RESEARCH ARTICLE OPEN ACCESS

An Fuzzy logic controller based Autonomous Wheelchair Navigation in more complex Environments

*Dr.B.B.M.Krishna Kanth
Professor,Dept of ECE,Anurag College of Engineering,Kodada,Telanga ,India-508206.
*Corresponding author: *Dr.B.B.M.Krishna Kanth*

ABSTRACT
The electric wheelchair for handicapped is used to improve the displacement of disabled persons. An automatic navigation system is needed to ensure greater autonomy and security for the disabled person. Automatic control system is added to a manual control for autonomous displacement. This paper provides the design and implementation details of an autonomous, battery-powered robot that is based on Fuzzy Logic. The handicapped person needs more autonomy and flexibility in the home or in a hospital. The electric wheelchair can assist those with walking disabilities in getting around. In this paper, our purpose is to have an autonomous navigation for the electric wheelchair in the indoor environment. A method based on the use of an intermediate targets before reaching the final target is proposed. The used framework is considered as a structure of a disabled person home. The kinematic model of the robot is determined. Moreover, a fuzzy logic controller is developed. The proposed method is successfully tested in simulations.

Keywords: Electric wheelchair, Fuzzy Logic Controller, Ultrasonic Sensor, Complex environments.

Date of Submission: 24-07-2017 Date of acceptance: 10-08-2017

I. INTRODUCTION

One of the major challenges of the autonomous navigation for mobile robots is the detection and obstacles avoidance during the robot navigation task. This problem can be solved by relating different methods or algorithms in order to attain best results. Fuzzy logic is used in the design of possible solutions to perform local navigation, global navigation, path planning, steering control, and rate control of a mobile robot [1]. Many research literatures used soft computer algorithms to control mobile robots in academic field as well as in the engineering field. Yu et al. used Taguchi method to design an optimized fuzzy logic controller for trajectory tracking of a wheeled mobile robot [2]. Xiong and Qu elaborated a method for intelligent vehicles path tracking with two fuzzy controllers combining with vehicle control direction [3]. Selekwa et al. detailed the design of a preferencebased fuzzy behaviour system for navigating robotic vehicles employing the multivalued logic framework. The proposed technique permits the robot to effectively navigate through cluttered environments [4]. Jia et al. developed a method of fuzzy control of the smart tennis chair using pressure sensors and omnidirectional wheels. The wheelchair can be master of a manual way with joystick device [5]. For this paper, we developed a fuzzy controller for the mobile robot navigation with different desired positions. Then, a second intelligent controller based on fuzzy logic has been developed to achieve the navigation and obstacle avoidance tasks. The latter is provided by infrared range (IR) sensors and the discrete kinematic model. Zero-order Sugeno model is used to develop different fuzzy logic controllers. The implication method is simply multiplication, and the aggregation operator just includes all of the singletons. Each Mobile robot is primarily designed to perform a number of tasks.

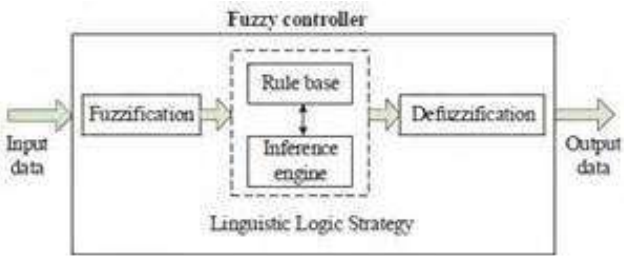

Fig 1: The Fuzzy logic controller.

The task depends on the scope for which the robot has been designed as the medical field which is the case for our work. So that the robot can work, it is necessary to develop systems of perception, localization, path planning or control. The architecture of the robot can be summarized by two tasks (the task of navigation and of localization). The objective of this work is to have an autonomous navigation for the electric wheelchair in the indoor environment. The goal of the wheelchair is to provide an assistance to the user in indoor and outdoor environments and also to drive it with more easily and efficiently. Since the wheelchair is a mobile robot, our research is focused on the study of the autonomous navigation of a mobile robot. The autonomous navigation of a mobile robot in unknown environments is one of the most research area. In fact, to move from a room to another one, it is necessary to take into consideration the positions of each door and the obstacles in the environment. For that, due to complex or long path between the robot and the final target, the use of an intermediate target is proposed to facilitate navigation towards the goal. To prevent the robot from getting trapped in front of an obstacle or wandering indefinitely, the intermediate target is used as a solution for these cases in this work.

