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Path Planning for Visually Impaired People in an Unfamiliar Environment Using Particle Swarm Optimization

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Abstract

Exploring a new environment is a huge challenge for the visually impaired. Hence there is a need for a system that is able to assist them safely during their journey. Here, in this paper, we propose a path planning with predetermined waypoints method using Particle Swarm Optimization (PSO) algorithm. This method computes shortest possible path given the predetermined waypoints from initial position to final position. By using predetermined waypoints which is a collection of coordinates along the pedestrian walkaway, a resulting accessible pedestrian path could be offered to the visually impaired. The system consists of a destination selection process and path planning process. For the destination selection process, a list of available places is given and the user will select the places that they want to visit from the list. The path planning process calculates path length between all nodes which includes predetermined waypoints, start point and final destination using Euclidean distance formula. The PSO algorithm will optimise possible shortest route by minimizing the total cost for path length. The simulation analyses of the proposed method have shown promising results of optimal route for different destinations. Results from this paper will be used further to explore the potential development of path guidance system for the visually impaired people by allowing them to travel independently in an unfamiliar environment.

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*Keywords:*Path planning; Particle Swarm Optimization; Visually impaired people; Unfamiliar environment; Path guidance system

1. Introduction

Exploring or visiting places that is unfamiliar and new to visually impaired people is very hard. While normal people will rely on their vision to find the places, they have to rely on their other senses to find the place correctly.

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Due to this reliance, they frequently get lost, returning at the same place over and over again or found themselves at other places instead of their target place. Previously, to cope with this problem, they used traditional white cane or guide dog as a support. However, the advancement of technology enables new ways of navigating people with vision disability. A system where ultrasonic sensor integrated into the cane to detect obstacles on the ground and also mounted on the user's shoulder to detect surroundings obstacles was introduced [1]. Even though the canes are effective to provide obstacle-free safe walkways, they cannot locate a user's destination. Other than that, indoor navigation system that utilize the technology of visible light communication [2] and for the outdoor navigation, Global Positioning System (GPS) technology that integrate together with Geographic Information Systems (GIS) [3].

Nevertheless, a survey on current existing navigation system for visually impaired people shows that the system have yet achieve large scale exploitation [4]. The survey highlights various navigation technologies based on their practical usefulness, design and working challenges. The result obtained is mainly due to several factors such as unaffordable cost, accuracy and usability. Therefore, in this paper we propose a PSO based path planning computation in unfamiliar environment. This research serves as the initial stage in order to develop path guidance system for the visually impaired people which assists independent walking of them.

There have been various methods introduced by researchers to solve path planning problem. The main requirement of the optimal path planning is finding a minimum length path from starting node to target node together with free collision path. Two popular heuristic-based algorithm for shortest path computation are Dijkstra and A* algorithm [5]. These two algorithms successfully give the optimal path for various research on path planning problem. For example, path planning method using Dijkstra's algorithm for indoor environment to navigate visually impaired people [6] and also the combination of Dijkstra and Floyd algorithm to develop path planning for mobile robot in life science laboratories [7]. However, there are disadvantage to this approach as it consuming a lot of time and becomes inefficient when the dimension of the problem is very big.

There are also numerous research works have been successfully conducted using artificial intelligence techniques to solve the path problems such as genetic algorithm (GA), PSO, ant colony optimization(ACO). The use of basic PSO and multi-objective PSO to solve the vehicle routing problem respectively [8], [9]. There is also hybrid of PSO and ACO algorithm for solving path planning [10]. PSO is applied to optimize the parameters in ACO and the result shows that the performance greatly enhanced. The implementation of GA algorithm to find optimal path while avoiding radars for Unmanned Aerial Vehicle (UAV) also give the great result [11]. These algorithms have the advantages over conventional search algorithm due to its simple implementation and fast solution.

For this research, we propose a path planning method using PSO algorithm. Research has shown that PSO has a greater impact in term of robustness and computation time compared to other intelligence techniques [12], [13]. In this study, the research is focused with finding route that connects the starting position to selected places while determining the shortest pedestrian route. In order to achieve the objective which is to produce accessible pedestrian path, two assumptions have been made: 1) there is no ground obstacles and 2) the database of waypoints along the pedestrian walkways have been installed in the system. The system aims to free them from fear of travelling alone and facing the real world without having to feel paranoid on being hit or getting lost.

2. Particle swarm optimization

Particle swarm optimization (PSO) algorithm is an evolutionary computation technique developed by Kennedy and Eberhart corresponds to the social behavior of birds flocking and fish schooling [14]. In PSO, individuals or particles are randomly initialized. Each particle represents a potential solution to a problem and moving around within search space to search region of optima position. PSO has advantage over other soft computing techniques as it finds solutions faster as compared to others. This is because PSO does not have evaluation operators. The flowchart of the PSO algorithm is shown in Fig. 1.

