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PSO Based Path Planning Strategy in Manufacturing Plants with Unknown Environmental Criteria

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Abstract: In the present era, mobile robots have been widely used in industrial sectors for transferring goods/tools from one place to another with in the manufacturing plant. It is a challenging task to develop an efficient motion planner of a mobile robot, if the robot is moving in unknown environments. Hence, the current research work aims at developing an intelligent motion planning strategy using particle swarm optimization in order to transport the goods within the manufacturing plant. Finally, simulation results have been presented to validate the efficiency of the proposed algorithm.

Keywords*:* Mobile robot, motion planning, unknown environment, PSO, Artificial Intelligence.

1. Introduction

Path planning is one of the vital research interests in the field of robotics. It is impossible to perform tasks properly by robots without an efficient path planning [1]. In the past, huge amount of work has been devoted towards the development of intelligent path planners for mobile robot navigation using various artificial intelligence techniques [2-4].

Few researchers concentrated on genetic operators for mobile robot navigation in unknown environments [5-6]. They used crossover and mutation operation to find the best suitable robot action while the robot is navigating. Another biological inspired algorithm namely, Artificial Immune Systems (AIS) successfully implemented for developing an intelligent motion planning strategy [7, 8]. Clonal selection and immune network theories are the popular tools that have been used widely for path planning of autonomous mobile robot.

Apart from the biological inspired techniques, swarm intelligence has been implemented for mobile robot navigation [9-11]. Ant Colony Optimization [9] has been implemented to solve mobile robot path planning problem by calculating the pheromone concentration as the objective function. Particle Swarm Optimization [10, 11] has been implemented considering the objective function as distance from the robot to its target position.

The past works dealt with the known environments of partially known environments. But, the autonomous guided vehicle moves in the manufacturing plant without the known information about the environments while reaching to desired position. Hence, the current study focus on the development of a motion planning strategy for a mobile robot which can move in the manufacturing plant without prior knowledge about the environment.

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2. PSO Structure

PSO is one of the popular swarmintelligence techniques which are inspired from fish schooling or bird flocking nature. The number of birds or a group is flocking to reach the food destination, each individual communicates with others for deciding next best position to be moved.

Let us assume there are n number of birds (known as particles) in the swarm. Each bird in the swarm has individual position and velocity as represented in equation (1).

$$\left.\begin{array}{l}\{\hat{X}\} = \{x_1, x_2, \dots, x_n\} \\ \{\hat{V}\} = \{v_1, v_2, \dots, v_n\}\end{array}\right\} \quad (1)$$

Assume a particle i.e. p^{th} bird in a swarm which has its initial position and velocity as x_p and v_p as represented in Figure 1.

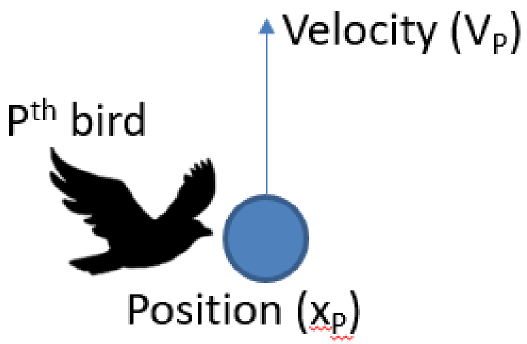

Fig.1 Position & Velocity representation

Now the bird tends to move to its best position which is known as position best (P_{best}) as shown in Figure 2. This $P_{best}$is known as individual best position for the particular bird. Since there are n number of particles in the swarm, there will be n number P_{best}values corresponds to each bird.

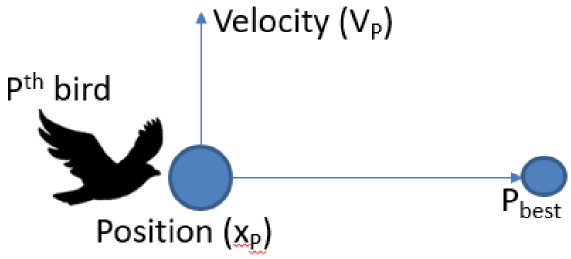

Fig.2 Position best representation for an individual bird

The same way all the particles in the swarm tend to move to their corresponding best positions. However, after communicating among the swarm of particles with their best position of each individual, they finalise one global best position as represented in Figure 3.

