Automated E-Chair Controlled using Hand Gesture and Smartphone Application

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Abstract - Persons with Disability (PWD) face problems moving unaided so they use the wheelchair. The researchers' aimed to develop “Automated E-Chair Controlled using Hand Gesture and Smartphone Application” to help orthopedic PWD’s move independently. It is significant to PWDs, patients, caretakers, hospitals, the government, and future researchers. For methodology, data gathering, interview, survey, and Agile model was used. Arduino microcontroller-based embedded system to control the wheelchair’s motion using hand gestures and Smartphone Application was developed using MIT software. 5 IT Experts, 5 Clinical Instructors, 5 PWDs and 35 End-users evaluated it using Five-point Likert Scale based from ISO 9126. Overall Weighted Performance Evaluation of Respondents was a mean of 4.12, End Users’ evaluation 4.28, IT Experts’ Evaluation 4.0, Clinical Instructors’ and PWD’s evaluation 4.1. All marks were Very Acceptable. We recommend its implementation subject to service and maintenance issues for user satisfaction being considered, as well as clinicians proposed practices on wheelchair prescription and use.

Keywords - automated, hand gesture, smartphone, microcontroller, embedded system

I. INTRODUCTION

In the Philippines, physical handicap is one of the social issues influencing a segment of the Philippines’ population. To guarantee the fairness and privileges of handicapped people, there are Philippine laws and arrangements that were passed in regards to people with disabilities (PWDs). There are likewise various non-government affiliations that try to empower and help to enhance the prosperity of individuals with handicaps.

Persons with Disability Affairs Office (PDAO) located at City Hall of Caloocan City is the government body which centers on the activities, issues, and concerns that are identified with PWDs in the nation. Their need is to track and execute laws to guarantee the security of PWDs' political and social equality. It is a declared policy of Republic Act 7277 that individuals with handicaps are part of the Philippine society and thus the state shall give support to the improvement of their total well-being and their integration into mainstream society. They have the same rights like other individuals to assume their proper place in society. Further, Republic Act No. 10070 was approved on April 6, 2010 to guarantee that the policies, programs and administration for individuals with disabilities are implemented at the local level so they can fully participate in building an inclusive society for all through the establishment of the Persons with Disability Affairs Office (PDAO); or appointment of focal persons in case of class municipalities in lieu of the creation of PDAO. PDAO shall develop, promote and monitor the implementation of policies, plans, programs, and services for the development of persons with disabilities in coordination with national and local government agencies.

PWD or persons with disability usually depend on assistive devices for their mobility to accommodate their needs. Assistive devices include wheelchairs, canes, crutches, walkers, prosthesis, hearing aids and visual aids. An assistive device is well designed to assist in or support independent living for the handicapped and disabled seniors or those with medical condition or injury to perform tasks in their daily activities and community life. Hence, PDAO’s mission is to provide interventions and opportunities that will uplift the living condition of the distressed and disabled individuals, families and communities and enable them to become self-reliant and active partners in development. Thus, the researchers aim to develop an “Automated E-Chair Controlled using Hand Gesture and Smartphone Application” to help orthopedic PWD’s to move independently.

II. METHODOLOGY

A. The Agile Model

In figure 1, the Agile Development Model is designed to accommodate change and the need for faster hardware development. The project leader typically facilitates the work of the development team, eliminates bottlenecks, and helps the team stay focused in order to deliver software iterations on a regular basis. It is less about milestones than it is about hours, feature selection, prioritization, and meetings. The overall goal is to adapt to change and deliver working software as quickly as possible.
Furthermore, each team’s process flow may vary depending on the specific project or situation. As an example, the full Agile software development lifecycle includes the concept, inception, construction, release, production, and retirement phases. It is mainly an iterative process. Each iteration results in the next piece of the software development puzzle - working software and supporting elements until the final product is complete.

![Figure 1. Agile Development Model](image1)

In the Define Requirements phase, after the survey and interview to the respondents, the researchers designed the E-Chair using a block diagram, circuit layout, and the system architecture for the E-Chair, Hand Gesture, and Smartphone Application. Then in the IU Design phase, the Smartphone Mobile application screen was decided to be simple with arrows – up, down, left, right which the user can tap in moving the E-Chair. Furthermore, in the Development phase, the 12 volts batteries were connected in series, then other hardware like: Arduino Mega, DC motors, motor drivers, relay modules, Arduino Pro Mini (attached on top of the hand gestures glove), Bluetooth transmitter module, NRF24L01 Transmitter and Receiver, and the rest of the hardware were assembled to the wheelchair. For the Smartphone application, MIT software was used to develop the Android app. Furthermore, in Quality Assurance (QA) phase, tests were made on switching on/off the power supply, connecting the Bluetooth of the Smartphone to the E-Chair, the Hand Gestures recognition by the module, the response of the Smartphone app to the user’s tap on the arrows of the app’s screen, and the potentiometer’s response. Bugs are recorded during this phase and fixed. Next, in the User Acceptance Testing (UAT) phase, the respondents used the E-Chair. A seatbelt was placed on them. Then one hand was placed in the hand gestures glove. Pointing the hand downward/upward or the palm facing the left/right, tests the E-Chair’s response to such gestures. Afterwards, the user then tests the Bluetooth connection of the Smartphone app and taps the arrows to command the E-Chair to move forward/backward/left/right. Researchers conduct a survey during this phase. After UAT, Release phase follows next which means the system can then be deployed to the beneficiary. If not yet for release, the system goes through Define Requirements again.