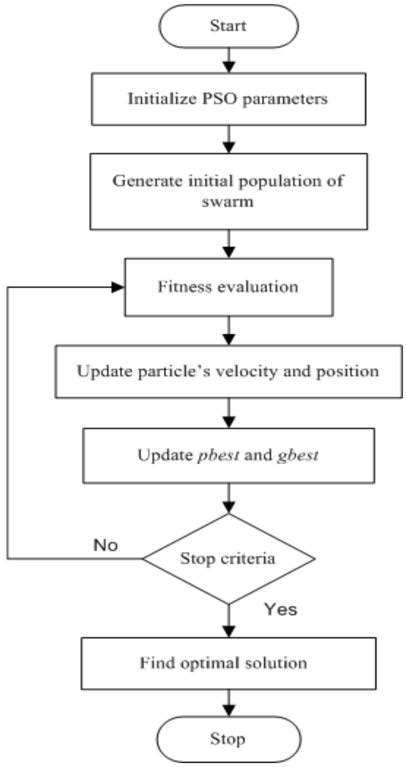

Fig. 1. Particle swarm optimization process

Each particle has its individual velocity, V_i and individual position, X_i and move towards their local best position, P_i and global best position, P_g. Local best position is the position at which the particles encounter its best fitness during fitness evaluation stage. For global best position, X_i' is the best position of entire swarm obtained by particles. They achieve the optimal solution by iteration. In each iteration, each particle will update their velocity and position until maximum iteration is reached. Their update velocity and position equation are listed as in Eqn. (1) and Eqn. (2) below.

$$V_i' = wV_i + c_1 r_1 (P_i - X_i) + c_2 r_2 (P_g - X_i) \tag{1}$$

$$X'_i = X_i + V_i' \tag{2}$$

The parameter w is called inertia weight. c_1 and c_2 are constants known as acceleration coefficients and r_1 and r_2 are two separate random numbers generated uniformly.

3. Methodology

3.1. Search space representation

The virtual environment for the simulation is depicted as a graph shown in Fig. 2. It is constructed based on a faculty area which consists of various department buildings. Each department building will have its own ID_{node} that contains coordinates of the place. The user will select the places they want to go from the provided list as shown in Table 1. The closed rectangles represent department buildings, and the green boxes represent the nodes for the starting point, predetermined waypoint and the points of listed places.

Table 1. List of the faculty departments and their ID_{Node}

ID_{Node}	Department	Coordinate
1	Mechatronics	(70,215)
2	Electrical	(190,115)
3	Biotechnology	(70,215)
4	Mechanical	(190,215)
5	Manufacturing	(90,60)

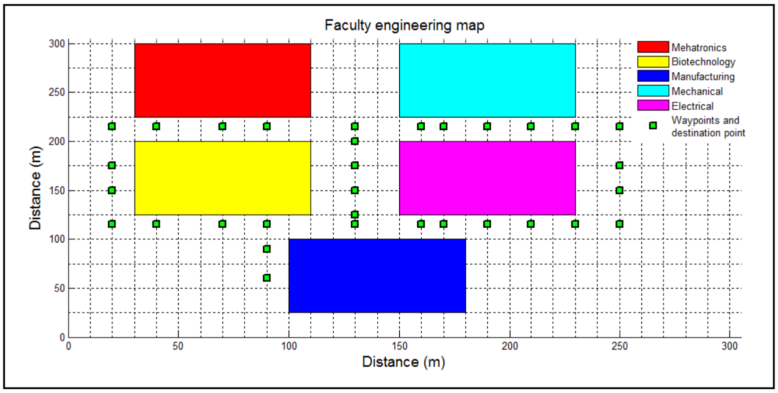

Fig. 2. Virtual environment for simulation

3.2. PSO implementation algorithm

The goal of the fitness function is minimizing the total cost path length. Fitness function is defined as Eqn. (3).

$$F(x) = \sum_{j=1}^{n_{i-1}} C_{sg} \tag{3}$$

Where C_{sg} is the total cost path length from starting point, s to destination point, g. The proposed algorithm for path planning with predetermined waypoints can be summarized as below.

