LARN: *Implementation of Automatic Navigation in Indoor Navigation for Physically Challenged*

Rajesh Kannan Megalingam
Electronics and Communication Engineering
Amrita Vishwa Vidyapeetham University, Amritapuri
Clappana P.O., Kollam, Kerala, India
rajeshm@am.amrita.edu

Ananthakrishnan Ponnileth Rajendran, Deepak Dileepkumar
Electronics and Communication Engineering
Amrita Vishwa Vidyapeetham University, Amritapuri
Clappana P.O., Kollam, Kerala, India
ananthakrishnan.pr@ieee.org, deepakdileep@ieee.org

***Abstract*— Mobility is one of the greatest challenges faced by elderly and physically challenged people. The immediate solution to their problem is powered wheelchairs with automatic navigation systems. However, effective low cost automatic navigation systems have not been developed and implemented. We propose a low cost navigation system which incorporates indoor automatic navigation system using LARN Algorithm, an implementation of Djikstra's Algorithm. This navigation system consists of a conventional powered wheelchair controlled by joystick, along with a processing system which maps and monitors the location of the wheelchair inside the house. The wheelchair system makes use of the LARN algorithm to traverse from anywhere inside a house to predefined locations within it. The LARN Algorithm measures the distance traversed by the wheelchair from the rotation of the wheelchair and the orientation angle with the help of a digital compass that is incorporated into the system.**

Keywords- navigation; LARN; wheelchair; grid; algorithm

I. INTRODUCTION

According to the World Health Organization, disability affects more than 7% of the world's population [1]. This means that several millions of people are affected by one form of disability or other. A large portion of these individuals are physically disabled. Physical disability greatly affects the functional capabilities of the individual thereby restricting their access to socio economic opportunities.

One of the major hurdles faced by the physically challenged people as well as disabled people is the issue of mobility. They often have to depend on other individuals for their day to day navigation even inside their homes. The existing solutions to the problems of mobility for these people are powered wheelchairs which use joystick, push button or voice based systems. Most of these systems are very costly and require the user to apply some physical effort to navigate.

An effective automatic navigation system will be the best option for the elderly and the physically disabled people. An ideal automatic navigation system is one in which the user can navigate automatically to predefined locations inside the house without continuously applying physical effort. However, effective automatic navigation systems have not yet been designed and implemented and the existing systems are either too complex or costly to be implemented in a real time indoor scenario.

We propose an indoor automatic navigation system for wheelchairs, which makes use of Location Aware and Remembering Navigation (LARN) algorithm, an implementation of the Djikstraw's algorithm to implement automatic navigation. This system consists of a conventional powered wheelchair, such as a joystick controlled wheelchair, into which a processing system has been incorporated. This system is capable of identifying the present location of the wheelchair and uses this information to navigate to specific predefined locations inside the house automatically.

II. MOTIVATION

The biggest hurdle faced by the disabled is the issue of mobility. Often, the disabled individual is forced to depend on others as he or she might not possess the physical strength required to use a manual wheelchair. This hurdle can be overcome with the help of powered wheelchairs. Powered wheelchairs use different methods such as control by joystick, push buttons or user voice for navigation. However, these powered wheelchairs face two major drawbacks. Firstly, the existing designs for powered wheelchairs require a certain amount of physical exertion to be applied to the system for navigation. A quadriplegic who has very little control over the movement of his or her hand finds it difficult to use these wheelchairs. Secondly, the cost of these wheelchairs is too high and not affordable for the majority of the disabled individuals.

We propose a system which makes day to day navigation of quadriplegics inside their homes easier. This system makes use of hand gestures to automatically navigate inside the house. The automatic navigation system is designed in such a way that cost of the systems considerably low when compared to existing systems. The existing system makes use of wireless transmitters to calibrate the location inside a house. The major disadvantage of this system is that it is very costly and at the same time accuracy of the system depends on signal reception. Moreover, there is great possibility of signal interference from other devices inside a house while using wireless technology for determining the location and navigating automatically inside a house.