![Figure 2. Block Diagram](image2)
Figure 2 shows that in the Block Diagram, all modules like relay, and Light Emitting Diode (LED) indicator lights are connected to the microcontroller. The Hand Gesture has an accelerometer sensor that can detect the movement of Forward, Backward, Left and Right that are connected to the microcontroller and relays so that the DC Motor will move the wheels of the wheelchair. Moreover, researchers used motor drivers to take a low-current control signal and then turn it into a higher-current signal that can drive a motor and there is a potentiometer to control the speed of the wheels. Using the power supply, i.e. the battery, the microcontroller unit, and the Hand Gesture, the wheelchair will move on its own place by just moving the user’s fist in the accurate position.

C. Circuit Layout of Automated E-Chair

In figure 3, the electric current connects the battery to the motor. Electrical current is a measure of the amount of electrical charge transferred per unit of time. It represents the flow of electrons through a conductive material. A power supply is an electrical device that supplies electric power to an electrical load to connect motor driver IC is an integrated circuit chip which is usually used to control motors then the motor driver connects to relay then the relay controls the motor.

A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used – one end and the wiper – it acts as a variable resistor or rheostat. It controlled the wheelchair’s speed. A motor controller is a device or group of devices that serves to govern in some predetermined manner the performance of an electric motor.

D. System Architecture

The system architecture in figure 4, next page, includes the hardware for the wheelchair components namely: two (2) 12 volts batteries in series, one (1) 12 volts UPS battery, (2) Buck Converters, Arduino Mega 2560 R3, LED indicators, two (2) DC motors and two (2) motor drivers, 2 Channel Relay modules, two (2) PWM DC Speed Controllers, NRF24L01 Transmitter, and sensors – i.e. ultrasonic sensor, HC–05 Bluetooth sensor; while the Smartphone application’s hardware included a power bank, Arduino Pro Mini, MPU6050, and NRF24L01 Receiver. To develop an automated e-chair controlled using hand gesture and smartphone application controller, researchers used MIT software for the smartphone application which runs only on Android platforms.
III. RESULTS

Depending on the daily needs of the users, they may need to choose whether they feel a manual or an automated chair is suited for them. A common misconception is that automated wheelchairs are without argument the best type of wheelchair available. This is proven to be false on many merits. The most effective argument against automated wheelchairs is that the user is going to use the hand gesture all the time without any sort of physical activity in the process and with the optional use of the smartphone application to control the movement of the wheelchair.

Some PWD’s find the system to be comfortable to use and it lessened muscle pain from constant pushing of the wheelchair’s wheels. Some find the Smartphone application more convenient.

Likewise, consideration on the weight of the user, i.e. 55 – 60 kgs., and use of the system should only be for indoor use should be made.

A. Project Evaluation

Table 1 shows the respondents of the study which include: thirty five (35) End Users, five (5) Information Technology Experts, five (5) Persons with Disability and five (5) Clinical Instructors with a total of fifty (50) respondents that evaluated the system.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-User</td>
<td>35</td>
<td>10%</td>
</tr>
<tr>
<td>IT Experts</td>
<td>5</td>
<td>10%</td>
</tr>
<tr>
<td>Clinical Instructors</td>
<td>5</td>
<td>10%</td>
</tr>
<tr>
<td>PWD</td>
<td>5</td>
<td>10%</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>100%</td>
</tr>
</tbody>
</table>

We used the Five-Point Likert Scale to evaluate the operational feasibility of the proposed system as shown in Table II.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Range</th>
<th>Descriptive Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4.50-5.00</td>
<td>Highly Acceptable</td>
</tr>
<tr>
<td>4</td>
<td>3.50-4.49</td>
<td>Very Acceptable</td>
</tr>
<tr>
<td>3</td>
<td>2.50-3.49</td>
<td>Acceptable</td>
</tr>
<tr>
<td>2</td>
<td>1.50-2.49</td>
<td>Moderately Acceptable</td>
</tr>
<tr>
<td>1</td>
<td>1.00-1.49</td>
<td>UnAcceptable</td>
</tr>
</tbody>
</table>

The Five Point Likert Scale equation is given by:

\[
WM = \sum_{i} \left( \frac{w_i \cdot N_i}{n_i} \right)
\]

Where:

- \( W \) = sum of data set
- \( N_i \) = sub-criteria
- \( n_i \) = number of sub-criteria

Functionality, Reliability, Usability, Efficiency, Maintainability and Portability are the criteria for evaluating the proposed system. Researchers used the rating 1 to 5: 1 – Unacceptable, 2 – Acceptable, 3 – Moderately Acceptable, 4 – Very Acceptable, 5 – Highly Acceptable. The standard of reference was ISO 9126.
Table III above shows the summary of the weighted mean from the End User Evaluation. The system received 4.46 – Very Acceptable – on Usability while it received the lowest mark 4.17 – Very Acceptable – on Compatibility. Conclusively, the End User Evaluation obtained a 4.29 overall mean that proves its strengths in the different criteria mentioned in the said table.

