Human tracking control system using Kinect sensors on wheelchair based on Arduino

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Abstract. Many people with disabilities who do not get the opportunity to work or the same rights as non-disabled people give encouragement to conduct research to help persons with disabilities. Currently there are several types of research and development on mind wave wheelchairs, but the developed wheelchair has limitations for blind users. Most of the wheelchairs require the user to see the surrounding area in order to move the wheelchair. Therefore, it is not optimal for disabled people who are also visually impaired. To help blind people with disabilities, a wheelchair system with human tracking control capabilities need to be developed. In this study, a prototype of a wheelchair system was developed using Kinect Xbox 360 sensor to read motion data which will then be processed on a mini PC before being sent to an Arduino pro micro based main control to drive the DC motor and track the wheelchair. The prototype has been tested by conducting start and stop maneuver. The results show that the wheelchair prototype has an average success rate for conducting a start maneuver of 87.50% and the average success rate for being able to stop after carrying out a maneuver of 85.83%. In the future the wheelchair is expected to be used by persons with multiple disabilities, namely those who are blind who cannot use an electric wheelchair with mind wave control to help with their daily mobility.

1. Introduction
Humans with disabilities are the largest minority group in the world. Around 82 percent of people with disabilities are in developing countries and live below the poverty line and are oftentimes face limited access to health, education, training and decent work [1]. Thus, an effort is needed that is able to fulfill the rights of persons with disabilities such as the presence of wheelchairs as a mobile device for persons with disabilities.

Currently, wheelchairs have developed with the addition of facilities that can ease users and other people to drive wheelchairs. One example is the mind wave wheelchair with the command of the brain [2]. Even so, the function of a mind wave wheelchair will not be optimal if used by blind people with disabilities. Therefore we need a tool that allows people with disabilities to use a wheelchair without the need to encourage and carry out brain commands by making a wheelchair that follows someone in front of him. This is known as human tracking.

Human tracking is a system that is capable of capturing well the tracking of human models by synchronizing objects into grayscale images in a single camera or double coordinate system. This is
included in the human segmentation techniques taken into video and will be carried out continuously [3][14].

Segmentation is a process for separating objects from one another or between objects with a background in an image so that it can be used as input to other processes. With this process so that objects can be obtained from an image that can be used as input to other processes [4].

Research conducted by Zanetello [5] uses the RGB-D feature on the Kinect sensor as the camera detects the presence of someone and an Omnidirectional camera as a person tracking camera. In addition, the research conducted by Baklouti et al. [6] Kinect sensors are implemented in a wheelchair as the detection of 3D objects to avoid obstacles automatically then move towards the static target position. Then the research conducted by Agrwal et al. [7] uses the Kinect sensor as a sensor to move a wheeled robot with three instructions, which are forward, backward and stopped.

Human tracking can be done by Kinect sensor technology because it has features that include RGB cameras, depth sensors, motorized tilt, and multi-array microphones. The depth sensor aims to get video data in three-dimensional conditions in ambient light conditions (adjusting sources in the environment). Depth sensors consist of a combination of an infrared laser projector and a monochrome CMOS (Complementary metal-oxide-semiconductor) sensor [8][12][13].

DC motor in a human tracking wheelchair uses Pulse Width Modulation (PWM). PWM is a mechanism to generate an output signal that has repeated periods between high and low where we can control the duration of the high and low signals as we want. The duty cycle is the percentage of the high signal period and full signal period, the percentage of duty cycle will be directly proportional to the average voltage produced [9].

The objectives of the study are designing a human tracking control system in a wheelchair to help the mobility of persons with disabilities with visual impairments and knowing the accuracy of the movement of the wheelchair in carrying out the gestures of the guide (motion gestures) guides using the Kinect sensor.

2. Research Methodology
The flow of implementation in this study is based on a flow chart as shown in Figure 1.

![Figure 1. Research Implementation.](image-url)
movement to the right and left motors of each motor driver based on the Arduino IDE program which is uploaded to the Arduino Pro Micro board. If the circuits are not interconnected and the motors do not move as expected, an analysis of the circuit repairs is performed. Otherwise if connected to each other and the motor moves as expected, then proceed with the next steps are run the entire system and detect user by Kinect sensor. After that, the Kinect sensor will start tracking and get the head and hand coordinate value of the user. Then Kinect sensor will send coordinates data to Arduino for a wheelchair movement. If the wheelchair doesn’t follow the user, the program and mechanical systems of the wheelchair will be evaluated.

![Block diagram of the system](image1.png)

**Figure 2.** Block diagram of the system.

The block diagram of the system is shown in Figure 2. The system consists of a Kinect sensor, mini PC, Arduino and Bluetooth. Kinect sensor functions as data acquisition by taking video in real-time then detecting the user. The results of data acquisition will be further processed by a mini PC by doing image processing. Segmentation is one of the Image processing techniques that able to track and be able to distinguish the background from the object to be tracked. The results of the main control electronic circuit design can be seen in Figure 3.