Step 1: Calculate the distance of all pair waypoints, *n(x,y)* using Euclidean formula below

$$D(i,j) = \sqrt{(n_X(i) - n_X(j))^2 + (n_y(i) - n_y(j))^2} \tag{4}$$

Step 2: Initialize starting point and destination point

Step 3: Initialize PSO parameters. Initialize the position and velocity randomly

Step 4: Calculate fitness value of each particle. Calculate local best position, P_i and global best position, P_g for each particle

Step 5: While ite<ite_max, for each particle,

- Update particle velocity using Eq. (1)
- Update particle position using Eq. (2)
- Calculate fitness value of function F.
- Update P_i and P_g if its current fitness value is better than previous

End while

4. Result and discussion

The path planning algorithm has been coded with MATLAB, runs on a PC with Intel Core i7 2.26GHz processor and 4G of memory. In order to analyze the performance of the proposed algorithm, simulation were run several times to obtain best value of algorithm's parameters. All the parameters for the simulation are set as Table 2. The PSO algorithm is implemented and run for 100 iterations.

Table 2. PSO parameters

Parameter	Value
Size of swarm (N)	50
Inertia weight (w_{max}, w_{min})	0.9, 0.4
Acceleration coefficient (c1,c2)	2.0, 2.2
Number of iteration	100

Based on Fig. 2 above, for the simulation purpose, the starting point is set at (20,215) and the final desired destination is set to electrical department as shown in Fig. 3.

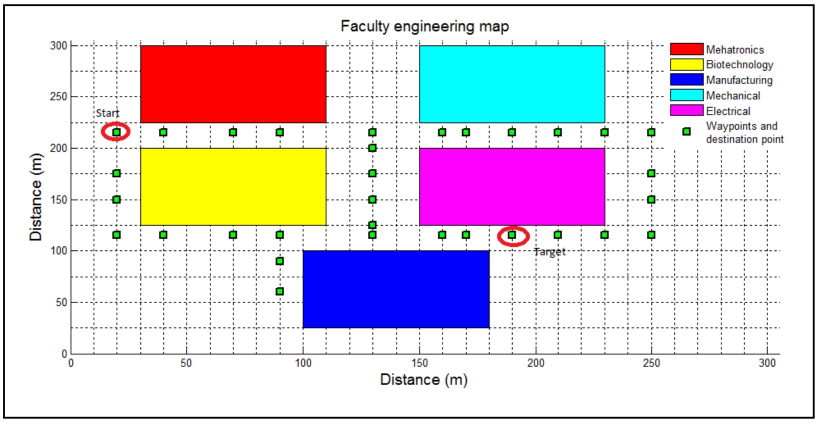

Fig. 3. Starting position and destination

The result from the simulation is presented in Fig. 3. The graph shows the total cost of path length on particular number of iteration. From the graph, it can be seen that the cost of path is 519 at 2nd iteration and at the 22nd iteration onward, the minimum path is 456 which is optimal path from user's initial position. Table 3 listed the results for all four different destinations.

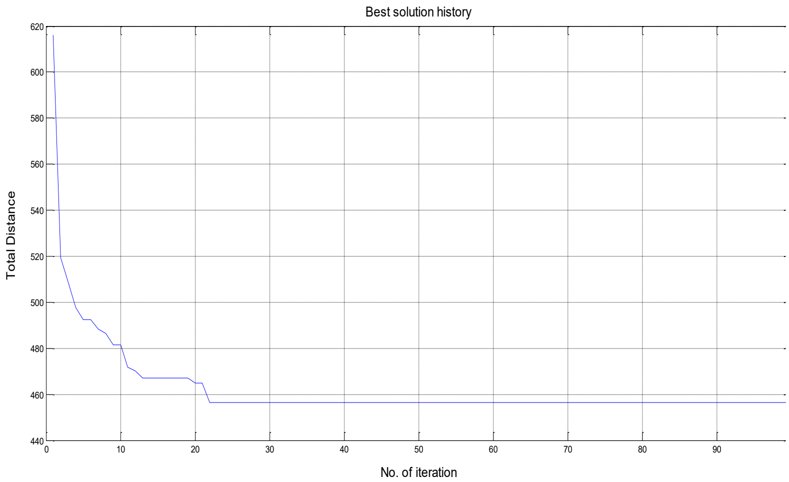

Fig. 4. Simulation result

Table 3. Optimal path distance for five destinations

Destination	Optimal distance	Iteration
Mechatronics	55	4
Electrical	456	22
Biotechnology	248	28
Mechanical	178	11
Manufacturing	385	21

5. Conclusion and recommendation

Visually impaired people have difficulty in perceive and understand the physical reality in environment that they are not familiar with. Therefore, this paper proposing a solution to assist blind people in their navigation by developing a method of path planning using PSO algorithm. The method will give the shortest route to be taken by user from their starting position to the destination. The simulation result shows that the PSO algorithm will provide a great efficiency in solving path planning with the constraint of each place is visited exactly once. For future work, the proposed algorithm will be extended with many more parameters that need to be considered to improve the system.

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