I. RELATED WORKS

The move towards incorporating automatic navigation in powered wheelchairs, started from 1996 onwards. The earlier methods made use of rangefinders, particularly laser rangefinders to make a virtual map of the local environment. The map is virtual in the sense that, from the readings of the range finders, the system understands where all obstacles are present, and where all open paths are available. These systems are capable of moving through a path, traversing all obstacles, but we cannot arbitrarily give a destination. The user needs to direct the wheelchair subsequently. This system has got the capability to track moving obstacles too.

Some other navigation systems make use of sonar sensors to make polar grids for navigation, with the current position of the wheelchair as the origin. There, the method followed is that, if we want to navigate from a point to another, the entire path is divided into several sub distances, which will be the range of the sonar sensors. First the system asks the user, to which point the wheelchair to be moved. The inputs are given on a touch screen based interface. As the wheelchair moves to the specified point, the location is updated and the new polar grids are formed with the updated position as the origin. So at each point, user must tell which direction to be followed and the user must know the exact direction from source to destination. This is a kind of point to point navigation, which makes use of a divide and conquers method to navigate from source to destination. But it involves a lot of human interaction, in the sense that user need to give the directions subsequently.

A wall following method is also employed which travels near to the wall while going from one point to another. This method needs extremely precise obstacle sensors, and the number of sensors required will be more.

Several system localization and mapping techniques uses the feedback from sensors to make a probabilistic map of moving and static obstacles. This is obtained after taking a number of observations, and they place the obstacles-static and dynamic, in certain grids, where they are more likely to be found. This enables the system to avoid that path and of course, the probability of static obstacles is unity.

Some other methods use conventional line following methods to navigate automatically from one place to another [7]. Lines are drawn, connecting various sources and destinations. The wheelchair follows the line, with the help of input from an array of IR detectors. A major problem faced by the method is that if there are multiple paths originating from the same point, it's often difficult to distinguish between them and there will be ambiguity in choosing the path. The accuracy of the IR sensors is also a crucial factor here.

Recent methods avoid the use line following techniques. Instead, they store the path on the memory. It requires a microcontroller with considerably larger flash memory. The paths from various source and destinations are stored in the memory. Destinations are given as key inputs. According to the input given, the controller chose the desired path. If the wheelchair deviates from the fixed path, the system fails to recognize, where it is in the present situation and eventually stops. Systems that can run in multiple modes are there. They can switch between manual and automatic modes of navigations, using specific inputs. Under manual mode the motion needs to be precisely tracked so that, system knows the current position when it switches to automatic mode.

II. PROPOSED SOLUTION

Our solution is a wheelchair system which can navigate automatically to specific predefined locations inside a house without using complex wireless techniques. We have developed an algorithm, Location Aware and Remembering Navigation (LARN) algorithm, with which the wheelchair system is able to identify its present location by itself. The wheelchair system makes use of commercially available methods for navigation such as joysticks, push buttons or voice interface. In addition to the conventional navigation interface, the system also has five push buttons which are used for specifying the destination for automatic navigation.

The wheelchair system makes use of the LARN algorithm for automatic navigation. In this algorithm, the floor space of the house is considered as a polygon, and it is divided into a number of grids, with a coordinate associated with each grid. The wheelchair keeps track of its current grid position and updates its location as it navigates. 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 orientation is constantly monitored by a digital compass which is used to automatically correct the error in navigation of the wheelchair. The advantage of LARN over most other method is that it does not require wireless transmitters or receivers for navigation.

III. METHOD

In the LARN method, the entire house is divided into a number of grids. Fig 1 shows the floor plan of a sample house. Here, the house is divided into 7x7 square grids, each of size NxN feet. This size of individual grids has been chosen after considering the size of the wheelchair and the circumference of its wheels. The length of each grid is equal to the circumference of the wheelchair. This means that when the wheels of the wheelchair make a complete rotation, it will traverse one gird.

