Fuzzy Logic Based Wheelchair

Dr. Rama Rao PVV
Professor and Head of EEE Department
Shri Vishnu Engineering College for Women,
Bhimavaram, A.P., INDIA
pvvmadhuram@gmail.com

Ms. Sai Spandana P.
IV B.Tech, EEE
Shri Vishnu Engineering College for Women,
Bhimavaram, A.P., INDIA
saispandana.pappula@gmail.com

Abstract: An intelligent controller for a wheelchair means smart motorized wheelchair may provide independent mobility for the people with physical, perceptual, or cognitive deficits. The control system algorithm designed for this smart model is based on the fuzzy logic control theory and its main purpose is to augment the user ability to navigate the wheelchair and will provide a safe and comfortable journey to the user. Smart wheelchair provides mobility to the needy in a number of different ways, such as autonomously transporting the user between locations assuring collision-free travel and aiding the performance of specific tasks. This paper presents how fuzzy logic is employed for controlling wheelchair, resolve conflicting perceived information and plan the best path.

1. Introduction

Several smart wheelchairs have been developed till today and the researchers have used different methods and technologies to control the wheelchair. But quite a few technologies have made the transition to a commercial product. Smart wheelchairs, from control point of view, can be divided into three groups; a) Autonomous, b) Semi-Autonomous, c) Autonomous and Semi-Autonomous mode.

A smart wheelchair typically consists of either a standard power wheelchair to which a computer and a collection of sensors have been added or a mobile robot base to which a seat has been attached. It assists the user with a disability or person who is unable to operate a regular power wheelchair and to reduce or eliminate the burden of driving [1]. Various Control techniques such as path-planning, artificial reasoning, and behaviour based control are being used to replace manual control of the wheelchair [2]. Independent mobility is critical to individuals of any age. Children without safe and independent mobility are denied critical learning opportunities, which place them at a developmental disadvantage relative to their self-ambulating peers [3]. This will often produces a cycle of deprivation and reduced motivation that leads to learned helplessness [4].

Adults who lack an independent means of locomotion is less self-sufficient, which can manifest itself in a negative self-image and self-esteem [5]. A lack of independent mobility at any age places additional obstacles in the pursuit of vocational and educational goals [6], and while the needs of many individuals with disabilities can be satisfied with power wheelchairs, some members of the disabled community find operating a standard power wheelchair difficult or impossible. Different input methods have been used for smart wheelchairs ranging from the traditional input methods such as joystick and switches to the more advanced techniques such as touch screen interfaces [7] and voice recognition [8].

2. Smart wheel chair

In a conventional electric power wheelchair as shown in figure 1 a joystick or any user interface system (switches, touch screen displays, etc.) is linked to the wheelchair main controller (which acts as a motor controller) and the controller is connected to the two motors. Batteries are also connected to the controller, providing the necessary power for the system. The user selects the desired speed and direction using the joystick and the controller drives the motors based on the signal received by the joystick.

In the proposed system as shown in figure 2 however, the connection between the joystick and the controller was interrupted by inserting an embedded microcontroller in between them. There are also multiple sensors added and interfaced to the embedded microcontroller. The user chooses the direction and speed with the joystick, the joystick sends the information to the embedded microcontroller and the microcontroller checks it's surrounding with the help of the sensors and then corrects and alternates the joystick signals if necessary based on the control system algorithm before sending it to the motor controller. So if the user selects a direction and speed but there is an obstacle in the way the microcontroller will change the initial direction and speed so the wheelchair can avoid possible collisions.

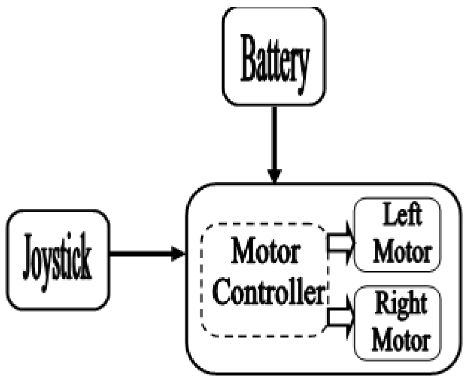

Figure 1. Electric power wheelchair block diagram

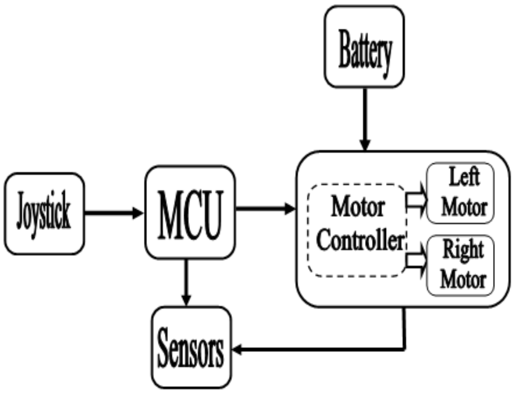

Figure 2. Proposed prototype system block diagram

3. Fuzzy Logic Control

Fuzzy logic is a form of many valued logic that deals with type of reasoning that is robust and approximate rather than brittle and exact. In contrast with "crisp logic", where binary sets have two valued logic (0 or 1); fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. A form of reasoning, derived from fuzzy set theory, doesn't need to be exactly zero (false) or one (true), but rather can be zero, one, or any value in between. Fuzzy logic is designed for situations where information is inexact and traditional digital on/off decisions are not possible. It divides data into vague categories such as "hot", "medium" and "cold" called linguistic variables. Fuzzy logic differs from conventional control methods because incorporates a simple, rule-based IF X AND Y THEN Z approach to a solving control problem rather than attempting to model a system mathematically. The fuzzy logic model is empirically-based, relying on an operator's experience rather than their technical understanding of the system.