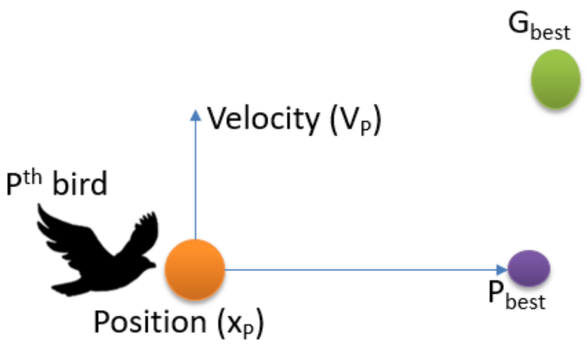

Fig.3 Global best representation

Thereby, each individual update its velocity to $\{\hat{v}_p\}_{i+1}$by updating its position $\{\hat{x}_p\}_{i+1}$ while approaching towards the G_best position as represented in Figure.4

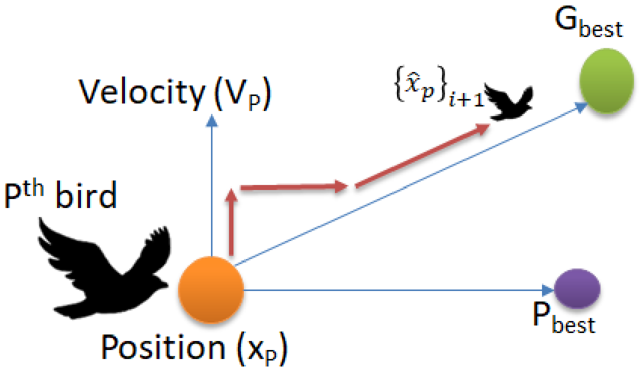

Fig.4 representation of Updated Position

The position and velocity of the p[th]particle are updated from i[th] iteration to (i+1)[th] iteration as a function of individual position best and global best as represented in equations (2) & (3).

$$\{\hat{v}_p\}_{i+1} = \{\hat{v}_p\}_i + c_1 r_1 \left((\hat{x}_p)_{pbest,i} - (\hat{x}_p)_i \right) + c_2 r_2 \left((Gbest)_i - (\hat{x}_p)_i \right) \quad (2)$$

$$\{\hat{x}_p\}_{i+1} = (\hat{x}_p)_i + \{\hat{v}_p\}_{i+1} \quad (3)$$

Where $r_1 and\ r_2$ are random values

$c_1 and\ c_2$are cognitive or acceleration values

3. Fitness function for Mobile robot navigation

The objective of the study is to optimize the path travelled by the robot within its unknown environment. Hence, a fitness function is to be assigned in terms of distance between robot and target position / cell position in the plant. In the meanwhile, the robot has to avoid the obstacles or the existed manufacturing cells in the environment.

Let us consider,

Robot position = (R_x, R_y)

Target position = (T_x, T_y)

d_{rt} = distance between robot and the target position (d_{rt})

$$d_{rt} = \sqrt{(R_x - T_x)^2 + (R_y - T_y)^2} \quad (4)$$

The aim of algorithm is to minimize the d_{rt}.

i.e. $F \propto d_{rt}$ (5)

Further, the robot has to avoid the obstacles while reaching its target position. In this study, the manufacturing cells which are existed in the environment are treated as static obstacles during the mobile robot navigation.

Therefore, the robot has to maintain more distance when it is sensed any obstacle during its motion.

Let us consider,

Obstacle /cell position = (C_x, C_y)

d_{rc} = distance between robot and the obstacle (d_{rc})

$$d_{rc} = \sqrt{(R_x - C_x)^2 + (R_y - C_y)^2} \quad (6)$$

The aim of algorithm is to maximize d_{rc}.

i.e. $F \propto \frac{1}{d_{rc}}$ (7)

Observing the fitness equations (5) & (7), the final fitness function can be restructuring according to equations (8) and (9).

$$F \propto \frac{d_{rt}}{d_{rc}} \quad (8)$$

$$\therefore F = w \times \left(\frac{d_{rt}}{d_{rc}}\right) \quad (9)$$

Here w is the weighing factor which normalizes the values of distance from the robot to target position and sensed obstacle.

