Unconventional Indoor Navigation: Gesture Based Wheelchair Control

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Abstract—**There are large number of people in the world with debilitating physical disabilities and elderly who experience significant difficulties in performing even very basic tasks such as locomotion, speaking, writing etc. The worst affected class of physically challenged are those who have become paralyzed over a significant percentage of their bodies, i.e. quadriplegics. These people find it extremely difficult to perform any task that requires even small amount of force. We propose a gesture based wheelchair for the benefit of physically challenged and elderly to navigate inside house without much effort. Our proposed system uses a small camera mounted very close to the user's hand, which tracks the small movements of their fingers to understand the direction of movement of the wheelchair. A recognition system which identifies the gesture is then interfaced to the wheelchair control system in order move it to the desired location. For point to point navigation without human intervention we propose two unconventional methods: Line Following Navigation (LFN) and Location Aware and Remembering Navigation (LARN). These two methods are simple and cost effective for indoor positioning or navigation.**

Keywords—**physically challenged, gesture-based, wheelchair, customizable, indoor navigation**

I. INTRODUCTION

The gesture based wheelchair is suitable for the elderly and the physically challenged people who are unfortunate to have lost ability in their limbs due to paralysis or by birth or by old age. Elders find it tough to move inside the house for day to day activities without help or external aid. Our proposed system makes use of a wheelchair that can be used by elderly or physically challenged to move inside the home without difficulty and without external aid. The elders may also forget the way to the different rooms in house due to the increase in forgetfulness as they become older. The physically challenged, find difficult to move the wheel chair without help from others. By making use of the system, the elderly and the physically challenged can go to different rooms in the house like kitchen, living room, dining room etc by just showing a gesture which is predefined to that particular room. It is also a virtue of the system that even the foot can be substituted in place of the hand for users who might find that more convenient.

II. AVAILABLE SOLUTION AND SHORTCOMINGS

Most of the recent solutions for the indoor navigation have a constraint that ultrasonic and or RF beacons should be installed at different positions in the house. 'Cricket Localization System' [1] developed by the team from MIT has a good accuracy but it is expensive for installation in India and many other countries. SLAM (Simultaneous Localization And Mapping) implementation has some issues in using available sensors like sonar and laser range finders. Sonar does not have good precision and is highly prone to environmental noise. RSS localization has an accuracy of about 3-4 meters tolerance. There is a need that errors in localization should be minimized by using available optimization methods. One such method was discussed in [2] where in the error in localization is considered is optimized by using Particle swarm optimization and Bacterial foraging algorithm. Ref. [3] shows a gesture based wheelchair, which makes use of the ultrasonic sensors to avoid obstacle avoidance in crowd. Ref. [4] explains the defects of ultrasonic sensors and its usage defects in crowd. Ref. [5] discusses a navigation system which makes use of sonar maps to get location identity.

III. SYSTEM DESCRIPTION

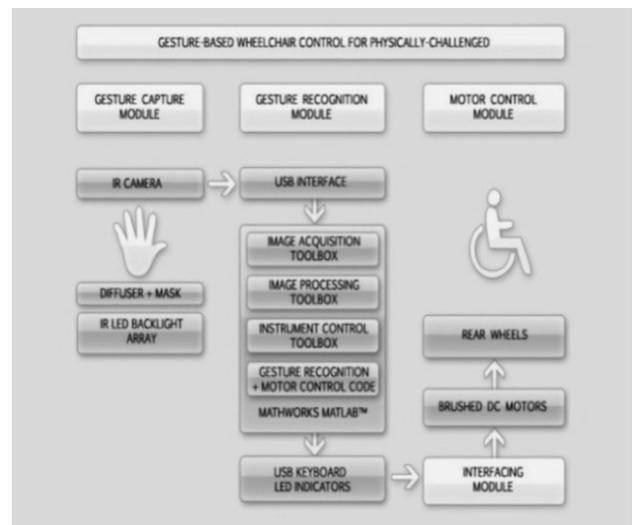Fig. 1 shows the entire system block diagram.