![PCB human tracking system](image2.png)

**Figure 3.** PCB human tracking system.

Figure 3 is a PCB image of a human tracking system. PCB human tracking system has dimensions of 13 x 8 cm. The PCB is placed in a special box under the wheelchair beside a white milk acrylic accumulator with a 5 mm thick box frame.

### 2.1. Arduino Programming and Processing

The first process in the human tracking system is image acquisition and processing using the Kinect sensor using Software Processing 2.2.1 on a Mini PC. The images obtained and analyzed are images of parts of the human body that have been tracked by Kinect sensors. In this study, the Kinect sensor will conduct image acquisition with a head and hand target as a frame for the human body to be tracked. The head target in this system is intended so that the wheelchair can move according to the body position of the guide. While the target on the right hand is intended to stop the system. When the right hand is raised at a certain height above the guide's head, the automatic system stops. Figure 4 displays the flow diagram of the processing program that has been created.
3. **Results and Discussion**

3.1 *Physical Shape of a Wheelchair*

The wheelchair used in this study is a wheelchair that has been assembled and then modified by adding new devices which are the Kinect sensor as a tracking device and Arduino based control device. The wheelchair used in this study is the blue AVICO brand wheelchair shown in Figure 4.

![Physical shape of a wheelchair](image)

**Figure 4.** Physical shape of a wheelchair.

3.2 *Detection Distance Tracking*

Kinect sensor position on a wheelchair is located behind the patient with a height of 60 cm from the floor. This test is carried out to find out how far the Kinect sensor can detect a guide in front of a wheelchair. Testing is done by varying the distance from one meter to 8m with 1m intervals.

| Distance between sensors and guides (m) | Detection Status |
|----------------------------------------|------------------|
| 1                                      | Detected         |
| 2                                      | Detected         |
| 3                                      | Detected         |
| 4                                      | Detected         |
| 5                                      | Detected         |
| 6                                      | Not Detected     |
| 7                                      | Not Detected     |
| 8                                      | Not Detected     |

Based on the data obtained in Table 1, the Kinect sensor cannot detect a guide if it is more than 5m away in front of the Kinect sensor. While at a distance of 1m to 5m, the Kinect sensor can still detect...
guide movements. This result is within the specification of the Kinect sensor, in which in the default mode the sensor can detect an object within a distance of 80 cm to 4 m. Therefore, if the guide is located in the distance more than 4m in the default mode, it will be categorized as too far from the sensor [10]. Even so, the Kinect sensor still detects the movement of the guide at a distance of five meters. If more than 5m, the Kinect sensor will difficult to detect the guide's motion.

3.3 Effect of Light Conditions on Tracking Detection
The human tracking wheelchair uses a Kinect sensor which consists of four features, one of them is the depth sensor. Cameras that are used for tracking must be flexible to use in various lighting conditions. To find out the flexibility, the test is carried out with two lighting conditions namely when the environment is bright and when the environment is dark. The test was carried out eight times by observing the acquisition display response on the detection screen when the guide's right hand was raised up. The results of the acquisition of sensor testing in a dark environment are shown in Figure 5 and Figure 6.

![Figure 5](image1.png)
**Figure 5.** The first test at a distance of 1 meter.

![Figure 6](image2.png)
**Figure 6.** The 6th test at a distance of 6 meters.

The results of taking the tracking distance between the sensor and the guide can be seen in Table 2.

| Distance between sensors and guides (m) | Detection Status |
|--------------------------------------|------------------|
| 1                                    | Detected         |
| 2                                    | Detected         |
| 3                                    | Detected         |
| 4                                    | Detected         |
| 5                                    | Detected         |

Table 2 Detection status of tracking distance.
Table 2 is a detection table performed by the Kinect sensor on the guide. When the area around the wheelchair is bright, the Kinect sensor can detect the guiding motion gestures in front of it well up to a distance of 5m. Then when the condition of the wheelchair area is in the dark, the Kinect sensor can still read the guiding motion gestures well up to a distance of five meters. Based on tests that have been done prove that the Kinect sensor can work even though the environmental conditions are dark. This happens because, the Kinect sensor has a depth sensor feature. Depth sensor Kinect on a wheelchair works by shooting infrared light at the guide as the object to be tracked so that object reflection will occur. These reflections will be received by the CMOS camera sensor and will be processed as input.

3.4 Guiding Detection Testing
This test is conducted to determine the influence of people around the guide and the ability of sensors to distinguish a guide from a person who is not a guide. The test begins by detecting the guide as a first step in the human tracking system by pressing the run button on processing. This test is done with a distance between the guide and the sensor as far as two meters. The mini PC screen will show the response in the form of a sentence when the guide raises his right hand. Then let people pass by in three conditions namely behind the guide, in front of the guide, and parallel to the guide. Figure 7 and Figure 8 show the results of the acquisition of the Kinect sensor on the influence of pedestrians with different conditions.

Figure 7. The influence of pedestrians behind the guide when the guide raises his right hand.