The wheelchair basically has two modes of navigation. One is the manual mode and the other is the automatic mode. In the manual mode of navigation, the user makes use of the conventional system such as a joystick to navigate inside the house. While the user is navigating, the wheelchair continuously monitors its location and updates each time it traverses a grid.

Each house will have specific locations to which the user of the wheelchair visits frequently. These locations are identified and stored in the system. About five such locations can be identified and stored in the wheelchair system and a push button is assigned to each of the five destinations. These push buttons can be used whenever the user wishes to navigate to the specific location automatically. When the push button is pressed, the system uses the LARN algorithm to identify all the shortest paths from its current location to the specified location.

In fig.1, the grid (1,4), marked in blue color, is the entrance to the house and is set as a reference grid. The grids (4,1), (4,7) and (6,3) marked in red color are the grids to be reached in the three rooms inside the house. The reference grid is used to preset the position of the wheelchair. Initially, the wheelchair has to be brought to this grid and the grid should be loaded manually so that the wheelchair system will be aware of the initial location.

The automatic navigation system is designed in such a way that the user can navigate to the three rooms automatically from any of the girds. The user has to give the input through a push button to specify the destination and the wheelchair uses the LARN algorithm to find the shortest path between the present location of the wheelchair and its destination.

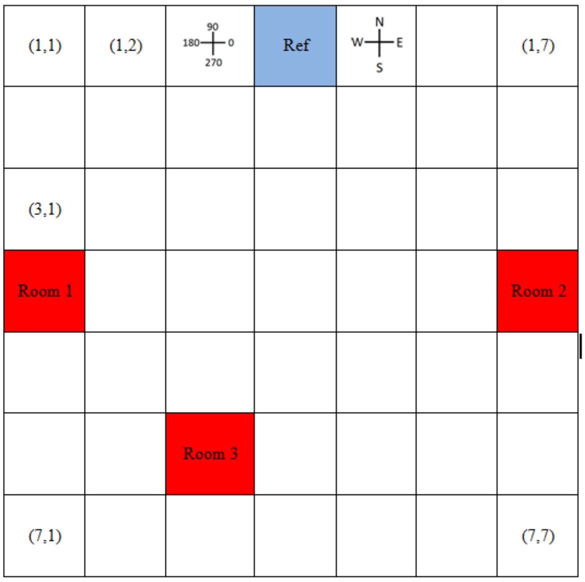

Figure 1. Floor plan of sample house

Angles with reference to the magnetic poles are used to determine the orientation of the wheelchair. A digital compass is used for this purpose. In this case, the orientation of the wheelchair when it is preset will be in the north-south direction, meaning the wheelchair should face the south. North, South, East and West correspond to angles 90°, 270°, 0° and 180° respectively as seen in fig 1. Once the wheelchair is brought to the reference grid and preset, it will align automatically in the North-South direction.

IV. ALGORITHM

We have developed an algorithm to find the shortest and easiest path between a source and a destination. This algorithm is an implementation of Dijkstra's algorithm and is named as Location Aware and Remembering Algorithm. By using this algorithm, the wheelchair will be able to find all possible paths to a specific location and choose the optimum path it can take. The working of the algorithm can be illustrated using an example.

Consider the grid system in Fig 2. Here, we can assume that the present location of the wheelchair is gird (2,3). From this grid, the wheelchair has to automatically navigate to Room 2. Grid (4,7) is a grid inside Room 2 and is preset as the destination. The first goal of the wheelchair will be to determine all the shortest paths thorough which the wheelchair can reach its destination. So, the wheelchair system initially forms a rectangular region in which all the shortest paths to the destination will be located. The border of the rectangular region in this example is marked with red lines.