II. LITERATURE SURVEY

Previously there are several authors proposes theire methodologies for this.Most of these Mousa T. AL-Akhras, Mohammad O. Salameh, Maha K. Saadeh, and Mohammed A. ALAwairdhi proposes an Fuzzy-controlled Indoor Mobile Robot for Path Following and Obstacle Avoidance .The fuzzy logic controller is a useful tool when we want to emulate the human reasoning and to be closer to human behaviour. Two types of fuzzy logic inference systems exist: Mamdani type and Sugeno type. To develop the fuzzy logic controller Zeroorder Sugeno model is used. Note that the Sugeno output membership functions are either linear or constant. For the zero-order Sugeno model, the output level is a constant. There are several techniques used to aid disabled people and move the wheelchair. In the work of Razali Tomari and al. [1] they propose a method of navigation in indoor environments with presence of humans based on the observation of head information obtained from color and range images. We cited other proposed works in literature, we note The “AGENT-BASED” system proposed by Chung-Hsien-Kuo and all [13]. This control system of electric wheelchair navigation use fuzzy logic. This method composed by different part, then goal-seeking to join the target, obstacle-avoidance and wall-following. Also we cited the "Hephaestus system" developed by Richard C. Simpson and all is mounted on the wheelchair "Everest and Jennings Lancer 2000" [15]. This intelligent wheelchair system uses the Mobility aid to allow an individual to have more mobility and independence when moving.Several methods of localization give the mobile robot position. Then the relative localization [11] is based by using odometers or the inertial sensors. The current robot position is calculated from the knowledge of the initial point, by the integration of information from sensors of displacement, velocity or acceleration. Also the absolute localization used in other works [4], then the principle of this method is based on the use of active or passive tags which are placed in the environment. Usually the active tags are of transmitters (infrared, Laser) and/or receptors (photodiode, camera, ultrasound transducer, radio antenna). Then we cite the method of an indoor localization proposed by Yan Bingbing and al. [2] based on RFID.Also, in the work of Kum Qian and al. [6] they use a unified and probabilistic method for simultaneously localization of a mobile service robot and states estimation of surrounding objects and co-existing people.

III. METHODOLGY TO IMPLEMENT

The displacement of the electric wheelchair is given by the kinematic model defined with equations 1 which Vd is the linear velocity of the right wheel, Vg is the linear velocity of the left wheel, and ω is the angular velocity of the wheelchair. The position of the electric wheelchair is given by three parameters which are the x-coordinate, the y- coordinate and θ the orientation. mobile robot platform is studied. The employed wheelchair is kinematically equivalent to a unicycle mobile robot type. Then, our mobile robot model is a unicycle type which equipped of two free rotating wheels and two independent driving wheels.

$$\begin{cases} \frac{dx}{dy} = \frac{V_d + V_g}{2} \cos\theta \\ \frac{dy}{dt} = \frac{V_d + V_g}{2} \sin\theta \\ \frac{d\theta}{dt} = \omega = \frac{V_d - V_g}{L} \end{cases} \quad \text{……….} (1)$$

The free rotating wheels ensures the static stability of the vehicle. By acting on the speed of each wheel the independent driving wheels can be oriented and commended.

$$\begin{cases} x_k = x_{k-1} + T \frac{V_{dk} + V_{gk}}{2} \cos\theta_k \\ y_k = y_{k-1} + T \frac{V_{dk} + V_{gk}}{2} \sin\theta_k \\ \theta_k = \theta_{k-1} + T \frac{V_{dk} - V_{gk}}{L} \end{cases} \quad \text{……………} (2)$$

Figure 2 shows the used variables in the kinematic model. The configuration of the mobile robot is characterized by the position (X,) and the orientation θ in a cartesian coordinate.