Figure 8. The influence of pedestrians in front of the guide when the guide raises his right hand.

Figure 8 and Figure 9 are the acquisition screens that are displayed by mini PCs with different conditions i.e. when pedestrians are in front of and behind the guides. When the pedestrian is behind the guide, the Kinect sensor can still detect the guide well, this is evidenced on the tracking screen on the mini PC that can detect the guide's right-hand movement. But when the pedestrian is in front of the
guide, the Kinect sensor cannot detect the guide properly. This is because the position of the guide is covered by pedestrians.

For pedestrian conditions parallel to the guide, the test is carried out at a distance of two meters with two pedestrians and one guide. The guide in this test is the rightmost person in black and white clothing and in addition is a pedestrian. Some of the acquisition images are shown in Figure 9, Figure 10, and Figure 11.

**Figure 9.** The influence of the pedestrian is parallel to the guide when pedestrian 1 raises his right hand.

**Figure 10.** The influence of the pedestrian is parallel to the guide when Pedestrian 2 raises his right hand.

**Figure 11.** The influence of the pedestrian is parallel to the guide when the guide raises the right hand.

Based on Figure 9, Figure 10, and Figure 11, the Kinect sensor can distinguish pedestrians and guides well when pedestrians are in a position parallel to the guides. This is evidenced when the pedestrian raises his right hand in front of the sensor, the acquisition screen does not display the words "Right-hand Detection on Top Side". Meanwhile, when the guide raises his right hand, the acquisition screen will display the words "Right-hand Detection on Top Side" in the upper left corner of the screen. This test is carried out 10 times in each condition. Detection test results can be seen in Table 3.
Based on the data obtained in Table 3 it can be seen that the average level of success in differentiating guides when pedestrians are behind and parallel to each guide is 90%. Whereas when the pedestrian is in front of the guide, the guide is not detected at all. This is because the pedestrian position covers the Kinect sensor to detect guides. Thus the human tracking wheelchair can distinguish guides and non-guides well enough if the pedestrian (not the guide) is not covering the sensor with the guide. This is because the system is made with an algorithm that is only for following one person as a guide and tracking. The first time the Kinect sensor is active, the sensor will immediately detect the presence of someone and lock it so that only the first person will be a guide.

3.5 Test Results for Accuracy of Motion Guides with Actual Wheelchair Maneuvers.
This test is carried out by means of one user performing a maneuver and stopping 30 times for each wheelchair maneuver. This study intends to determine the degree of success of the desired maneuver execution by a user with actual wheelchair maneuvers.

Details of calculating the success rate for each maneuver from start to stop can be seen in the calculation below:
a. forward movement

\[
\% \text{Start} = \frac{27}{30} \times 100\% = 90\%
\]

\[
\% \text{Stop} = \frac{25}{30} \times 100\% = 83.33\%
\]

b. reverse movement

\[
\% \text{Start} = \frac{25}{30} \times 100\% = 83.33\%
\]

\[
\% \text{Stop} = \frac{26}{30} \times 100\% = 86.67\%
\]

c. Left movement

\[
\% \text{Start} = \frac{26}{30} \times 100\% = 86.67\%
\]

\[
\% \text{Stop} = \frac{27}{30} \times 100\% = 90\%
\]
d. Right movement

\[
\% \text{Start} = \frac{27}{30} \times 100\% = 90\% \\
\% \text{Stop} = \frac{25}{30} \times 100\% = 83.33\%
\]  

(7) (8)

e. Average success

\[
\% \text{Start} = \frac{105}{120} \times 100\% = 87.5\% \\
\% \text{Stop} = \frac{103}{120} \times 100\% = 85.83\%
\]  

(9) (10)

Based on the data obtained, it is known that the average success rate for carrying out the desired start maneuver is 87.50% and the average success rate for being able to maneuver to stop after performing a maneuver is 85.83%. But the percentage of accuracy is different from research conducted by Gahlot et al. with a Kinect accuracy percentage of 90% [11]. The difference is due to the Kinect sensor in this study being installed in a wheelchair that moves dynamically, while in the Gahlot et al. sensor the Kinect study is placed on a static object. Thus, the movement caused by a wheelchair gives effect to the accuracy of the Kinect sensor.

4. Conclusion

Based on the discussion that has been described previously, the conclusions that can be drawn are as follows:

1. A wheelchair human tracking control system has been designed using the Kinect Xbox 360 sensor, Software Processing, HC-06 module and Arduino pro micro. Wheelchair movement utilizes the ability of sensors to detect movements (motion gestures) of a guide.
2. The average success rate for starting a maneuver (forward, backward, left turn, or right turn) of a guide is 87.50% and the average success rate for stopping maneuver is 85.83%. The maximum ability of the Kinect sensor with a height of 60 cm in a wheelchair to detect the movement of a guide is as far as five meters in dark and bright conditions. The movement of the guide can be detected if the people around him do not cover between the Kinect sensor and the guide.

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