Wheelchair Ramp Boarding Supporter for Public Bus Transportation Service using RFID and Fuzzy Proportional plus Integral Control System

Songkran Kantawong

1 Department of Electronics and Telecommunication Engineering, Bangkok University Rangsit Campus
9/1 Moo 5 Phaholyothin Road, Pathumtani 12120, Thailand

Abstract. This paper presents the development of wheelchair ramp lift boarding supporter system that is applied for wheelchair passenger accessible on public transport bus service system (WCPB) which is the first step to develop a wheelchair user guide for more safety and comfortable to public transit services system that can be benefited to support a person with disabilities on wheelchair in urban bus stop service areas. A RFID reader is installed on the side of the bus to read the wheelchair RFID tag and sent it on wire line or wireless transceiver channel to display on monitor or ramp lift automatically operation by computer command. This RFID technique deals with multi-wheelchairs that it provides an efficiency time management scheme with correct data reporting, in which a dynamic time schedule is worked out in real time for the bus driver or user of each wheelchair boarding situations. The ramp lift mechanisms are controlled by fuzzy proportional plus integral controller (F-PI) functions which installed on PLC that applied to generate an adequate setting voltage for controlling signal acted to maintain a wheelchair ramp lift operation processes in a specific state. By unknown the wheelchair passenger’s weight and velocity, the fuzzy proportional plus integral controller can be used to solve this kind of problems that the main advantage of fuzzy logic is that no mathematical modeling is required but can be achieved higher performance with effective tuning parameters in initial setting status. The proposed ramp lift design described here takes an advantage of single link lift to gain the geometrical criteria that shorter ramp lift dwell time while still maintain electric or manual wheelchair user easily used by them self. By applying the proposed method, performance has been improved which indicated that the wheelchair mechanism can work well and satisfied the design concept for computer simulation with fuzzy ladder plus PI controlled while the RFID tags of each wheelchairs data are more correctly data recorded and can be send this correct data to the bus driver’s monitor to make a decision for ramp lift operation via on wire line or wireless transceiver channel simultaneously.

Keywords: Wheelchair ramp lift, RFID, fuzzy PI, fuzzy ladder, CDM, public bus transport service

1. Introduction

The RFID solutions [1] in the fields of transit intelligent transportation system [2] started more recently and increase rapidly especially in the topic of automatic vehicle identification (AVI) system. Public transportation is a key lifeline to independent, opportunity and sustainability for many people with disabilities [3]. A major challenge of the urban public bus transport service for wheelchair user is that developing an automatic wheelchair boarding supporter system that have been safety [4], reliable and affordable for transportation services [5]. One of the key elements of wheelchair passengers are requires a comfortable boarding lift to get on the bus, safety travelling time and get off easily. Conventional public bus transports with high floor are not responsible for wheelchair user because their have high ramp slope between the road and bus’s stairs, unreliable and more complexity lift mechanism operated, while lower floor buses are more easily used for this objective, but not cover for all transportations. The process performance of the wheelchair mechanism operation was evaluated by a solid works simulation, while the mathematically analysis are done for fuzzy PI controlled by computer processing unit. Finally, the wheelchair RFID solution and fuzzy PLC functions were tested in the laboratory room. The remaining of this paper is organized as follows. Section II proposed the wheelchair boarding supporter mechanism designed and described for conventional public bus transport operation system. Section III described for RFID installation. Section IV provides the fuzzy proportional plus integral controller. Section V illustrates the experimental results and finally section VI for conclusions.
2. Proposed of ramp lift wheelchair on Semi-Low Floor Public Bus Transportation System

2.1 Wheelchair Bus Space Standard

The wheelchair’s space that was occupied by wheelchair user on a public bus must be considering with the majority problems about the enough of dimensions space that have more than 700 mm wider or 1200 mm longer or 1600 mm higher and very heavy weight. For more safety this will be required some conditions about handhold, an adjustable curb climbers, protection behind seat or wheelchair locks. The COST 322 recommendation [5] for the wheelchair space in a low floor bus service was referred in this proposed model.

2.2 Wheelchair ramp lift design

The wheelchair ramp lift boarding supporter designed here has 50-70 cm. long drove by two 24VDC electric wound motors that are installed for vertical axis and horizontal axis controlled which are linked by gear box joints. The ramp lift operations are mainly composted of three steps. First, an automatic detected wheelchair passenger by RFID reader at the side of the door and then the cover sheet of stair will be lift up. Second, the thin plat sheet that act as a ramp was slide out side the bus and supported on the boarding road floor and then the wheelchair was kept into the bus. Finally, the security wheelchair lock is done by two roller bars in the wheelchair safety area simultaneously by COST 322 recommendation. In getting on process, the ramp is lifted up by vertical motor from the initial state and expands outside the bus by horizontal motor until the ramp is aligned up as straight line in the same level of the top of stair floor or bus floor level and then lay down smoothly to the floor and boarding on the road, next the thin plate at the end side of the ramp is laid down for wheelchair climb easily by link mechanism operation.