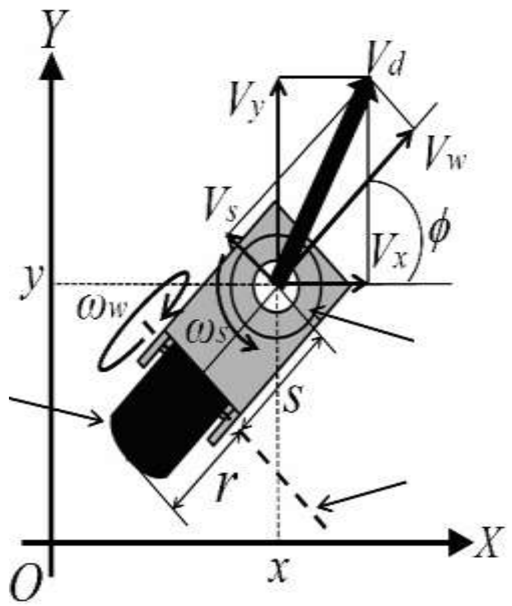

Figure 2. Kinematic scheme of a two-wheeled mobile electric.

Vd,Vg : are respectively the linear speeds of the wheels left and right.

L: is the distance between the two driving wheels.
 : is the angle of the orientation of the robot.
V : is the linear speed of the robot.
(X,Y) is the position of the robot.

A simplifying hypothesis considered for the modulation are :

· The wheel ground contact is a simple point.
· The rolling motion of the robot wheel without slipping.
· The system evolves on horizontal ground.
· The configuration of the mobile robot is described with the three coordinates (x, y, θ).

Where (X, Y and θ) are the robot actual position and
orientation angle in world reference frame. In simulation, we use the discrete form to build a model of the robot. These equations are used to simulate the robot in MATLAB software. Where T is the sampling time. To build a model of the robot, the discrete form is used. The fuzzy logic controller has exploited the information given by the discrete form.

IV. ALGORITHM IMPLEMENTATION

The robot reads sensory data provided through the attached light and the ultrasonic sensors and sends commands to the motors to follow the path and to avoid the obstacles. The general flow of the system is shown in Fig. 3. The aim is to develop an efficient method that allows controlling the wheelchair to reach its goal while avoiding unknown obstacles on its way. The developed approach is based on the fuzzy logic controller and on the intermediate target concept which proposed to facilitate the navigation. Figure. 3 shows the robot navigation environment which supposed a planar surface or anything else.

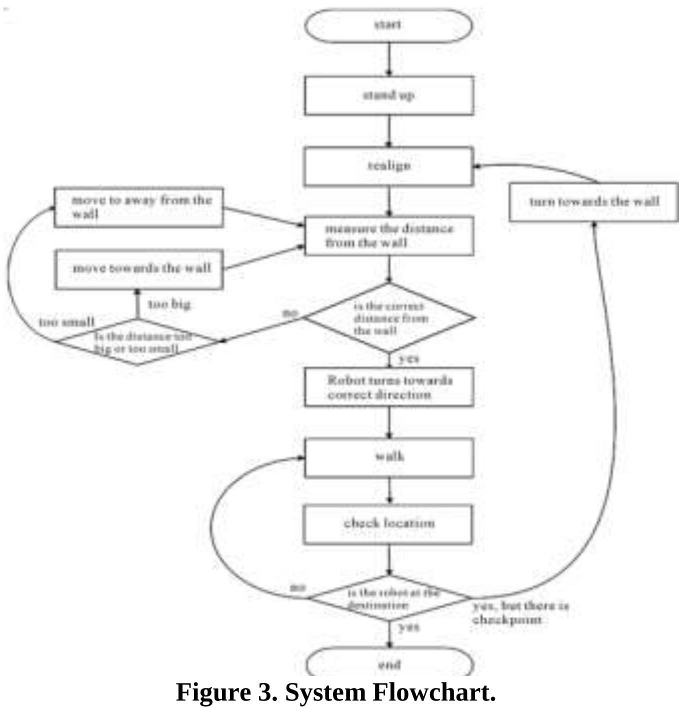

Figure 3. System Flowchart.

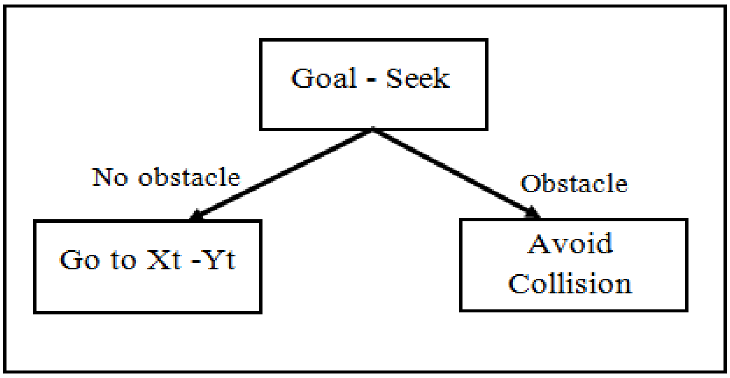

Fig. 4. Navigation behavior of the mobile robot.