After determining the region of all possible shortest paths, the wheelchair system calculates the number of grids the wheelchair has to traverse for it to reach a particular grid. For example, in order for the wheelchair to reach grid (2,4) and (3,3), it has to traverse only 1 grid and to reach grids (3,7) and (4,6), the wheelchair has to traverse 5 grids. This way, the system calculates the number of grids it has to traverse in order to reach each grid. Our destination in this case is grid (4,7). The three adjacent grids to this the destination are (3,7), (4,6) and (5,7). To reach grids (3,7) and (4,6) the wheelchair has to traverse 5 grids. However, in order to reach grid (5,7) the wheelchair has to traverse 7 grids. It is obvious that we have to reach either of the above three grids in order to make it to room 2. The best choice in this case is to either reach grid (3,7) or grid (4,6) than grid (5,7) as the wheelchair will have to traverse only 5 grids to reach them while it has to traverse 7 girds to reach the latter.

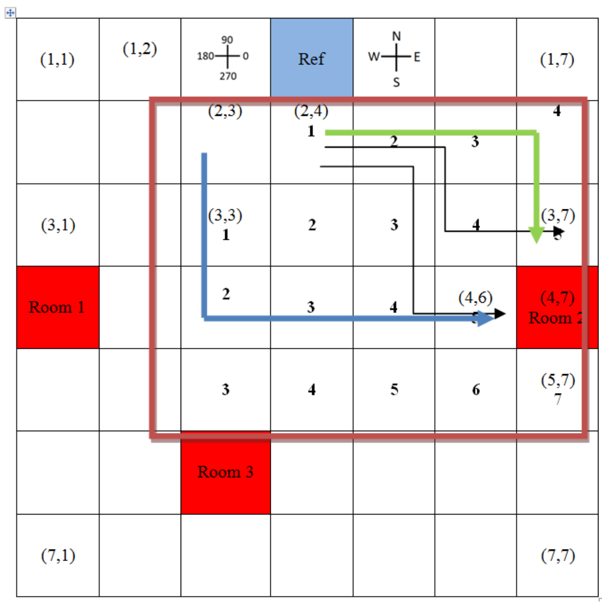

Figure 2. Implementaion of LARN Algorithm

Even though we have identified the least number of grids the wheelchair has to traverse, there is more than one path to reach these grids and some of the paths have been marked in figure 2. Of all the identified shortest paths, the algorithm checks for the ones which require the least number of 90° turns. It is clearly visible here that the paths marked in green and blue color require only one 90° turn each, which means that they are the best choices. From these two paths, one path is chosen with respect to the current orientation of the wheelchair. If the wheelchair is oriented in 270°, the wheelchair will take the blue colored path and if it is oriented in 0°, then it will take the green path. If the wheelchair is not oriented in either of the two orientations, then it checks for the least amount of rotation required to take a shortest path.