Fuzzy sets are sets whose elements have degrees of membership (DOM) .There are different ways to map the data into fuzzy sets such as Gaussian membership function, singleton membership function, triangular membership function, etc. The membership function is a graphical representation of the magnitude of participation of each input. It associates a weighting with each of the inputs that are processed, define functional overlap between inputs, and ultimately determines an output response. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion. A Fuzzy Inference System (FIS) as shown in figure 3 is a way of mapping an input space to an output space using fuzzy logic. A FIS tries to formalize the reasoning process of human language by means of fuzzy logic (that is, by building fuzzy IF-THEN rules). Rules form the basis for the fuzzy logic to obtain the fuzzy output. The inference engine combines If-Then type fuzzy rules and converts the fuzzy inputs to the fuzzy outputs.

Once the functions are inferred, scaled, and combined, they are defuzzified. Defuzzification process is the opposite of fuzzification which means converting the fuzzy output to crisp values.

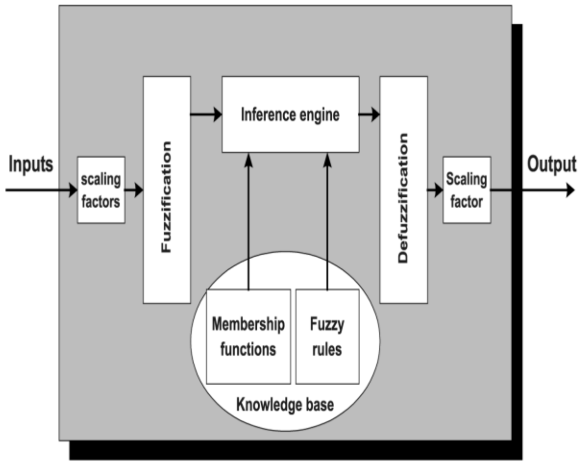

Figure 3. Fuzzy controller block diagram

Various steps involved in the controller design are given below.

Step 1 is to set the control objectives and criteria. Depending on the requirement of output (response) and estimating the failures the type of control is to be selected.

Step 2 is to obtain the input and output relationships and decide a minimum number of variables for input to the fuzzy logic system.

Step 3 is forming the rule-base of fuzzy logic, using IF – THEN rules that gives the desired output/ system response for given input. The complexity and number of rules depends on the number of input parameters that are selected and the number of fuzzy variables associated with each parameter.

Step 4 is choosing fuzzy logic membership functions that define the meaning and values of Input/output terms used in the rules.

Step 5 is creating the necessary pre- and post-processing fuzzy logic routines or program rules into the fuzzy logic system.

Step 6 is to test the system, evaluate the results, tune the rules and membership functions, and retest until satisfactory results are obtained.

4. Application of Fuzzy logic to wheelchair

Fuzzy logic control has been used to design the controller for the motorized wheelchair shown in figure 4. The proposed system has nine inputs consisting of eight sonar sensors distance inputs and one joystick direction input. The fuzzifier converts each crisp input values to linguistic variables which are described by fuzzy sets. In our system each input is fuzzified using triangular membership function method. The main reason for using the triangular membership function is that it will be easier when transferring them to the microcontroller and embedded language.

The joystick is fuzzified to five membership functions each representing a direction selected by the user. The linguistic terms used in this fuzification are rearL (Rear left direction), left, front, right, and rearR

(Rear right direction). The input output membership functions are designed from the experience, other similar projects, and mostly the simulation results.

Mamdani's method is been used to design the system which is the most commonly used in applications, due to its simple structure of 'min-max' operations. Rules are given in Table 1. Min operation has been used for the fuzzy AND method and the fuzzy implication. Max operation has been used for the fuzzy OR method and the fuzzy aggregation.