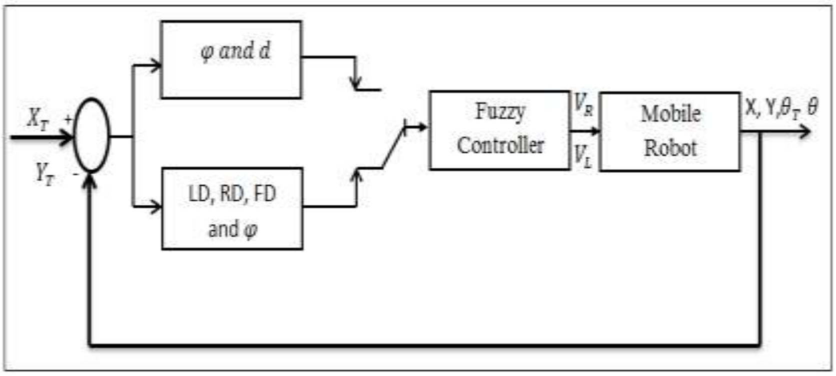

Fig. 5. Block diagram of the robotic system.

The ability to sense the surrounding environment is a fundamental requirement to any autonomous system. The appropriate sensors, able to specify distance to the walls, to the obstacles and to the target, are mounted on the wheelchair. Three steps are considered to create a fuzzy controlled :

· Fuzzification: transform each real value inputs and outputs into grades of membership for linguistic terms of fuzzy sets.
· Rule evaluation: combine the facts obtained from the fuzzification with the rule base and conduct the fuzzy reasoning process.
· Defuzzification : transform the subsets of the outputs to obtain the actual results. The navigation behavior consists of an avoidance behavior and goal-seeking behavior.

Figure. 4 shows a schematic diagram of the navigation behavior. The mobile robot should be equipped with sensor system to detect obstacles. In our application, an ultrasonic sensor is selected. The ultrasonic gives information that can be used to calculate the distance between the robot and the obstacles. The navigation control process start with the obstacle detection that may collide the robot. This is accomplished by a set of three ultrasonic sensors mounted on front of the robot. The sensors are located at left, right, and front sides of the robot. The distances obtained from these equations can be exploited by the fuzzy controller to avoid obstacles. Hence, the inputs of the controller measured by the ultrasonic sensors are the left distance (LD), the right distance (RD) and the front distance (FD) see Figure 6. The output variables are the speed of the left and the right wheels. The measured distances and angle is received by the fuzzy controller. Based on these data, the controller can change the actual trajectory to avoid the obstacle. Therefore, the objective of the fuzzy control system is to enable the robot to navigate from a start position to a goal position without collisions. Figure. 5 illustrates the block diagram of the robotic system. Before the robot moves ahead, the position of the desired target is checked. Afterward, an appropriate intermediate target is chosen.

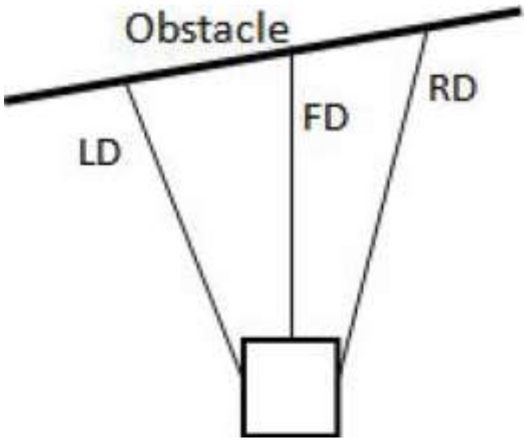

Fig. 6. The distances measured by the ultrasonic sensor.

V. SIMULATION RESULTS

We focus now on the simulation results obtained by the particle filter for the mobile electric wheelchair localization. The first simulations consist of a linear displacement of 3000 mm the initial start point coordinates are) and the end point are. Two obstacles are placed on y=750mm and y=500. We performed the simulation of the particle filter with 1000 particles. Figure 7 shows us the result obtained by applying the fuzzy controller to join target and localization method with particle filter. The black cross on the curve position, show particles having the highest weights. We notice the decrease of the particle"s cloud which is due to the resampling. When a large number of particles deviate from the path, the estimated data may be incorrect.