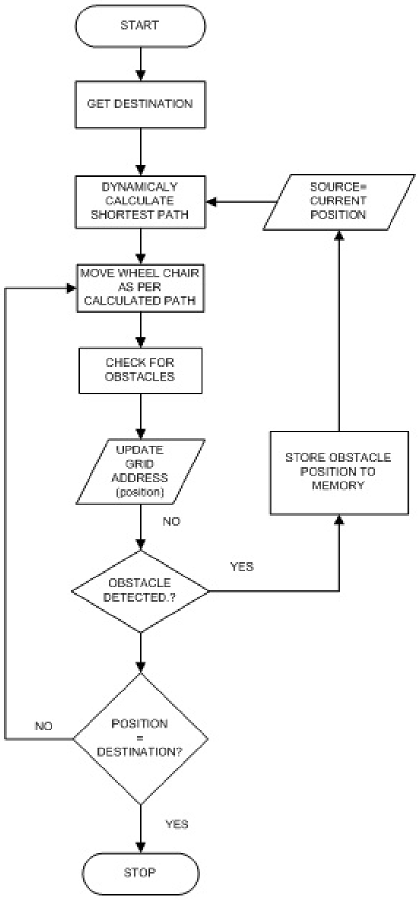

Figure 3. Flowchart of LARN Algorithm

Figure 3 shows the block diagram of the LARN Algorithm. The destination grid is the input to the system. The system already has the current grid of the system. Once the destination grid is received, the system will calculate the shortest path of to the destination. The wheelchair will then take the shortest path calculated and keeps on updating its grid position. Simultaneously, it checks for obstacles in its path. If the wheelchair comes across an obstacle in its path, it takes its current position as the source and calculates an alternate path to the destination grid.

V. MODES OF OPERATION

The wheelchair system can basically be operated in two modes viz. manual navigation mode and the automatic navigation mode. The operation of the wheelchair in both modes is discussed below.

A. Manual Mode of Navigation

In the manual mode of operation, the user has the freedom to control the motion of the wheelchair using a conventional navigating interface such as a joystick. The user has the may navigate to any location inside the house. While the wheelchair is manual mode of navigation and is in motion, it is very important to keep track of its location. As mentioned before, the wheelchair can move only in a straight line path. If the user wants to turn the wheelchair, he will have to bring the wheelchair to a halt and then rotate the wheelchair to turn.

As the wheelchair moves, it takes feedback from the wheels and calculates the distance it traverses from the rotation of the wheels. When the user brings the wheelchair to a halt, the system first checks if the initial angle stored in the system is a multiple of ($\pi/2$). If so, the corresponding row or column will be incremented. If the orientation angle is not a multiple of ($\pi/2$) then the system will calculate the horizontal and vertical distance travelled by the wheelchair by constructing a right angled triangle, taking the initial orientation angle as the adjacent angle and the distance traversed by the wheelchair as the hypotenuse. Once the triangle is constructed, the horizontal and vertical distances can be calculated using the equations (1) and (2).

$$H=h*\sin(\theta) \quad (1)$$

$$V=h*\cos(\theta) \quad (2)$$

H and V in (1) and (2) represent the horizontal and vertical distances respectively. _ represents the orientation angle and ‘h’ is the length of the hypotenuse. By using these formulae we can find out the distance the wheelchair has traversed in the horizontal and vertical directions. With these two distances, the wheelchair can locate its current grid position. By calculating and updating the grid position this way, the wheelchair will be able to keep track of its current location and the LARN algorithm can be directly implemented when the user switches to the Automatic Mode.

LARN becomes invalid under the following cases-The system occupies two grids, when it stops. In that case, the controller fails to recognize the current position of the wheelchair. Secondly, a very strong magnetic field environment can alter the readings of the digital compass proposed for the system. There also, the controller fails to recognize the current position. Except for these two cases, LARN algorithm is valid. So the assumption made here is that the user has not stopped the wheelchair in between two grids and we assume that the wheelchair completely traverses one grid and then brings it to a stop inside one grid and not between two grids. Moreover, the wheelchair is operating in an environment where very strong magnetic field is not present.

The user can switch the wheelchair to automatic mode of navigation whenever he wishes to go to one of the predefined rooms which have been identified earlier. Once switched to this mode, the wheelchair comes to a halt and waits for the user to specify the destination. They may do so by pressing a button that is dedicated to a particular room. Once the key has been pressed, the wheelchair system identifies its destination. It then calculates the optimum path to its destination using the LARN algorithm as mentioned in the previous section.

Once the shortest path is identified, the system will give the required signals to the motors of the wheelchair. The wheelchair will receive the input from the wheels and continuously updates its grid location. If the wheelchair reaches a particular grid from which it has to take a 90° turn, the systems stops the forward motion of the wheelchair. It checks if a right turn or a left turn is required. If the wheelchair has to turn to the left, then the system gives signals to rotate the left wheel backwards and the right wheel forward. The digital compass continuously monitors the orientation angle of the wheelchair and feeds it back to the system. Once a 90° rotation is complete, the system stops rotation and starts moving forward again. When the wheelchair reaches the destination grid, the wheelchair comes to a halt and the system switches back to manual mode of navigation.