3. Transit System Module and RFID installation

The RFID Mifare Read/Write Module SL015M-1 was selected to use for high frequency range about 13.56 MHz, UART interface, baud rate about 9,600-115,200 bps depend on protocol ISO 14443A (Mifare) that supporting for Tag Mifare 1Kbyte, Mifare 4Kbyte, Mifare Ultra Light with built in antenna. By using passive RFID tags, the identification range can reach 80 mm. long with 0.5 m/sec speed and certain models are susceptible to moisture and ambient temperature ($-20^\circ C - 70^\circ C$) in operating process. The RFID wheelchair described here takes an advantage of RFID system [6] that non-contact data communication is possible which can read and write data on a tag via radio waves or electromagnetic waves. It consists of a tag (data carrier, ID card) with data store which having a capacity enough to record more information than
identification codes, an antenna which communicates with the tag, a controller which controls the antenna, higher-level equipment (system) which controls the controller and small size enough to carry around or to use by attaching on an object. The tag can be read even if the position or angle of the tag and antenna is not proper. The data signal from RFID tag can be read by RFID reader with enough efficiency media channel and not obstacle signal in line of sigh even if they are passed by air, water, plastic, mirror and etc.

Fig. 4: RFID Mifare Read /Write module with ID Tag and RFID transit station model.

The transit system model is composed of road ways, traffic lights, pedestrian lights, vehicle sensing modules and RFID reader station as shown in figure 4. The RFID tags were installed on vehicles that transit on the conveyor belt drove by DC motor, while RFID reader/ writer run on wheelchair in detection area and can be done even if the vehicle module were fixed position or movable not quickly. The car model with RFID tag (wheelchair) can be detected and identified when its pass to the RFID station located in transit system model via on wire line or Wi-Fi channel to client computer. The essential data from this tag are composed of reading number, car ID (wheelchair ID), location of RFID station and time of record.

4. Fuzzy Proportional plus Integral (F-PI) Controller Design

The aim of a fuzzy PI controller is to reach a setting motor drive voltage control [7] of ramp lift wheelchair boarding supporter process rapidly, smoothly and reduce steady state error in a specific state and can embody better behavior comparing with the classical linear PI controller because of its non linear characteristics. Fuzzy PI controllers are quite simple and widely used in practice which provides similar results to conventional controllers but the main problems are the adjustment of its initial setting parameters. To improve system behavior and system time varying response it is necessary to well tuned fuzzy controller that can be also more stable and more robust. The system parameters need to be tuned can be approximately adjusted by using known rules for classical controller, so the initial setting adjustment of fuzzy controller are assumed to have an initial symmetrical layout and used for Coefficient Diagram Method (CDM) tuning methods to verify this problems, the fine tune method is evaluated in final time. The time response of wheelchair motor drive was acted as load curve change of DC motor even if it appear the dynamic change in transients state and the DC motor parameters in the conventional transfer function are defined below.

\[
\frac{C(s)}{R(s)} = \frac{0.01(k_p + k_i/s)}{0.01(k_p + k_i/s) + 0.05s^2 + 0.06s + 0.1001} \quad (1)
\]

For more accuracy response of speed and torque controlled when load are changed or loading effect, the fuzzy logic are selected to modified the conventional PI controller by Fuzzy PI controller as below.

Fig. 5: Closed loop system simulation results between conventional PI and fuzzy PI controller via on CQM1 PLC with fuzzy ladder control (Step response simulation with Math Lab).

The linguistic fuzzy sets parameters of two inputs F-PI are designed for trapezoidal and triangular membership functions of Mamdani in Max-Min interference method. First, the linguistic levels assigned to the input variable error \( e(t) \) of the system is obtained by different between the input and the output of the process and next for the change in error \( de(t)/dt \) are in general fuzzy set as NB: Negative Big, NS: Negative Small, Z: Zero, PS: Positive Small and PB: Positive Big. While the F-PI controller output sets is defined in the same abbreviations. Interference method is Max-Min using the trapezoidal and triangular membership functions when the singletons are used to verify the vertex of the fuzzy membership functions.
while the defuzzification using the triangular membership function with COG method. The validity of these F-PI tuning parameters in this paper will be setting by the CDM method that is widely used to tuning parameters process designed which give the good controller performance both in the transient state and steady state time response. The CDM transfer functions by undetermined coefficient are express below.

\[
P(s) = a_n \left( \sum_{j=1}^{n} \prod_{i=1}^{j-1} \frac{1}{\gamma_{i,j}} \right) \left( s \gamma^2 + \tau \gamma \right)
\]  
(2)

