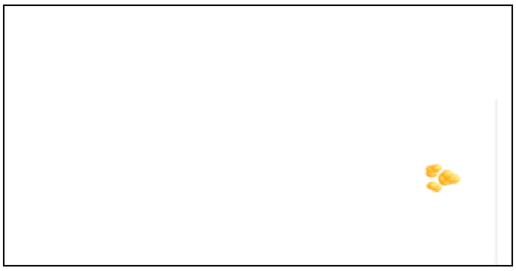

Figure 3: Final condition of agents

Table 1
Initial condition

Agent	Position of goal		Position of agent		Concentration
	x-position	y-position	x-position	y-position	
1	**192**	**-59**	**-160.5**	**143.5**	327.91179
2	192	-59	-197	156	444.072066
3	192	-59	-169.5	148	472.001059
4	192	-59	165.5	-181.5	457.386598
5	192	-59	162	-183.5	461.524647
6	192	-59	-157.5	156.5	438.755057
7	192	-59	-176.5	150.5	423.516824
8	192	-59	-197	165	464.486814
9	192	-59	-214	132	448.206426
10	192	-59	-183.5	139.5	446.838897

Table 2
Final condition

Agent	Position of goal		Position of agent		Concentration
	x-position	y-position	x-position	y-position	
1	192	-59	180.5	-44.5	18.721645
2	192	-59	180.5	-71.5	15.572412
3	**192**	**-59**	**189.5**	**-62.5**	2.915476
4	192	-59	191.5	-53.5	10.511898
5	192	-59	175.5	-52.5	24.052027
6	192	-59	194.5	-57.5	4.301163
7	192	-59	176.5	-68.5	19.557607
8	192	-59	198.5	-59.5	17.734148
9	192	-59	175.5	-46.5	38.451268
10	192	-59	187.5	-58.5	3.807887

B. Position of mobile robot agent was arranged by randomly

For the second situation, the position of all mobile robot simulation agent were placed randomly different from the first situation that have been placed in group. The result was taken to show that all the mobile robot simulation agent exchanged their information to find their path towards goal of agent. Figure 4 shows how the all agent were arranged.

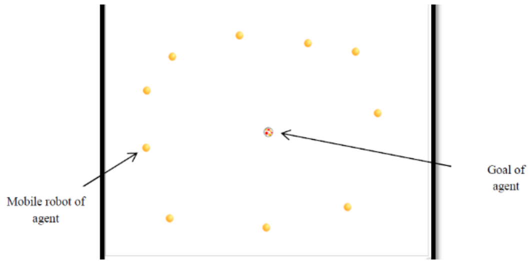

Figure 4: Initial condition of agents in second position

The situation taken to show that all the agents move to find their path among them, and after that they find the path to the goal of agent. This condition proved that all the particle agent exchanged their information when PSO is applied on it based on the criteria of basic function PSO. Before they went towards to the goal agents, they were moved by grouping together. The movement of each iteration was recorded as shown in Table 3 and 4 below.

Table 3
Initial condition

Agent	Position of goal		Position of agent		Concentration
	x-position	y-position	x-position	y-position	
1	17	-18	61	121	139.129436
2	17	-18	6	-132	172.904598
3	17	-18	-10	-126	190.373317
4	17	-18	-3	24	165.221064
5	17	-18	1	-154	183.881755
6	17	-18	6	-127	158.61904
7	17	-18	-41	132	143.589693
8	17	-18	13	-155	191.031411
9	**17**	**-18**	**-1**	**-140**	135.033329
10	17	-18	5	-122	178.600112

Table 4
Final condition

Agent	Position of goal		Position of agent		Concentration
	x-position	y-position	x-position	y-position	
1	17	-18	2	9	14
2	17	-18	4	7	12.165525
3	17	-18	12	-6	10.049876
4	17	-18	24	3	18.788294
5	17	-18	-9	1	127.251719
6	17	-18	4	-2	13
7	17	-18	-6	7	14.422205
8	17	-18	12	0	11.18034
9	17	-18	-4	6	12.529964
10	**17**	**-18**	**10**	**0**	9.433981

From five iterations, it shows that the movement of all agent were move to be in group and after that they find the path to move to the goal of agent. The marked color at the concentration shows the value of gbest in each iteration of agent. The value of the concentration becomes lower when it is near to the goal of agent due to the distance.

From both situations that were recorded, it can be seen that where ever the position of goal being setted, all the mobile robot agent simulation were followed as it was the objective function that has been declared. All of the mobile robot agent simulation continuously find the path to their goal (source of odor) as long they did not reach it.

C. Position of mobile robot agent was arranged randomly (separate position)

The last data was taken from the third situation. This time the particles of mobile robot agent was placed separately, as shown in Figure 5 below. The position of the goal agent was changed. The third simulation proved that whenever the goal of agents was placed at changing position, all of the particle mobile robot agents still find the paths to follow the source of agents.

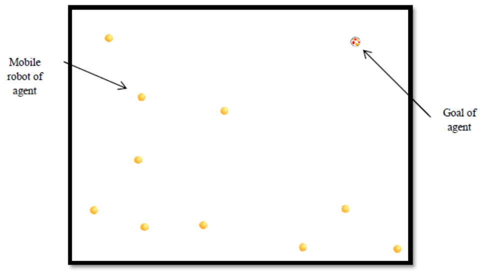

Figure 5: Initial condition of agents in third position

Table 5 and 6 show the data of its iteration. This time, the particle mobile robot agent take about 17 iteration to reach the goal of agents. As in the previous data result, the marked value were the gbest value.

Table 5
Initial condition

Agent	Position of goal		Position of agent		Concentration
	x-position	y-position	x-position	y-position	
1	163	137	-41	36	352.03551
2	163	137	-130	28	352.03551
3	163	137	-38	62	315.065073
4	163	137	-34	-117	239.409691
5	163	137	-145	-35	353.073647
6	163	137	-21	-100	444.083326
7	**163**	**137**	**-22**	**35**	211.589225
8	163	137	-23	-148	340.195532
9	163	137	-28	31	301.822796
10	163	137	84	-145	303.415557

Table 6
Final condition

Agent	Position of goal		Position of agent		Concentration
	x-position	y-position	x-position	y-position	
1	163	137	166	118	16.03122
2	163	137	161	143	9.848858
3	163	137	159	134	6
4	163	137	103	98	71.693793
5	163	137	160	136	5.385165
6	**163**	**137**	**162**	**131**	4.242641
7	163	137	158	147	14.764823
8	163	137	167	130	4.472136
9	163	137	159	131	6.708204
10	163	137	151	140	15.231546

V. CONCLUSION

Based on the result, this paper presented three (3) situation to observe the movement of mobile robot simulation agent. As recorded in position 1, the particle agents took about 32 iteration to reach their goal of agents as in initial position as captured in Figure 2 in Section 4. All the agents took a movement not exactly at random because they actually move towards the goal agent based on the information from the gbest and pbest value function. Different from position 2 (Section 4.2), the mobile robot simulation agents has been set their position separately. This condition was to prove that all the particles exchanged their information to find their path based on the objectives function and they moved by grouping toward the goal of agent. In other words, although they get the information among them, their movement was without thinking. It means that along their paths towards goal of agents, they did not find the shortest path to reach it. From the cases in this research, it only focused on that the particle agents that can move independently without any interruption from outside factors. Other than that, the implementation of the PSO technique in this research aimed to achieve their objective function. This research is limited only in its ideal condition (no disturbance, for example wind). In other words, a research that includes dynamic environment, that means the space of condition contains outside factors.

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