4. PSO Implementation

The proposed algorithm is to be implemented in the unknown manufacturing environments as follows:

Swarm Population (n) = 50

Value of random variables $r_1 = r_2 = 1$

Value of cognitive variables $c_1 = c_2 = 1$

Position and velocity of swarm in i[th]iteration:

$$\left.\begin{matrix}\{\hat{X}\}_i = \{x_1, x_2, \dots, x_n\} \\ \{\hat{V}\}_i = \{v_1, v_2, \dots, v_n\}\end{matrix}\right\} for\ n = 50$$

Algorithm initialization:

Initially the mobile robot checks the environment for its further motion. If the robot not found any obstacles in the environment, it tends to move towards its target position. If the robot detects any objects or manufacturing cells in its sensing range, PSO will be activated. Once the PSO activated, the robot generates a swarm of 50 particles in the sensed range.

At the initial situation, the positions of the 50 particles in the sensing range are equal to the position best value$(\hat{x}_p)_{pbest,1} for\ p = 1\ to\ 50$ of each individual and global best value$(Gbest)_1$ is nothing but the position of particle which has minimum fitness value. Positions and Velocities of all particles will be updated according to equations (2) and (3) from second iteration onwards.

5. Results & Discussion

Various simulation results are presented to validate the proposed algorithm. The simulation is performed in MATLAB 2021 and the program is compiled in the personal computer with i5 generation, 16GB RAM specification.

The manufacturing plant of 400 *400m^2 environment is considered to check the efficiency of the proposed technique. The robot is given the information about its target position in the unknown environment. The robot is tending to move in the manufacturing plant which has 5 manufacturing cells as represented in Figure.5.

Once the robot starts its operation of transferring goods in the environment, it will move towards the target position without any requirement of algorithm implementation. However, the robot generates a swarm in the environment within its sensing range as soon as the robot detects the manufacturing cell. The green path in the Figure.5 represents the robot motion towards the target position and swarm generated by the robot within its sensing range is represented with yellow dots in presence of obstacles in the environment.

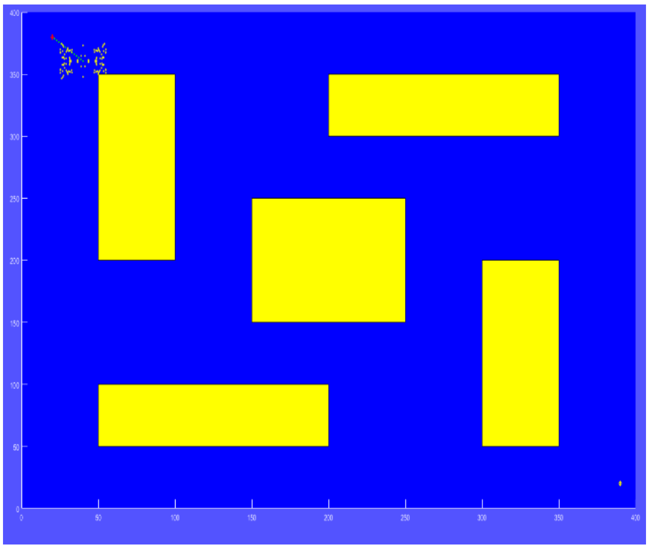

Fig 5 PSO activation and swarm representation

Once the swarm is generated, path planner calculates fitness to determine the $(Gbest)$ value. Then the robot moves towards the position of $Gbest$ until it moved away from the sensed manufacturing cell as represented in Figure.6.

