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A Development of Adjustable Standing and Automatic Stop Electric Wheelchair Prototype Operated with A Smartphone

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Abstract

The objective of this research is to develop a smart adjustable standing-sitting wheelchair prototype that can be operated with a smartphone. Its distinctive feature is the ability of standing-sitting adjustment and automatic stop when approaching obstacles. This device can be controlled from installed joysticks and Android smartphone control program. Arduino microcontroller is the main processing unit to control drive system operating. A Linear actuator is used for standing-sitting adjustment. An ultrasonic sensor is used to make the smart wheelchair stop automatically when detect obstacles. A wheelchair tested showed that it can move at a speed of approximately 3 kilometers per hour, take 14.30 seconds for standing upright adjustment, release down 13.56 seconds, and average automatic stopping distance is 43 centimeters.

Keywords: Electric wheelchair / Adjustable standing electric wheelchair /Automatic stop system / Smart wheelchair.

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INTRODUCTION

The United Nations expects that between the years 2001 – 2100, most of the countries are being the aging society. The growth in aging population occurs in almost every parts of the world differently depend on economic, social and environment. In 2018, the number of senior populations aged 80 years or older in Thailand was 1.32 million people of overall population of Thailand 69.2 million. Most of them have health problems especially problems of walking, standing and sitting [1]. Moreover, it was discovered that there were 2,027,500 registered disability persons, which was accounted to 3.05 percent of total population. Of which 1,002,083 people have problems of mobility or physical disabilities (49.42 percent of the total disabilities). For these reasons, both the elderly and the disabilities need to live in bed or rely on mobility aids like wheelchairs [2]. However, prolonged sitting in a wheelchair can lead to health problems, namely reduced bone density, stiffness joints, muscle contraction and problems with the circulatory system and pressure sores[3] - [6] This includes patients with spinal cord injuries who require supervision, rehabilitation and mobility aids that enhance more freedom in mobility [7].
From many researches and development, an adjustable standing electric wheelchair is highly necessary to reduce the negative effects of prolonged sitting in a wheelchair [3] - [6]. Also including, patients with spinal cord injuries who need care and rehabilitation, for example, bone mass treatment, increasing blood flow throughout the body, and reducing pressure sores and bone disorders, preventing the occurrence of muscle spasms [7] that help rehabilitation of patients with spinal cord injuries. From psychological point of view; adjustable standing wheelchairs have increased the user's confidence higher than that of standard wheelchairs [9]. Because they can help patients do activities in standing positions conveniently such as communicating with staff on counter, withdrawing cash from an ATM and supporting elderly getting up from sitting in wheelchairs comfortably. Furthermore, the research team has an idea to develop the adjustable standing electric wheelchair for medical benefits, and enhance rehabilitation of the patient and elderly. Researchers also developed the wheelchair automatic stop systems to increase user safety, including control with smartphone functions.

MATERIALS AND METHODS

This research is continuously developed a standard wheelchair functions of adjustable standing and automatic stop when approaching obstacles. Overview of working design is shown in figure 1. When start-stop switch is turned on, moving function has not yet operated until the

user presses a switch on the joystick and the LED turns green so the control is started.

The Arduino microcontroller then checks the connection between Bluetooth and smartphone, only a connection is found, the wheelchair is in the smartphone control mode. If a connection is not found, the wheelchair will be operated by joystick instead. Upright moving control is done by turning the joystick counterclockwise and release down moving control is done by turning the joystick clockwise.

Mechanics system design

Wheelchair design was focused on user's safety and comfort. Width from the left rim to the right rim of wheelchair is 71.5 centimeters, length from the rear rim to the footrest is 98 centimeters, hight from floor to the handlebar in sitting position is 88 centimeters, and the height from floor to handlebar in standing position is 132 centimeters. There are 3 safety straps as chest strap, waist strap, and ankle strap.

Adjustable upright standing system design

Adjustable upright standing system was designed and developed by using a DC linear actuator as the main equipment in the adjustable standing system with a 12 V voltage and length 200 mm, load speed 14 mm/s. at Load 1,000 N are used, together with maximum weight loaded up to 140 kg.