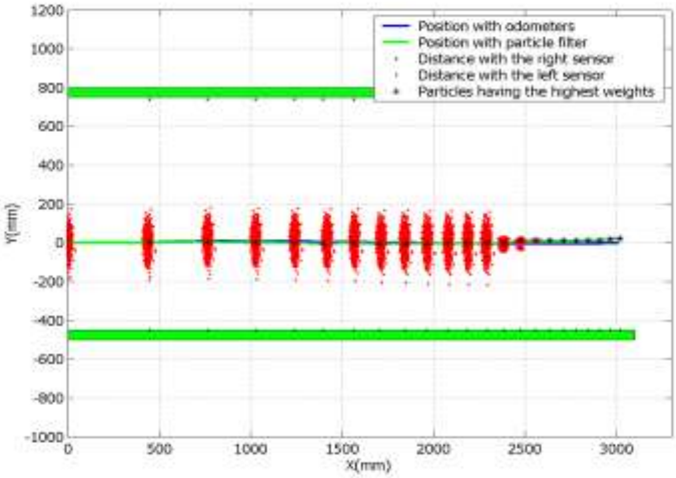

Figure 7. Simulation of particle filter with target (x=3000mm, y=0 mm).

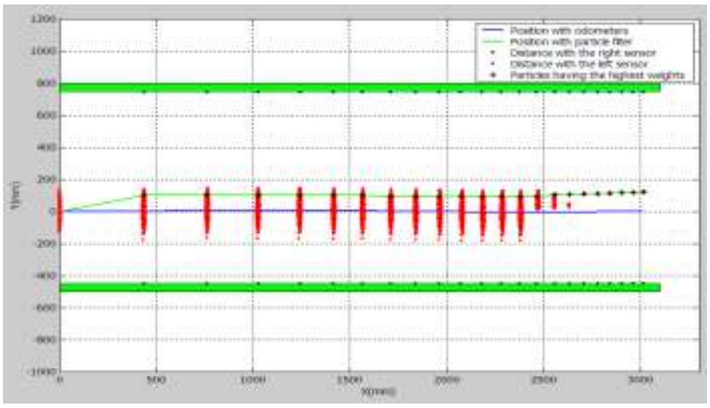

Figure 8. Simulation of particle filter with real start position (x=0mm, y=100 mm).

The role of resampling is to overcome this problem by removing the particles with low weight and duplicating those with high weight. Therefore the number of particles must be sufficient to avoid the divergence of the filter. But by increasing the number of particles the calculation time increase too. Therefore, it‟s necessary to have compromise between the number of particles to perform filtering and the calculation time. Figure 7 represent the simulation result using the ideal initial condition and the measure of displacement not affected by the error. The fuzzy controller permits to electric wheelchair to join the target. The localization by the particle filter is the same with odometers.
The purpose of this second simulation is to evaluate the performance of particle filter using data from ultrasonic sensors and odometers. We consider now the start position(x=0mm , y=0mm), but in reality it is (x=0mm, y=100mm). The real information obtained only by the ultrasonic sensors. The result shows a good localization using the particle filter. Indeed, the particle filter could correct the odometer's errors especially during wheel rotation. The green curve represents the position obtained with particle filter. The blue curve represents the position obtained with odometers. The third simulation represented by figure 9. We consider now the start position (x=0mm , y=0mm), but in reality it is (x=0mm, y= -100mm). In these simulations we managed to apply the data fusion using data from exteroceptive sensors and odometric information. The simulation results show that the particle filter method improves the localization. The results are more precise.

VI. CONCLUSION

And this paper study the autonomous navigation of an electric wheelchair in indoor environment. The proposed algorithm gives the shortest path and the control strategy that lead the robot to the target. The kinematic model of the robot system is determined. Moreover, the navigation fuzzy controller and the concept of intermediate target are introduced. Finally, the simulation results show that the proposed method can achieve a successful navigation with short execution time and path. This article treats the problem of sensor's data fusion for the localization of a mobile robot main issue is to use a localization algorithm which must correct the errors of the sensors in order to return the estimated configuration close to the actual one. After verifying the correct functioning of the particle filter in the simulation part we preceded with experiments to evaluate the performance of this filter. The particle filter is an efficient method for resolving the problem of localization. Finally, the particle filter gives the accepted result and improves the performance of the fuzzy controller to join a real target position and the obstacle avoidance.