Table IV above shows the summary of the weighted mean from the IT Experts Evaluation. It shows that the system is functional at a mean of 4.4 which means it is Very Acceptable. The project is also usable at a mean of 4.2 and Very Acceptable as gathered from the respondents. The system received the lowest mean of 3.47 - Acceptable – on Maintainability due to the fact that the system will be able to maintain the system most often. Overall, the system gained a 4.00 overall mean.

Table V above displays the summary of the weighted mean from the Persons with Disability Evaluation. It shows that the system is usable, portable, and compatible with a highest mean of 4.4 which means it is Very Acceptable. The project is also secure at a mean of 4.1 as Very Acceptable as gathered from the respondents. The system received the lowest mean of 3.8 – Very Acceptable – on Reliability which means that the system should not fail throughout a prescribed operating period. Hence, the system gained a 4.15 overall mean.

Table VI above shows the summary of the weighted mean from the Clinical Instructors Evaluation. It shows that the system is Reliable with a mean of 4.3 which means it is Very Acceptable. The project is also usable at a highest mean of 4.6 as Very Acceptable. The system received the lowest mean of 3.8 – Very Acceptable – on Maintainability and Portability which means that the system should maintain its operation and clarify its system’s platform. Thus, the system gained a 4.16 overall mean.

Table VII above shows the Overall Mean Summary Evaluation of the Respondents with a weighted mean of 4.16 – Very Acceptable. It shows that the Overall System is Usable with a mean of 4.4 which means it is Very Acceptable. The system is also Reliable and Portable with a similar mean of 4.1 – Very Acceptable – which means that it is easier and cheaper to use. The system received the
lowest mean of 4.0 – Very Acceptable – on Efficiency and Maintainability that the system should be efficient in providing and maintaining its operation to clarify its platform that generally talks about the system. Overall, the system gained a 4.16 overall mean.

Furthermore, Table VIII below shows the Overall Weighted Performance Evaluation of the Respondents with a mean of 4.12 – Very Acceptable. The highest mean is that of the End Users with 4.28, i.e. Very Acceptable, in the evaluation. IT Expert Evaluation has the lowest mean of 4.0 – Very Acceptable.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Overall Weighted Mean Performance Evaluation of the Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>End User</td>
<td>4.28 Very Acceptable</td>
</tr>
<tr>
<td>IT Expert</td>
<td>4 Very Acceptable</td>
</tr>
<tr>
<td>PWD</td>
<td>4.1 Very Acceptable</td>
</tr>
<tr>
<td>Clinical Instructors</td>
<td>4.1 Very Acceptable</td>
</tr>
<tr>
<td>Overall Weighted Mean</td>
<td>4.12 Very Acceptable</td>
</tr>
</tbody>
</table>

IV. DISCUSSION

The hardware design of an Automated E-Chair used different types of modules. We used microcontroller Arduino Mega 2560 which is an integrated circuit designed to govern a specific operation in an embedded system. To control the movement of the wheelchair, we used 2 channel relay, two (2) DC Motors connected to motor drivers with PWM or potentiometer which controlled the speed of the motor. NRF2401 Receiver and Bluetooth HC-05 made great solution for wireless communication. For security purposes of the wheelchair, they used ultrasonic sensor to detect high frequency, sensitivity, and penetrating power that made it easy to recognize external, deep or blocking objects. Moreover, we used DC to DC buck converter to the wheelchair to convert the source of direct current of electricity. To run the Automated E-Chair, we used UPS battery for the power supply of microcontroller Arduino Mega and (2) 12V 12AH battery for the power supply of the wheelchair.

V. CONCLUSION

In conclusion, we developed an Automated E-Chair Controlled using Hand Gesture and Smartphone Application for the Person with Disability Affairs Office of Caloocan City Hall (PDAO). The existing manual wheelchair is very useful but we built a similar wheelchair which had some intelligence and hence helped the user to move independently. Thus, a microcontroller – based embedded system was designed to control the hand gesture, mobile device and the wheelchair’s motion comfortably; as well as vertical movements of seat. The system provides several functions and we can conclude that the system provided a hand gesture device that moved the wheelchair forward, backward, left, or right. Consequently, it was controlled with a smartphone application device for optional use. This is not to imply, however, that automated wheelchair technology cannot be commercialized. Automated wheelchair technology is ready for use today in indoor environments that have been modified to prevent access to drop-offs.

REFERENCES