Linear actuator is placed in the center of wheelchair, at an angle of 45 degrees in sitting position and 70 degrees in highest standing position. The upright -and-release down function work in conjunction with a well-designed 4 main motion points, therefore, the Linear actuator does not move around the X axis as well.

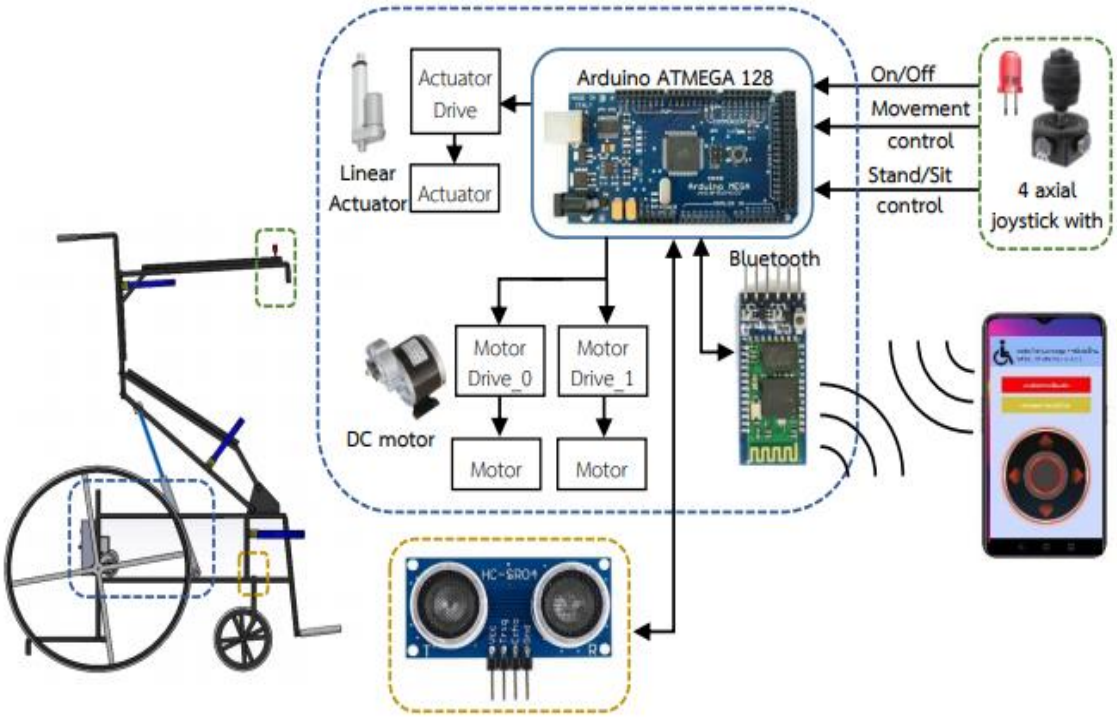
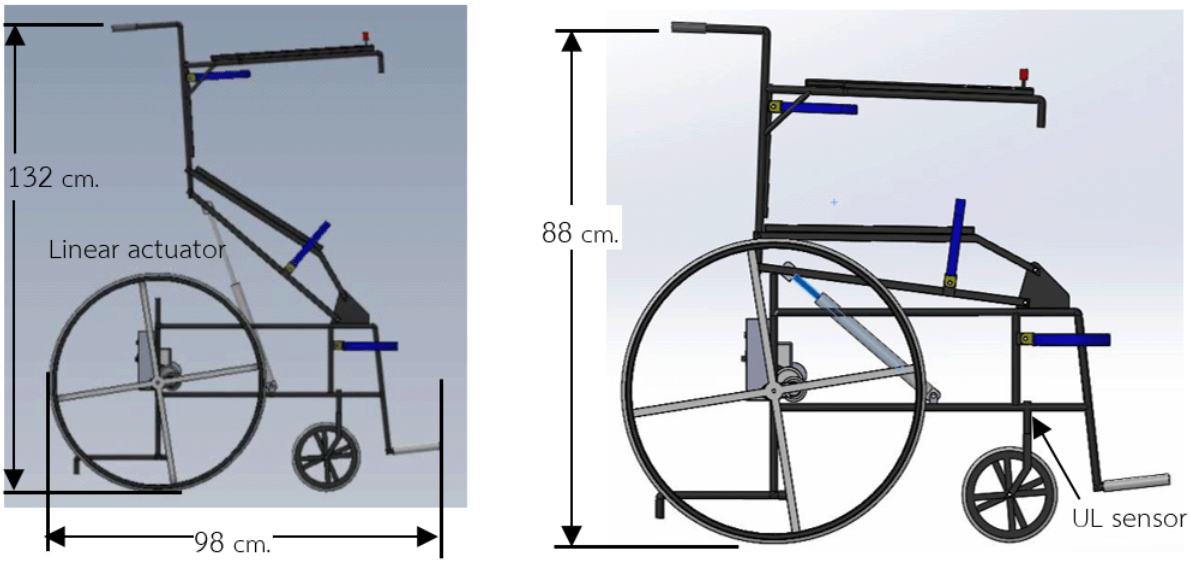
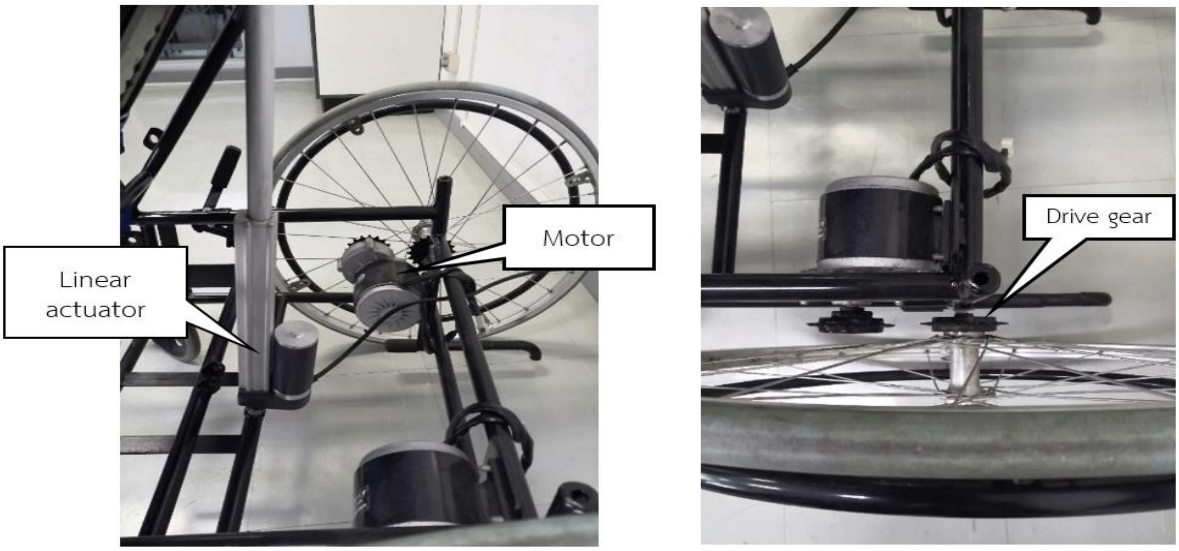


