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PARTICLE SWARM OPTIMIZATION APPROACH IN ROUTE NAVIGATION FOR PoSVI-Cane

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Abstract— Conventional white canes have been used for ages to help those with visual impairment to scan their surroundings as well as detecting potential obstacles. But these canes are not capable of providing any other information, nor helping the blinds to travel independently and efficiently. Hence, numerous research and solutions have been proposed to overcome and improve the function of white canes. These devices are nevertheless expensive, becoming more unaffordable for low-income categories. Therefore, this paper presents the development of a low-cost navigation device – White Cane with Positioning Solution for Visually Impaired (PoSVI-Cane) that can

White cane

assist those who are visually impaired to travel confidently, even with unfamiliar routes. In this work, path planning component is embedded to the normal white cane, which further improve its function. Here, Particle Swarm Optimization (PSO) path planning algorithm computes the shortest possible path based on the collection of coordinates along the pedestrian walkway. Results from the experiments shows that employing PSO algorithm in the device manage to assist VIP to travel independently. The cost of path at the optimal route is 823 at 40 iterations. In addition, only low-cost components are used to ensure that the total cost of the proposed cane is low, without jeopardizing its function.

I. Introduction

Travelling alone as a person with low or without vision might be terrifying, especially at unfamiliar places due to various constraints. Hence, visually impaired people (VIP) might often limit themselves to the areas that are known to them, being highly dependent on their memory, and assisted by a guide dog and/or a white cane[1-3]. With the advancement of technology, a variety of navigation devices have been developed to help VIP to travel independently. Various research and studies, focusing on obstacle avoidance [4-6], outdoor and indoor navigation[7-10], path planning and dead reckoning[11,12] have been actively conducted to improve the mobility and safety of these devices that are specifically tailored to these community.

Most of the developed navigation aids, especially for outdoor environment are based on Global Positioning System (GPS) and GSM module [13-16]. Several other approaches can also be used that include RFID-based devices [17,18] vision-based devices [19-21] and additional sensors [5-22]. However, using these devices might incur more cost.

In assisting the VIP to guide them towards their desired destinations, path planning or positioning solution is an essential component in designing a navigation device. There are various path planning algorithms that seek to find the shortest path between two points that can be implemented to help the VIP to travel independently including ant colony optimization [23] and discrete bat algorithm [24]. Apart from these bio-mimetic approaches, Hosny et. al (2015) used a shortest path construction for their indoor wheelchair navigation system, to be used by the visually impaired person.

Current navigation systems have yet to achieve large scale exploitation due to several factors such as unaffordable cost, accuracy, and usability. The simplicity of the device in term of operation as well as features is one of the most important characteristics in the development of navigation device for visual impaired users. The device should be portable, lightweight, and easy to carry by one hand. Though there exist several navigation aids, with some have been successfully commercialized, however, these devices are usually expensive. Since most of the VIP falls in the low-income category, hence it is essential to design a navigation device that is affordable for this community. Therefore, this paper presents the development of a low-cost navigation device that is able to assist those who are visually impaired to travel confidently, even with unfamiliar routes.

This paper is arranged in four sections. Section 1 presents the overview of the work while Section 2 describes the design of the cane used in this research. On the other hand, Section 3 discusses the feasibility of the device to carry its function. Finally, Section 4 concludes the work.

II. PoSVI-CANE

White cane, which is a device that is used by the visually impaired people (VIP) to scan their surroundings for obstacles or marks, is an essential item for the blind or visually impaired people. In this work, the function of the ordinary white cane is further extended as it is equipped with a path planning module for smooth and safe travelling. The improved cane, which comes with Positioning Solution for Visually Impaired and is named as PoSVI-Cane, utilizes Particle Swarm Optimization (PSO) technique to ensure fast and accurate travelling route from one point to the other. With such assurance, it is hoped that the motivational level within the VIP will increase and eventually lead to a better life.