Table 1: The smart wheelchair control system rules

Rule No.	Direction	N	M	F	V	Direction
1	Front			**S0** **S1**	F	Front
2	Left			**S4**	F	Left
3	Right			**S5**	F	Right
4	Left	**S4**			S	Right
5	Right	**S5**			S	Left
6	Front	**S1**			S	Left
7	Front	**S0**			S	Right
8	Left	**S2**	**S0**		M	Right
9	Right	**S3**	**S1**		M	Left
10	Left	**S2**			S	Right
11	Right	**S3**			S	Left
12	Front	**S0** **S1** **S2** **S3**			S	Rear right
13	Front	**S2**			S	Right
14	Front	**S3**			S	Left
15	Rear left	**S6**			S	Right
16	Rear Right	**S7**			S	Left
17	Rear left			**S6**	F	Rear left
18	Rear Right			**S7**	F	Rear right
19	Rear Left	**S6** **S7**			S	Right
20	Rear Right	**S6** **S7**			S	Left
21	Front	**S3**			S	Left
22	Front	**S2**			S	Right
23	Front	**S3**	**S1** **S5**		S	Rear left
24	Front	**S2**	**S0** **S4**		S	Rear right

Sensors abbreviations:

N – Near; *M* – Middle; *F* – Far

Output speed abbreviations:

S – Slow; *M* – Medium; *F* – Fast; *V* – Speed

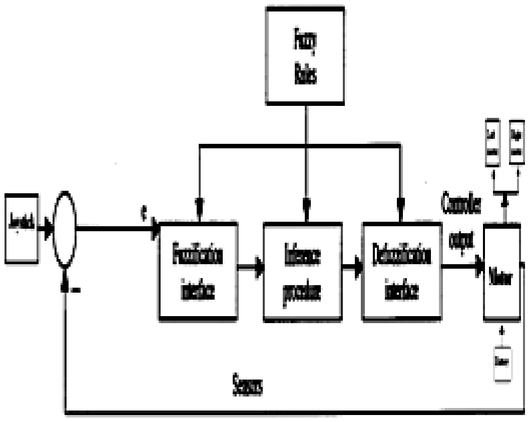

Figure 4. Fuzzy controlled wheel chair

To convert the output into crisp value i.e. for Defuzzification Centroid method is the most widely used method which has been also used in this system. Centroid Defuzzification returns the center of area under the curve. It also been called as center of gravity or center of area method.

5. Simulation Results

MATLAB is an interactive program for numerical computation and data visualization. It is used extensively by control engineers for analysis and design.

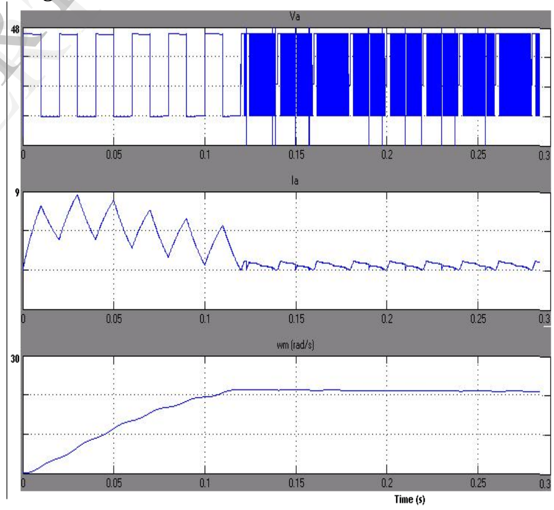

Figure 6. Motor output

MATLAB fuzzy logic toolbox was used to design the controller for the system. The fuzzy controller then was integrated to the Simulink environment along with the motor of the wheelchair model to test the validity of the designed system.

6. Conclusion

In this paper, fuzzy logic controller for speed control of motorized wheelchair is proposed. The simulation results demonstrate the fuzzy logic control for smooth operation of wheelchair. In the future work, more functions will be developed in order to make our wheelchair intelligent and adaptive to environment changes.

References

[1] Richard C. Simpson, ―Smart wheelchairs: A literature review‖, Journal of Rehabilitation Research & Development. Volume 42, Number 4, Pages 423–436 July/August 2005.

[2] Smart wheelchair, Wikipedia, http://en.wikipedia.org/wiki/Smart_wheelchair‖. [Accessed: 23 Sep. 2009].

[3] Rosenbloom L., "Consequences of impaired movement: a hypothesis and review. In: Movement and child development", Holt KS, editor. London, England: HarperCollins; 1975.

[4] Gignac MA, Cotta C, Badley EM., "Adaptation to chronic illness and disability and its relationship to perceptions of independence and dependence. J Gerontol B Psychol Science Society, 2000.

[5] Wright BAP. Physical disability—A psychosocial approach. New York: Addison-Wesley; 1983.

[6] Richard Simpson, Edmund LoPresti, Steve Hayashi, Illah Nourbakhsh, David Miller, "The Smart Wheelchair Component System", Journal of rehabilitation research & develop. May/June 2004.

[7] Abigail Drury, Rittika Shamsuddin, Melissa Frechette, Audrey Lee St. John, Dan Barry, William Kennedy, "Autonomous Wheelchair", wiki.cs.mtholyoke.edu/mediawiki/rmc_images/6/64/Spaulding10.ppt. [Accessed: 15 July 2009].

[8] Gabriel Pires and Urbano Nunes, "A Wheelchair Steered through Voice Commands and Assisted by a Reactive Fuzzy-Logic Controller", Journal of Intelligent and Robotic Systems 34: 301–314, 2002.

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