Figure 1: Operating diagram of the drive control system



(a) **(b)**

Figure 2: (a) Standing position design, (b) Sitting position design



(a) **(b)**

Figure 3: Placing position of driving motor (a) and upright unit drive gear (b)

Driving system and obstacles detection design

The driving system consists of two driving wheels and two balance wheels developed by using two 12 VDC motors, to drive each main wheel. Motion commands are transferred from a joystick or a wheelchair smartphone control program.

Command signal for signal movement is sent to the Arduino microcontroller to the two DC motors to move at specified direction. For standing or sitting command, the microcontroller is sending a signal to DC Linear actuator to lift up / release down according to the commands received.

Obstacle detection system is adopts from the HC-SR04 ultrasonic sensor, its maximum measuring up to 400 cm, 30 degrees angle, installed in the balance wheel (figure 1 (a)).

Whenever the wheelchair encounters an obstacle for a specified distance, the sensor will send signal to microcontroller to stop the two driving motors for prevention of a wheelchair collision to obstacle(s).

(a) **(b)**

Figure 4: (a) Joystick installation point (b) obstacle sensor installation point

Software design

Software design is aimed to control wheelchair systems for driving, lifting and obstacles detection systems.

All systems synchronal work with all functions to make wheelchairs operate effectively. Driving system can be control by joystick or Android smartphone.

When operating is started, microcontroller verifies that whether, there is a connection between Bluetooth network and the smartphone. If they are connected, driving is controlled in a smartphone Bluetooth. In case of no connection, the control will be done by joystick.