A. Hardware Design

The proposed framework for PoSVI-Cane is presented in Figure 1. PoSVI-cane creates a systematic system, that calculates the optimal route to reach the user's destination. Thorugh this system, it is anticipated that the user's confidence level can be increased especially when traveling alone.

Global Positioning System (GPS) is a vital component in the system that determines the position and orientation of the VIP. The information obtained later will be used in calculating and finding optimum route to the respective destination. The instruction and movement information are delivered to the users through auditory signal and the system gets the input from the users via a keypad.

The PoSVI-Cane comprises of a white cane and a Navigation Control Unit (NCU), as seen in Figure 2(a). NCU, which consists of Arduino Uno, GPS/GSM sim 908 modem, GPS and GSM antenna, earphone, keypad and four units of AA batteries, is the main central of the device that acquires processes and delivers all the required positioning data for the user. The system supports GPS technology for satellite navigation and allows PoSVI-Cane's control system to send messages and use the GSM network. The hardware is designed to be modular, compact, and lightweight. Users are able to inform their location

(GPS coordinates) by sending it to a number that is being set in the system. To ensure the safety of the user, the movement of the user can be monitored by other people in any locations.

Arduino Uno is used as the central processing unit for PoSVI-Cane, as shown in Figure 2(b). For a good estimation of the user location with an affordable price and reliability, the Skylab GPS Module MT3329 is employed. The GPS Skylab module communicated with the Arduino Uno using the UART port. The USB to TTL module was used to connect GPS module and Arduino Uno.

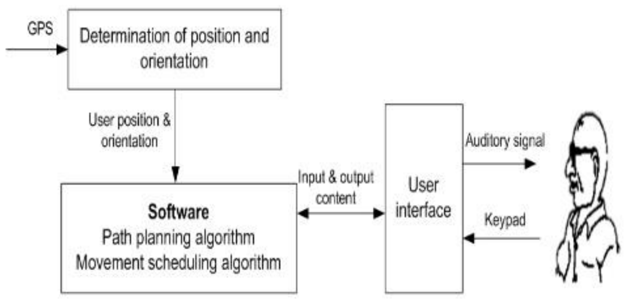
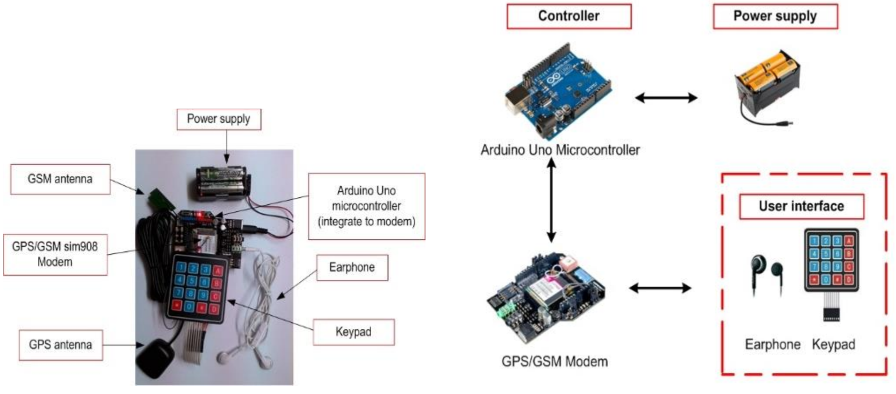
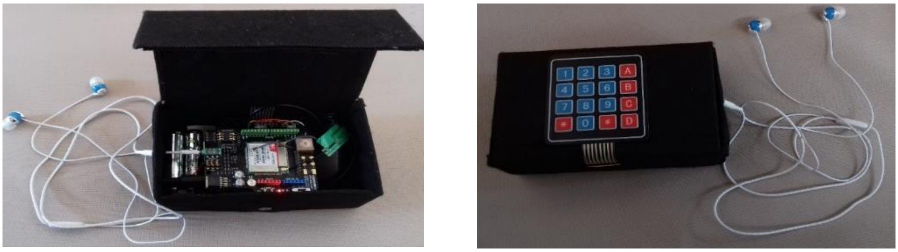