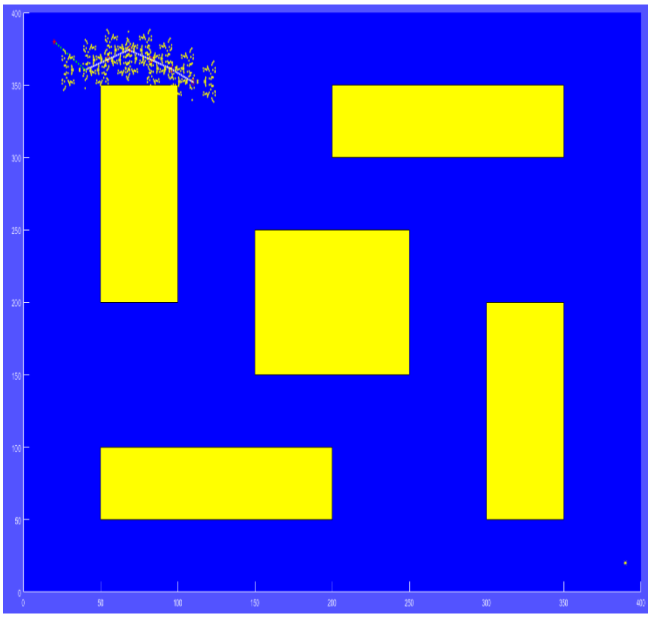

Fig 6. Obstacle avoidance with proposed PSO

Clear image of obstacle avoidance by the proposed algorithm is shown in Figure 7. Red colour '*' represents the robot start position in the manufacturing plant; green path represents the path with no sensed obstacles; yellow '.' represents the generated swarm in the sensing range; red 'o' represents the global best and the white colour path represents robot's motion towards the global best position.

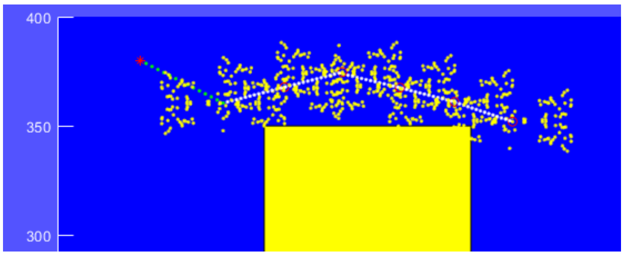

Fig.7 Algorithm implementation and robot path representation

Once the robot is away from the manufacturing cell, again it moves towards the goal position as represented in Figure.8.

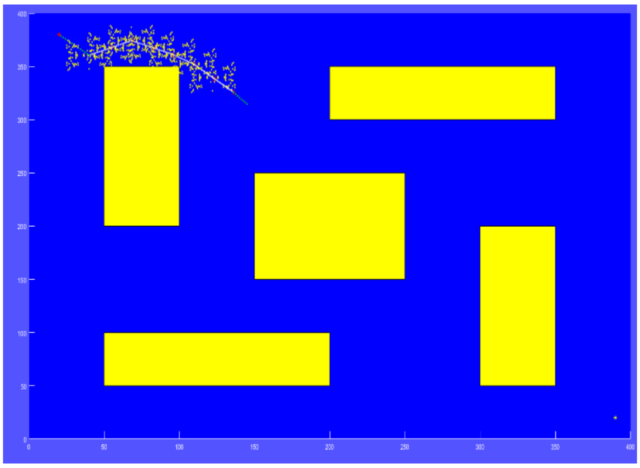

Fig.8 robot path representation with and without presence of obstacles

Similarly, robot tends to move to its target position while halting at the desired manufacturing cells in the plant without prior knowledge of environment. The detailed path of the robot is represented in Figure.9.

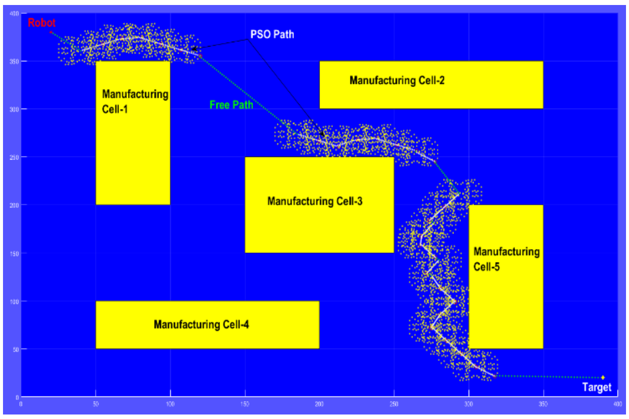

Fig.9 Complete path of the robot for the given manufacturing environment

6. Conclusion

In this study, mobile robot navigation problem for unknown environment has been solved. The robot navigation is achieved with the implementation of artificial intelligence technique known as particle swarm optimization. The swarm intelligence is applied to reach the target position in the manufacturing plant without prior knowledge on the environment. A form of fitness function is developed in terms of distance from robot to target position and obstacle position. Several case studies representing typical manufacturing environments have been considered in order to validate the proposed methodology. As a future work, the proposed methodology is to be implemented in real time environments.

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