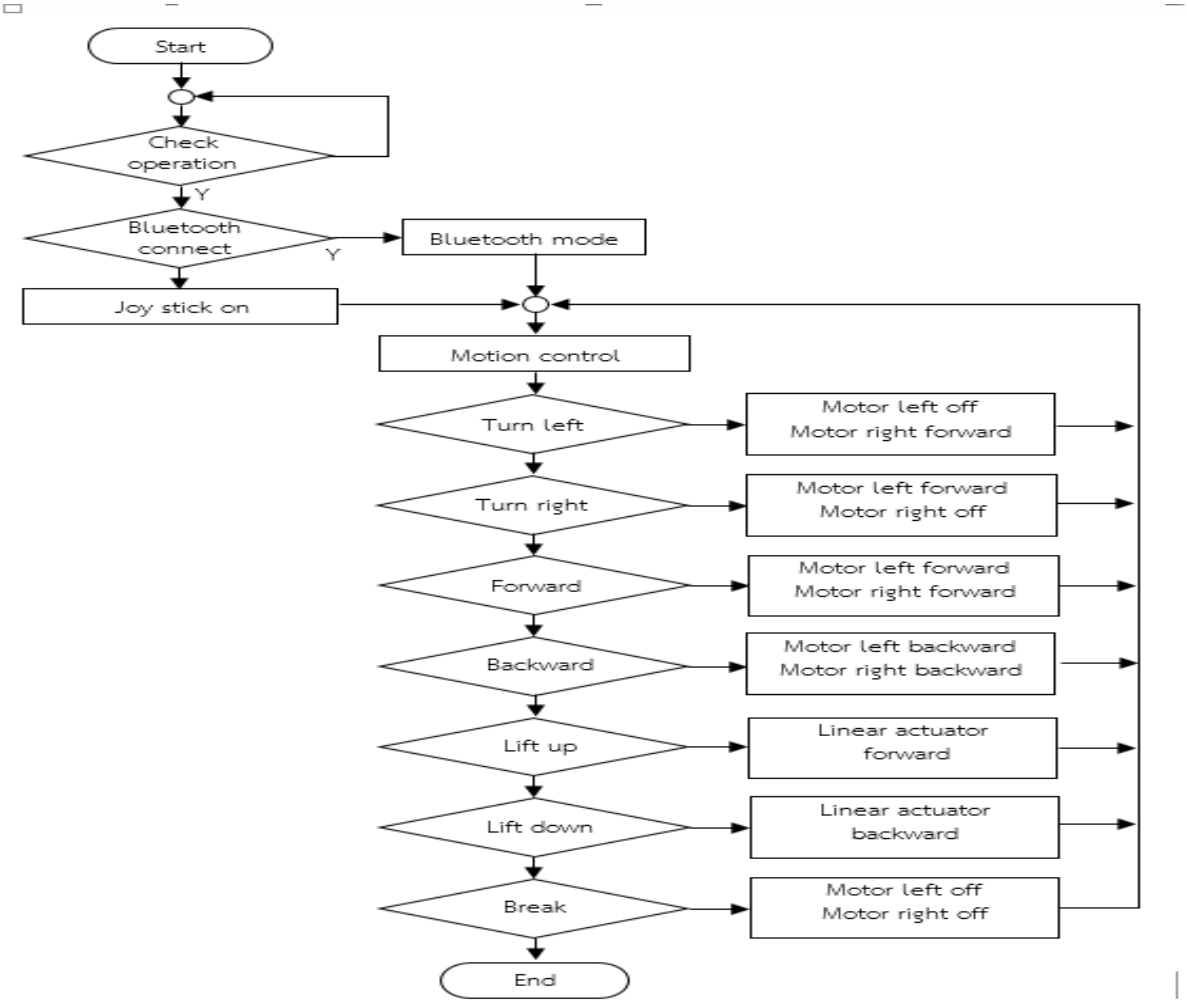


Figure 5: Operating diagram of the wheelchair control program

RESULTS AND DISCUSSION

Results of the development of adjustable standing and automatic stop electric wheelchair prototype are shown in figure 6 - 7, which use the structure of the wheelchair including the front and rear wheels to be modified and tested as follow.

(a) **(b)**

Figure 6: A smart wheelchair (a) when sitting adjustment (b)

(a) (b)

Figure7: Electric wheelchair tested in sitting adjustment (a) and standing adjustment (b)

1. Lifting and releasing adjustment speed test

The tests were carried out by assigning a group of volunteers sit on the device and control it to lift- release to measure the operation time. The test results are listed in table 1

Table 1: Sitting-standing wheelchair tested results

Sr. No.	Standing (Second)	Sitting (Second)
1	14.25	13.55
2	14.30	13.56
3	14.33	13.55
4	14.31	13.57
5	14.28	13.59
$\bar{X}$	**14.30**	**13.56**

2. Wheelchair driving speed test

Wheelchair speed tested by driving the device in forward direction for 20 meters and timing. The test results as shown in Table 2.

Table 2: Wheelchair driving speed tested results

Sr. No.	Time (Second)
1	20.12
2	20.15
3	20.16
4	20.13
5	20.16
$\bar{X}$	**20.14**

3. Wheelchair automatic stop test

The tests were carried out by placing an obstacle in front of the smart wheelchair and controlling the device in forward direction to encounter obstacles until the device automatic stops and measure distance between obstacles and the device stopping point. The obstacle s are divided into three types, they are:

3.1 Wheelchair tested for stopping motion in front of a solid obstacle.

Test by controlling the wheelchair in forward direction encounter obstacle until the device stops, then measure the distance between the obstacles and the device stopping point

Table 3: Stopping motion test results in front of solid obstacles

Sr. No.	Distance (cm.)
1	50
2	54
3	60
4	50
5	56
$\bar{X}$	**54**

Figure 8: Test for stopping motion in front of solid obstacles.

3.2 Stopping motion test in front of loose structured obstacles

Wheelchair tested by controlling the device in forward direction to encounter obstacles until it stops, then measure the distance between the obstacles and the device stopping point.

Table 4: Stopping motion test results in front of transparent obstacles

Sr. No.	Distance (cm.)
1	30
2	34
3	36
4	37
5	38
$\bar{X}$	**35**

Figure 9: Test for stopping motion in front of loose structured obstacles

3.3 Stopping motion test in front of human obstacles

Wheelchair tested were conducted by operating the device in forward direction facing an obstacle until it stops, then measure the distance between the obstacles and the device stopping point.

Table 5: Stopping motion test results in front of human obstacles

Sr. No.	Distance (cm.)
1	42
2	40
3	45
4	38
5	49
$\bar{X}$	42.8

Figure 10: Test for stopping motion in front of human obstacles

4. The development results of wheelchair control program on the smartphone

This program is developed to control the smart wheelchair with smartphone instead of joystick. The program is particular used on Android smartphones.