Figure 1: Proposed Framework for PoSVI-Cane



(a) (b)



(c) (d)

Figure 2: (a) Navigation Control Unit (NCU), (b) NCU electronics components, (c) and (d) prototype of Navigation Control Unit II for PoSVI-Cane

B. Positioning Solution using Particle Swarm Optimization (PSO)

In this work, Particle Swarm Optimization (PSO) algorithms was used to find the shortest path for multiple locations as well as multiple shortest paths. The algorithm was implemented to determine the connected networks and shortest paths based on a given set of road points (waypoints). This algorithm was implemented using MATLAB with waypoints stored in the database.

The PSO flowchart for shortest route selection and optimization is shown in Figure 3. The aim of the fitness function in this path planning problem is to minimize the total cost of path length in which the PSO will access the database to calculate the total distance using Haversine formula.

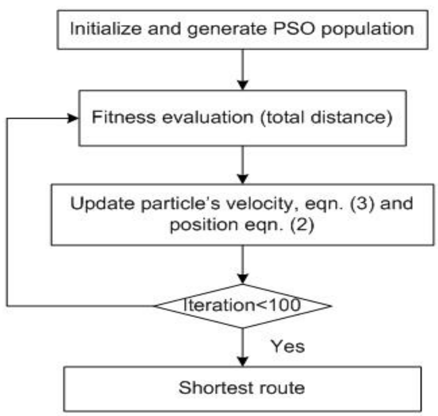


Figure 3: PSO Flowchart for shortest route optimization

Fitness function is defined as Equation (1) where function *f(x)* is the summation distance of the predetermined waypoints that connect from starting position, P_i to final position, P_n.

$$f(x) = \sum_{i=1}^{n} (P_{i+1} - P_i) \tag{1}$$

The velocity equation based on PSO particle positioning velocity can be written as in Equation (2).

$$Vi(t+1) = \chi(w * Vi(t) + c1 * r1 * (pBest - Xi) + c2 * r2 * (gBest - Xi)) \quad (2)$$

where:
i = index particle
$V_i(t)$ = particle's velocity at t
$X_i(t)$ = particle's position at t
$pBest$ = individual best position as of t
$gBest$ = swarm's best solution as of t.
w = inertia weight which influence the convergence of the algorithm
c_1 and c_2 = learning factors called social and cognitive parameters
r_1 and r_2 = value between 0 and 1 generated randomly.

The constriction factor, χ, can be expressed in a function of c_1 and c_2 as shown in Equations (3) and (4) [25]].

$$\chi = 2\left(\left|2 - \varphi - \sqrt{\varphi^2 - 4\varphi}\right|\right)^{-1} \quad (3)$$

where:

$$\varphi = c_1 + c_2 > 4 \quad (4)$$

On the other hand, the particle's new position, $X_i(t+1)$ can be calculated based on the particle's previous position at time t, $X_i(t)$, $V_i(t)$ is the particle's velocity at time t as in Equation (5).

$$X_i(t+1) = X_i(t) + V_i(t) \quad (5)$$

III. Result and Analysis

The PoSVI-Cane was tested within the vicinity of the research laboratory by three individuals. The route mode navigation guides the user through verbal instructions with turn by turn and point by point navigation. Speech-to-text program called E-speak was used to guide the user.

During path finding, the device first determines and initializes the position of the user using global positioning system (GPS). Then, the user enters the travelling location or destination via the matrix input keypad (with Braille indicator). Next, the device calculates and suggests the optimal route to the user.

In this experiment, the starting point, WPT001 (marked in red), the desired destination, WPT004 (yellow) as well as waypoints are shown in Figure 4. The total distance between these waypoints for each possible routes are taken to decide the best route. In the events of obstacles (such as buildings), the distance is infinite. Parameters used in this work is displayed in Table 1.