VI. TESTING OF LARN ALGORITHM

To test the LARN Algorithm, we developed a MATLAB program in which the elements of the grid are represented by the elements of the matrix. We have considered several cases of automatic navigation from a point A to point B.

Here, three cases are illustrated, which correspond to a scenario in which there are no obstacles, two obstacles and three obstacles in the path of the motion of the wheelchair. For illustration purpose, the element corresponding to an obstacle is stored with the value '2' and the grid traversed by the wheelchair is marked with a value '1'. The three cases are illustrated below.

A. Case 1: No obstacles

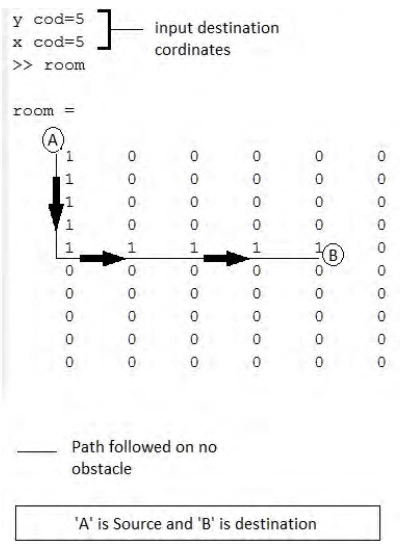

Figure 4. Algorithm testing with no obstacles

Figure 4 shows the result obtained by simulating the LARN algorithm and virtually mapping the path taken by the wheelchair to reach the destination. Here, the initial position of the wheelchair is marked as A, which is coordinate (1,1). The destination is coordinate (5,5) marked as B. The path simulated by the MATLAB code is illustrated as shown by the arrows in the figure. 'y cod' and 'x cod' are the input to the system which is the destination grid . In the real time system, the user will give an input such as a push button, which will automatically generate the destination grid and feed it to the system. For simplicity purpose, the destination grids are directly given as an input.

B. Case 2: Two obstacles

Figure 5 shows a scenario when an obstacle is present in the shortest path calculated by the wheelchair. Once the obstacle is detected, the system will identify an alternate path it can take in order to reach the destination.

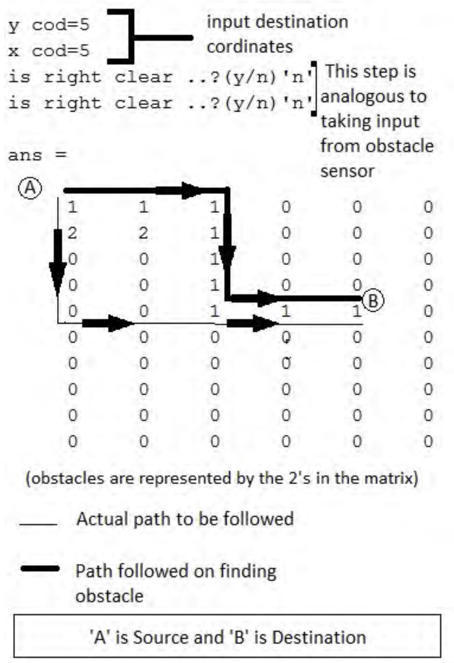

Figure 5. Algorithm testing with 2 obstacles

Similar to the previous case, the source and destination coordinates are (1,1) and (5,5) respectively. The system will initially generate a path similar to the first case and is indicated by the broken arrow marks on the thin line. However, in this case, there is an obstacle in the path of the wheelchair. This obstacle will be detected by the sensors on the wheelchair. Once an obstacle is detected, the wheelchair will scan to its left and right to check for other obstacles. If there are no obstacles present then the system will generate another path which can take the wheelchair to its destination. The path the wheelchair takes is indicated by the broken arrows on the thick line.