(a) (b)

Figure 11: (a) Motion control screen (b) lifting control screen

Development result conclusions

A development of adjustable standing and automatic stop electric wheelchair prototype in this research developed the mechanical system in general standard wheelchairs by adding device capability in lifting itself in a standing and sitting adjustment positions. Electronic systems in each part are synchronized and the control programs in a smartphone are developed, conclusions as follows;

1. Driving system is developed by allowing Arduino microcontroller get signal control from Joystick or wheelchair control program. Signal is sent to the drive board of the solid-state relay to control both DC motors. The average speed can be 1 meter per second or about 3 kilometers per hour.
2. Effective lifting mechanism with standing and sitting adjustment systems focus on the least complicate mechanic system design. Linear actuator is determined in lift seat lifting for standing and sitting adjustment. Average time for upright standing adjustment is 14.30 seconds and release down for sitting adjustment is13.56 seconds.
3. Obstacle detection system, Module ultrasonic can detect obstacles in front of a smart wheelchair. Micro-controller will automatically control the smart wheelchair to brake when detect any obstacle within 50 centimeters, to prevent collisions. Wheelchairs' ability of stopping are as follows:
   a. Distance of stopping point in front of solid obstacles is 54 centimeters.
   b. Distance of stopping point in front of loose structured obstacles is 35 centimeters.
   c. Distance of stopping point in front human obstacles is 42 centimeters.
4. A development of wheelchair control program can be used efficiently for the electric wheelchair operation.

Recommendation for development

A limitation of this study was wheel system, because a development of wheelchair is this research was developed from general standard wheelchairs and its' wheel system was designed for hand crank operation. Adding the electric motor to wheelchair was done by attached drive gear to the hub. Therefore, if drive sprocket between hub and motor does not match, the chain may fall out. Research team recommended designing a gear drive system that is connected from the motor shaft for driving.

ACKNOWLEDGEMENTS

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REFERENCES

1. Elderly Situation Report in Year 2018. [homepage on the Internet]. Thailand: Foundation of Thai Gerontology Research and Development Institute; [updated Nov 7, 2019; cited 2020 Aug 20]. Available from: https://thaitgri.org/?p=38670
2. Report on the situation of persons with disabilities in Thailand Report. [homepage on the Internet]. Thailand: Department of Promotion and Development of Quality of Life of Persons with Disabilities. [updated Mar. 31, 2020; cited 2020 Aug 20]. Available from: http://dep.go.th/Content/ View/6113/1
3. Cuddigan, Janet, Dan R. Berlowitz, and Elizabeth A. Ayello. Pressureulcers in America: prevalence, incidence, and implications for the future. Advances in skin & wound care 2001; 14.4: 208.
4. Miyahara, Kimiko, et al. Effect of sports activity on bone mineral density in wheelchair athletes. Journal of bone and mineral metabolism 2008; 26.1: 101-106.
5. Niezgoda, Jeffrey A., and Susan Mendez-Eastman. The effective management of pressure ulcers. Advances in skin & wound care 2006; 19.1: 3-15.
6. Thomas, David R., Marilyn R. Diebold, and Linda M. Eggemeyer. A controlled, randomized, comparative study of a radiant heat bandage on the healing of stage 3 – 4 pressure ulcers: A pilot study. Journal of the American Medical Directors Association 2005; 6.1: 46-49.
7. World Health Organization, and International Spinal Cord Society. International perspectives on spinal cord injury. World Health Organization, 2013.
8. Arva, J., Paleg, G., Lange, M., Lieberman, J., Schmeler, M., Dicianno, B., . . .and Rosen, L. RESNA position on the application of wheelchair standing devices. Assistive Technology 2009; 21(3) : 161-168.
9. Nordström, B., Näslund, A., Eriksson, M., Nyberg, L., and Ekenberg, L. The impact of supported standing on well-being and quality of life. Physiotherapy Canada 2013; 65(4) : 344-352.
10. Christian Schuss and Timo Rahkonen. Use of mobile phones as microcontrollers for control applications such as maximum power point tracking (MPPT). Electrotechnical Conference (MELECON), 2012 16th IEEE Mediterranean. 10 May 2012. Yasmine Hammamet, Tunisia. 2012 14.
11. Renaldo H P, Ahmad G W, Endah S N and Didik S P. Design and Stress Analysis on Electric Standing Wheelchair. 2017 International Electronics Symposium on Engineering Technology and Applications (IES-ETA). 2017 Sep 26-27. Surabaya, Indonesia. 2017.