Figure 1. System Block Diagram

A. Gesture Capture Module(GCM)

Capturing the image of the gesture performed by the user of the wheelchair is done using an IR-camera and

MATLAB®. The user's hand is placed on the palm-rest of the wheelchair. The camera for capturing the gesture is mounted just above the hand and focused downwards, for this; we require backlighting of the surface the user has placed his hand on. An IR backlighting array has been designed to provide a uniform illumination over the area being captured, since clustering of illumination results in poor quality of silhouettes captured owing to non-uniform distribution of light intensity. The outputs of this module as shown in Fig. 2 are the captured images of the gestures at the specified resolution of 320 x 240 pixels, which can be given to the Gesture recognition Module.
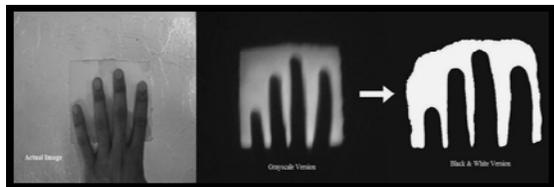

Figure 2. Output of gesture capture module

B. Gesture Recognition Module (GRM)

The user has to predefine the gesture templates that he/she is going to use for any of the directional movements viz., Forward, Reverse, Turn Left, Turn Right or Brake. Or gestures can be defined for travelling different rooms in houses; kitchen, living room, bed room etc. The user may use only one finger or all the fingers for each of the gesture. This is a simple exercise in which the system requires at least 4 set of gestures to be captured initially and stored as image templates before the user can start using the wheelchair. Even the toes can be used for this purpose. These set of images are called predefined gesture templates shown in Fig 3.
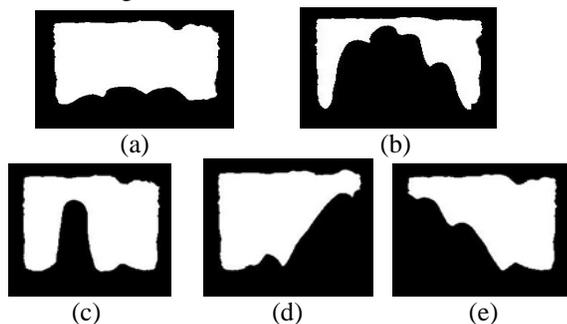

Figure 3. Suggested Gestures

C. Interfacing Module

TABLE I. RESPONSE TIME OF ARDUINO BOARD

Command Given	Time Taken (ms)
FW - Forward	28
RV - Reverse	29
TL - Turn Left	29
TR – Turn Right	29
BR - Brake	26

The ARDUINO based microcontroller board is used to drive the wheelchair motors. The interfacing module can be implemented by driving the ARDUINO board through the USB port of computer. Table 1 shows the response time of the Arduino board.

IV. INDOOR POSITIONING AND NAVIGATION

The GRM shall use any one of the navigation methods i.e. either Line Following Navigation (LFN) or Location Aware and Remembering Navigation (LARN) to locate itself and navigate automatically from one room to another room with human intervention.

V. LFN METHOD

Fig. 4 shows the structure of a sample room which we are considering for our experiment. It consists of four rooms namely the kitchen, living room, bed room and drawing room. Each room has a door and a IR TSOP (Thin Small-Outline Package) sensor is attached to each door. Four junctions are defined A, B, C and D as shown in the Fig. 4. As per our proposal the route is identified as bold black line with junctions A, B, C and D. The system can move along the line similar to 'line follower' robot. This line must be drawn inside the house for the system to move along.
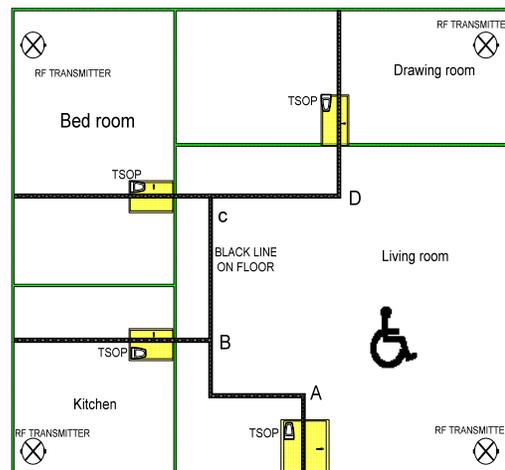

Figure.4 Sample Home Structure

The LFN method consists of five modules namely RF module, line follower module, IR-TSOP module, obstacle detection module and motor control module.