Where \( \gamma_i \) is stabilize index, \( \tau \) is time constant, \( t_i = 2.5 \tau \) and \( \gamma_{n+1} = \cdots = \gamma_1 = \gamma_2 = 2, \gamma_1 = 2.5 \) for the stabilize criteria. For made a comparison between conventional PID and CDM in the undetermined coefficient terms are computed step by step. These initial parameters have been test for several system time responses for seeking the optimum initial values that suitable for the transfer function of this process control which percent overshoot (%PO) was less than 5% as shown below.

\[
k_p = 35, k_i = 48
\]  
(3)

The fuzzy ladder control [8] are widely used for step by step controlling process, the fuzzy interference rules (Max-Min) that relatively with two inputs and two outputs are designed for six rules based. The outputs of ramp speed motor and roller lock voltage control are done by defuzzification method with the center of gravity (COG). The overshoot of ramp speed motor and roller lock motors are less than 5%, setting time are in a few 2-3 seconds and steady state error are quite smaller because of F-PI influent controlled behavior.

5. Experimental Results

The wheelchair ramp lift simulation results with solid works program are shown in figure 6 for step by step until wheelchair was kept on the bus already (getting on step and getting off step). While the performance of RFID tags/reader was evaluated by the Microsoft SQL Server 2005 program. RFID Mifare Read/Write Module SL015M-1 is processed on specification Pentium(R) 4 CPU 3.01 GHz shown in table 1.

![Fig. 6: The simulation of wheelchair ramp lifts mechanism in original step to the last step.](image)

Table 1: Experimental results of RFID wheelchair model detection and F-PI on PLC fuzzy ladder control system (S is for ramp speed motor and R is for roller rock motor, while Acc. is for % accuracy)

<table>
<thead>
<tr>
<th>Wheelchairs</th>
<th>RFID Tags (Five time of each room laboratory results)</th>
<th>Output (VDC)</th>
<th>Acc. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RFID reader</td>
<td>Correct</td>
<td>% Correct</td>
</tr>
<tr>
<td>BE C3 39 39 38 B5 C3 FF FF FF FF FF FF FF FF FF</td>
<td>5</td>
<td>100</td>
<td>24</td>
</tr>
<tr>
<td>A1C1 31 31 32 32 C0 A1 FF FF FF FF FF FF FF FF FF</td>
<td>5</td>
<td>100</td>
<td>24</td>
</tr>
<tr>
<td>CE C4 40 40 37 37 C4 E0 FF FF FF FF FF FF FF FF FF</td>
<td>5</td>
<td>100</td>
<td>24</td>
</tr>
<tr>
<td>EE C5 41 41 39 35 C5 FF FF FF FF FF FF FF FF FF</td>
<td>5</td>
<td>100</td>
<td>18</td>
</tr>
<tr>
<td>CE C1 32 32 33 33 C2 FF FF FF FF FF FF FF FF FF FF</td>
<td>5</td>
<td>100</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Average correction results (%)</td>
<td>100</td>
<td>95.00</td>
</tr>
</tbody>
</table>
The information of each wheelchair can be read and store in RFID tags by RFID software solution that developed for supporting this object and then sent this data to the bus driver’s monitor or traffic administration center via communication networks (internet network) both for wire line or wireless channel. The outputs voltage are controlled by fuzzy ladder control are satisfied selecting the adequate control actions to drive the ramp lift mechanical. This means that the performances of the all system are quite well and satisfied the design concept but for more accuracy results its must be improved for more efficiency in many wheelchair examples and perform many simulation experiments about differential loads until the acceptable values are found in practical use with a real public bus transport service for wheelchair guideline users.

6. Conclusions

In this paper, we proposed the development of RFID solution applied for the new design of wheelchair ramp lift boarding supporter with fuzzy PI control that suitable for wheelchair accessible easily on semi-low floor public bus transportation service and have better performance than conventional ramp in the same conditions. The RFID reader can be read correctly data enough that are in general more effective than a real environmental transit system, but must be improved for more efficiency detection range such as in 3-10 m. of RFID reading range with microwave frequency range that can be installed easily in any where of transit area. For more accuracy of wheelchair ramp lift position the fuzzy ladder PI controller was selected to control the setting DC voltage supply to the ramp lift motors both for vertical and horizontal ramp axis. The room experimental results were revealed that the proposed method was evaluated more effective than a real environmental. This means that the performance of wheelchair ramp lift operation must be improved for more efficiency in the disturbance situations such as wheelchair waiting time effect or load boarding effect.

7. Acknowledgements

Department of Electronics and Telecommunication Engineering, Bangkok University, Thailand.

8. References