The sensors on the wheelchair will determine if there is any obstacle to the left or the right of the wheelchair. In this case, there is no grid to the left of the wheelchair and it can be assumed to be a wall. "is right clear.. ?" is a representation of the wheelchair sensors checking the left and the right of the wheelchair for obstacles. Here the function is called twice.

C. Case 3: Three obstacles

Figure 5 shows the case where there are three obstacles in the path of the wheelchair. The "is right clear..?" function is called thrice in this case. The broken arrows on the thick line indicate the path followed by the wheelchair.

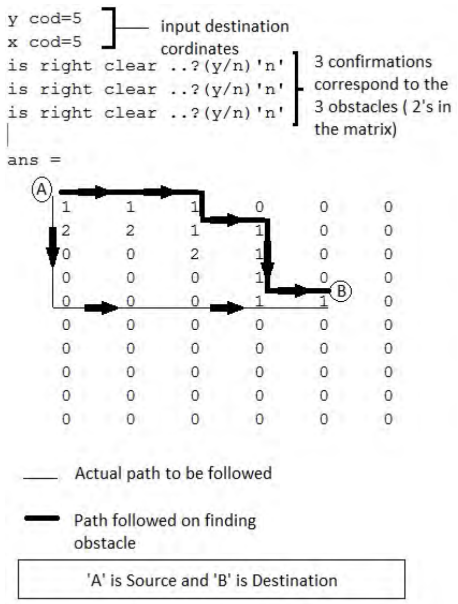

Figure 6. Algorithm testing with three obstacles

VII. CONCLUSION

In a world where now more than 7% of the entire population is suffering from one form of disability or other, a low power, low cost wheelchair navigation system can be very effective in helping these people overcome their difficulty in day to day locomotion. They will be able to cater for their daily needs much more efficiently and without the help of a third person. Moreover, the automatic navigation system proposed in the paper is a low cost system compared to the existing methods of navigation and can be afforded by the masses of a developing country such as India.

ACKNOWLEDGEMENT

We gratefully thank the Almighty God who gave us strength and health to successfully complete this venture. The authors wish to thank Amrita Vishwa Vidyapeetham, in particular the VLSI lab for the support lent out to us in completing this venture.

REFERENCE

[1] L. Montesano, J. Minguez, M. Diaz, and S. Bhaskar, “Towards an Intelligent Wheelchair System for Cerebral Palsy Subjects,” IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2009.

[2] L. Montesano, J. Minguez, and L. Montano, “Lessons learned in integration for sensor-based robot navigation systems,” International Journal of Advanced Robotic Systems, vol. 3, no. 1, pp. 85–91, 2006.

[3] L Montesano, J. Minguez, and L.Montano, “Modeling dynamic scenarios for local sensor-based motion planning,” Autonomous Robots,2008.

[4] J. Minguez and L. Montano, “Nearness Diagram (ND) Navigation: Collision Avoidance in Troublesome Scenarios,” IEEE Transactions on Robotics and Automation, vol. 20, no. 1, pp. 45–59, 2004.

[5] Richard C. Simpson, Simon P. Levine, David A. Bell, Lincoln A. Jaros, Yoram Koren, and Johann Borenstein, NavChair: An Assistive Wheelchair Navigation System with Automatic Adaptation.”

[6] Martinez-Cantin, R., de Freitas, N., & Castellanos, J. A. (2007). “Analysis of particle methods for simultaneous robot localization and mapping and a new algorithm: Marginal-slam.” In *Proceedings of* the IEEE international conference on robotics and automation *(ICRA)*, Rome, Italy.

[7] Jizhong LIU, Hua ZHANG, and Bingfei FAN , Guanghui WANG, and Jonathan WU, “A Novel Economical Embedded Multi-Mode Intelligent Control System for Powered Wheelchair.