A. RF Module

An RF transmitter transmitting specific data is fitted in each room. The RF transmitter used is TWS 434A which sends serial data modulated at 433.92 MHz. The RF receiver mounted on the system receives these specific data and identifies which room the system is in.

B. Line Follower Module

This module helps the system to automatically navigate inside house by following the black line on the floor of the

house. Thus the system navigates from one room to another based on the control input received.

C. IR -TSOP Module

This is setup at each door of the house. Each module will be sending a specific data by which the system comes to know that it has reached the entrance of a particular room.

D. Obstacle Detection Module

This module uses SONAR sensors to detect an obstacle in the proximity. Thus when the obstacle is detected, it sends an interrupt to the microcontroller by which the path of the system is deviated.

E. Motor Control Module

This module works on the feedback received from obstacle detection module or by the commands received from above mentioned module. The motors can rotate through various directions and its speed and direction of rotation is controlled using an Arduino board that is embedded into this module.

VI. ALGORITHM AND WORKING

The LFN method consists of two algorithms: LFNSA and LFNBA.

A. Line Following Navigation Sysytem Algorithm(LFNSA)

Once the system starts, it waits for the control input from the GRM, for general directions like left, right, front, back etc. The microcontroller drives the system in the desired direction. If the control input is for any particular room in the house, then the navigation module takes over the control of the system. Through the navigation module the motors are driven in specific routes and thus the system moves to the specific room without human intervention. The flow chart for LFNSA is shown in Fig. 5.

B. Line Following Navigation Block Algorithm(LFNBA)

When the control input for a specific room is detected then the line detection module is activated. The system moves straight until a line or an obstacle is detected as shown in Fig.4. If obstacle is detected then it takes left and moves in straight line until it detects the line. If the line is detected then the system follows the line till it receives any signal from IR TSOP module. By analyzing the data received from the IR TSOP the system can determine the current location i.e. the door which is in front of the system. If the current location matches with desired location, it enters the room and stops. The received data from IR TSOP is compared with the predetermined data bits stored in the system, which denote the destination room and checks for a match. If there is a match, the system enters the room and stops. If it is a mismatch, the line is followed until the destination room is reached. The entire flow chart is shown in Fig.6.

VII. EXPERIMENTAL RESULTS

The LFNSA was modeled in Verilog HDL and simulated in ModelSim SE PLUS 6.2c of Mentor Graphics. All the possibilities were taken into consideration. Various signal inputs are generated to this module.
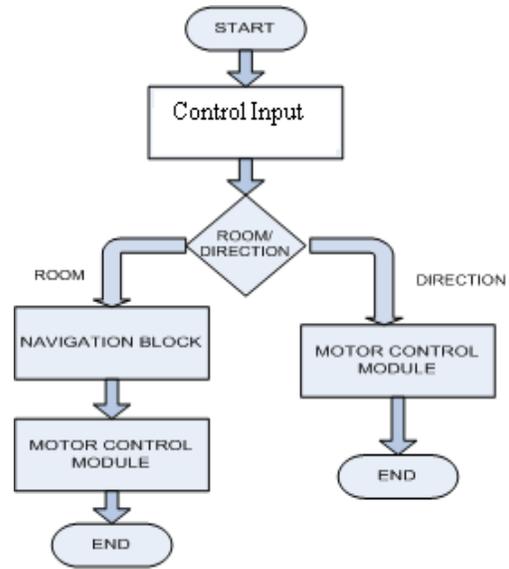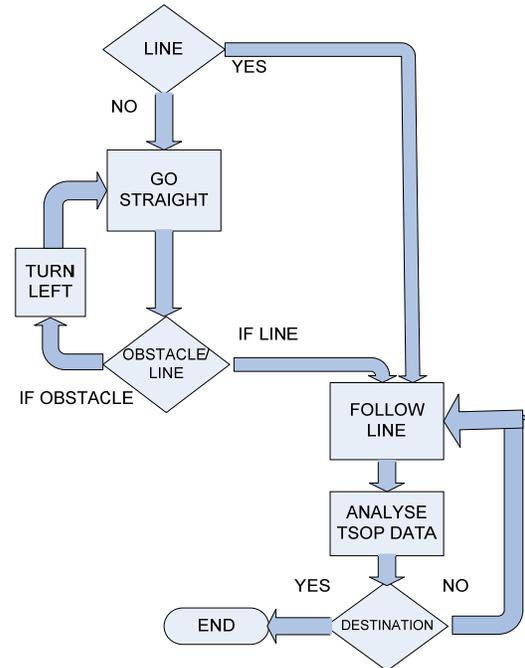
Figure. 5 LFNSA Flowchart