REFERENCES

[1]. R. Tomari, Y. Kobayashi and Y. Kuno,"Socially Acceptable Smart Wheelchair Navigation From Head Orientation Observation", International journal on smart sensing and intelligent systems, vol 7, No. 2, June 2014, pp. 630-643.

[2]. Y. Bingbing, R. Wenbo, Y. Bolin and L. Yang, "An Indoor Positioning Algorithm and its Experiment Research Based on RFID", International journal on smart sensing and intelligent systems, vol 7, No. 2, June 2014, pp. 879-897.

[3]. M. Njah, M. Jallouli, "Wheelchair Obstacle Avoidance Based on Fuzzy Controller and Ultrasonic Sensors", IEEE International Conference on Computer Applications Technology „ICCAT‟2013‟, 20-22 January, 2013, Sousse, Tunisia, S/N 106.

[4]. Y. Qingwei, Y. Debin, Z. Yu and W. Xiaodong, "Particle Filter on Nonlinear Vibration Signal of Bridge Stayed Cable", International journal on smart sensing and intelligent systems, vol 5, No. 4, December 2012, pp. 940-956.

[5]. D. Dias, R. Ventura, "Absolute Localization for Low Capability Robots in Structured Environments Using Barcode Landmarks", Journal of Automation, Mobile Robotics & Intelligent Systems, vol 7, No. 1, 2013, pp. 28-34.

[6]. K. Qian, X. Ma, X. Dai, F. Fang and B. Zhou, "Probabilistic Joint State Estimation of Robot and Non-static Objects for Mobile Manipulation", International journal on smart sensing and intelligent systems, vol 5, No. 4, December 2012, pp. 1081-1096. [7] M. Njah, M. Jallouli and N. Derbel, "Optimal Fuzzy Controller for the Navigation of an Electric Wheelchair", Transactions on Systems, Signals and Devices TSSD, Vol. 6, No.1, 2011, pp. 93-109.

[7]. T. K. Dakhlallah, M. A. Zohdy, "Type-2 Fuzzy Kalman Hybrid Application for Dynamic Security Monitoring Systems based on Multiple Sensor Fusion", International journal on smart sensing and intelligent systems, vol 4, No. 4, December 2011, pp. 607-629.

[8]. L. Brethes, F. Lerasle, P. Danes and M. Fontmarty, "Particle Filtering Strategies for Data Fusion Dedicated to Visual Tracking From a Mobile Robot", Springer, Machine Vision and Applications, vol 21, No. 4, October 2010, pp. 427-448.

[9]. M. Njah, M. Jallouli, "Synthesis of a Fuzzy Controller for the Navigation of an Electric Wheelchair for Handicapped", IEEE 6th International Multi-Conference on Systems, Signals and Devices, „SSD'09", 23-26 March, 2009, Djerba, pp. 222-226.

[10]. J. Pugh and A. Martinoli," Relative Localization and Communication Module for Small-Scale Multi-Robot Systems", International Conference on Robotics and Automation „ICRA", 15-19 May, 2006, Orlando, Florida, USA, pp. 188-193.

[11]. S. Sarrka, A. Vehtari, J. Lampinen, "Rao-Blackwellized Particle Filter for Multiple Target Tracking ", Elsevier, Journal Information Fusion, Vol. 8, No. 1, January 2007, pp. 2-15.

[12]. Mousa T. AL-Akhras, Mohammad O. Salameh, Maha K. Saadeh, and Mohammed A. ALAwairdhi," An Autonomous Fuzzy-controlled Indoor Mobile Robot for Path Following and Obstacle Avoidance"INTERNATIONAL JOURNAL OF COMPUTERS Issue 3, Volume 5, 2011.

International Journal of Engineering Research and Applications (IJERA) is **UGC approved** Journal with Sl. No. 4525, Journal no. 47088. Indexed in Cross Ref, Index Copernicus (ICV 80.82), NASA, Ads, Researcher Id Thomson Reuters, DOAJ.

*Dr.B.B.M.Krishna Kanth "An Fuzzy logic controller based Autonomous Wheelchair Navigation in more complex Environments." International Journal of Engineering Research and Applications (IJERA) 7.8 (2017): 66-72