Table 1: PSO parameters for path planning

Parameter	Value
Swarm	50
Inertia weight, *w*	1
Constriction factor, χ	0.729
Learning factor; c_1, c_2	2.05, 2.05
Number of iterations	100

Several routes can be generated based on this series of waypoints connections. From WPT001 to WPT004, five possible routes were proposed by the system, as listed in Table 2.

Table 2: Five different routes from WPT001 to WPT004

Route	Series of waypoints (WPT00X)
1	1-3-4
2	1-2-3-4
3	1-2-5-6-7-4
4	1-5-6-7-4
5	1-6-7-4

Here, Route 1 (WPT001 – WPT 003 – WPT 004) is taken as the best route. The total cost of path is 80.64 which means that the user must travel 80.64 m to reach to the desired destination.

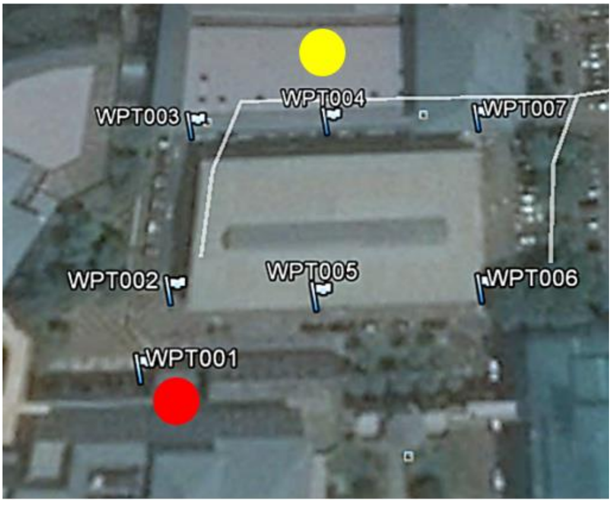


Figure 4: Waypoints marking

Figure 5 shows the convergence graph of this work. It is seen that the cost of path is 1000 at 20 iterations and at above 40 iterations, the minimum path is 823 which is optimal.

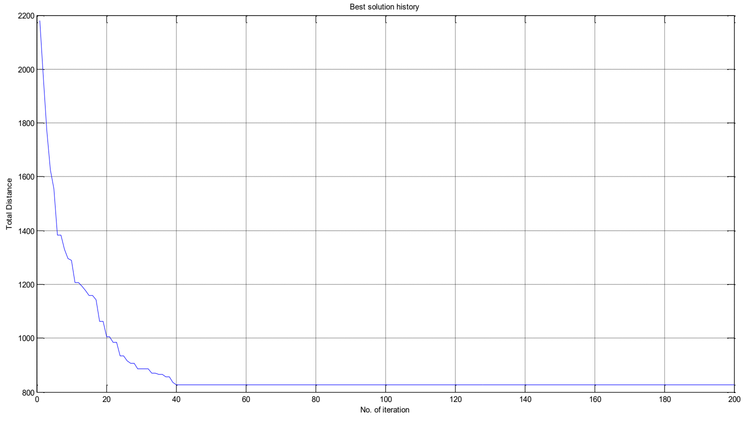


Figure 5: PSO convergence graph

IV. Conclusion

In Malaysia, visually impaired people (VIP) are often dependent on their white cane (walking stick) to move around. However, the normal white cane does not provide any spatial information needed for independent mobility. Hence, in this research, PoSVI-Cane, a device that is equipped with path planning module was developed. PoSVI-Cane acts as a guidance support system to extend the basic function provided using white cane. Results show that the implementation of PSO algorithm is able to generate the optimal path for the system. PoSVI-Cane will allow those with visual impairment to travel with auditory guidance. It is anticipated that with such assistance, the VIP is able to travel confidently and independently even to unfamiliar locations.

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