Figure. 6 LFNSA Flowchart

The signal input 'obstacle' will go high whenever an obstacle is found during navigation. The signal 'junction' goes high when a junction is reached. 'line' signal goes high when the black line is found. Signal 'IR' becomes high when the destination room's door is reached. The signal 'RF' goes high when it is in desired room. The table lists all the possibilities that can occur and these test vectors were tested for navigation from one room to all other rooms. The model was also tested with test vector for directional inputs like forward, reverse, left, right and brake. Various possible combination of test cases are shown in Table 2.

RF	IR	Line	Junction	obstacle
0	0	1	0	0
0	0	1	1	0
0	1	1	1	0
0	1	0	1	1
1	1	1	0	0
1	1	0	0	0

VIII. LOCATION AWARE AND REMEMBERING NAVIGATION (LARN) METHOD

The LARN works based on two facts viz. the house in which the system is going to be used is considered to be a polygon and the dimensions of the house is also fixed. The dimension is not going to be changing dynamically and that the entrance to each room in the house is also fixed.

A. Co-ordinate based mapping

As the house structure is that of a polygon, the entire house can be divided into many grids. A sample home structure with grids is shown in the figure. The entire house is divided into many grids. The accuracy of this algorithm is determined by the size of the grid, the angle in which the wheelchair moves and the ability to remember the coordinates of the grid it is traversing. The greatest advantage of this method is that it doesn't require any sophisticated wireless technology to work. The wireless part is completely eliminated using this algorithm. Using the LARN algorithm, the wheelchair stored the current coordinates of the grid in which it is in and also the previous coordinate where it was. As the wheelchair crosses each grid, these location coordinates are updated. As shown in Fig.7, the entire house is divided by 7x8 grids where (x,y) is the grid with coordinate (1,1). The entrance to the house is indicated by green grid and the entrance to various rooms inside the house is marked by red grids. It is just for simplicity that the the entrance is equal to grid. For the system to work properly the initial coordinates (5,1) of the wheelchair marked by the entrance (green grid) must be loaded manually. If the user wants to go to R3, then with the help of gesture the system knows the destination and the coordinates of the destination. It traverses the coordinates (5,2), (5,3), (5,4), (6,4), (6,5) and (6,6). Each time it crosses one grid, the new coordinates are stored. The system always identifies the shortest path to the destination. If there are any obstacles on the path, it avoids them and changes the route dynamically.

B. Error Correction Mechanism

Even if there is a small change in the angle of the wheels, the system might end up in a different coordinate which will not be known to the system. An error correction mechanism is fixed to the wheels handle this problem. If the wheelchair lost the contents of the location due to power cut or any other reason, the wheelchair has to be brought physically to the original location i.e. where the coordinates are fed manually and restart the system. Even

though this seems to be like a drawback of the system, the proposed algorithm is straight forward and doesn't require any complex wireless technology for indoor navigation.
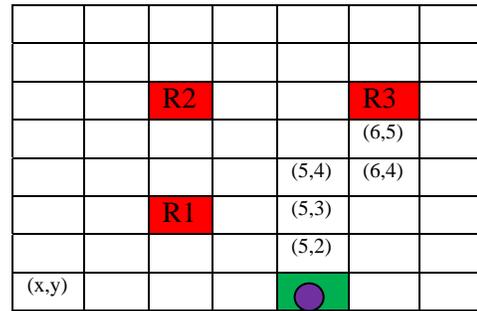
			R2		R3	
					(6,5)	
				(5,4)	(6,4)	
			R1	(5,3)		
				(5,2)		
(x,y)				●		

Figure. 7 LARN of a sample home structure

XI. CONCLUSION

In this paper we proposed two methods from which one shall be used for indoor navigation of gesture based wheelchair designed for elders and physically challenged. One method using Location Following Navigation is similar to line following robot. In the other method called Location Aware and Remembering Navigation we completely eliminate the use of any wireless technology for location identification and navigation.

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