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WHEELCHAIR NAVIGATION WITH OBSTACLE AVOIDANCE USING VISION SYSTEM AND SENSORS

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Abstract

Camera vision technology have been widely developed and implemented nowadays. One of the implementations of the vision technology is the smart wheelchair that can avoid any obstacle based on the camera vision detection. Based on Wheelchair Foundation (2016), 131 million people in this world need wheelchair, hence, smart wheelchair with obstacle avoidance could enhance the user's mobility. The objective of this paper is to design and develop the wheelchair with vision intelligence system by using the ultrasonic distance sensor and Raspberry Pi 4 as the microcomputer. The main feature is to detect the obstacle and process the signal to avoid the obstacle. The mechanical design of the wheelchair was evaluated by using Finite Element Analysis (FEA) to verify the structural design and stability. The evaluation included the effectiveness of image and distance detection, and the result showed the image detection required bright environment then can achieve 80% and above accuracy. For distance sensing, the average accuracy had reached 97.53% within the range of 3 cm to 63 cm.

Keywords: FEA, Image processing, Vision technology, Wheelchair.

1. Introduction

Due to some circumstances some people are having difficulties to walk, such as those people who are disabled, those who are injured and even for those astronauts that back to earth after living sometime in the space. Based on data in World Health Organization 2011, there are around 75 million people in this world that required wheelchair to support their mobility, while most of them are the one with disabilities. Furthermore, those wheelchair users that are lack of power to navigate or the elder disabilities might not be able to navigate the wheelchair manually. Moreover, the developing countries are finding it hard to get the wheelchair due to low production and costly. By producing Smart Wheelchair, the mobility of the users could be increased efficient and effectively. Furthermore, the low-cost wheelchair production will surely bring beneficial to the developing.

2. Literature Review

Smart wheelchair has been developed to enhances the user's mobility experience. Background research have been done to do this project regarding smart wheelchair. Utaminingrum et al. [1] and Wanluk et al. [2] have developed a smart wheelchair with obstacle avoidance that are based on camera vision technology with combination of other control method [3]. There are many techniques and methods had been developed to make wheelchair control become more versatile and accessible to disability.

Electromyogram (EMG) or electrooculogram (EOG) signal-based control system had started to take place in the control system. By using eye motion and muscle control, it greatly enhanced the quality of daily life of the disability users in term of mobility [4-6]. Eye-tracking control system even been elevated with additional actuator on the wheelchair to more specific and detail activities, and it is a proven reliable method [7].

Disability user, who able to move with lower or upper limbs has alternate solution for control system. The system included joysticks to assistive device without any hindrances. Kumar et al. [8] and Saharia et al. [9] have developed a smart wheelchair with joystick as the controller of the wheelchair. The technology moves to another level by having smart wheelchair which allow user to control with the gesture of specific body part [10-12]. Virtual reality (VR) become one of the common techniques in Industrial Revolution 4.0 (IR 4.0), and the emerging of the technology in assistive device is unavoidable. Tactile Brain-Computer Interfaces (BCI) for virtual wheelchair had been evaluated when muscle or eye gazing failed or impaired in special scenario, and it resulted an accuracy up to 70 % [13].

There was study to assess the effectiveness of control system by using alternate solution, which included jaw movement. The study integrated EEG and BCI into the system and showed eye and jaw combination movement is highly effective, and the whole study was conducted in a virtual reality environment [14]. Each control method provides different advantages and disadvantages. Joystick control could provide better accuracy among other method that have been mentioned and more reliable, however, body part gesture could ensure the easiness of controlling the wheelchair [15], while the brain computer interface method is very suitable for people with severe mobility disfunction [16]. Furthermore, camera vision could ensure the accuracy of obstacle avoidance compared to ultrasonic distance sensor. The aim of

the project which is to develop a low-cost smart wheelchair which could avoid any obstacle with the aid of vision intelligence and sensors.

3.Methodology and Conceptual Design

The overall block diagram is the whole system process that will be processed by the Raspberry Pi 4 which contain 4 different sub process with different colour of diagram as showed in Fig. 1. The reason of this selection is the Raspberry Pi 4 provide more faster processor with 64-bit 1.5 GHz and powerful memory at variation of 1 to 8 GB DDR4. Furthermore, the Raspberry Pi 4 provide wireless connection by embedding Wi-Fi 802.11/b/g/n/ac and Bluetooth 5.0 connectivity.

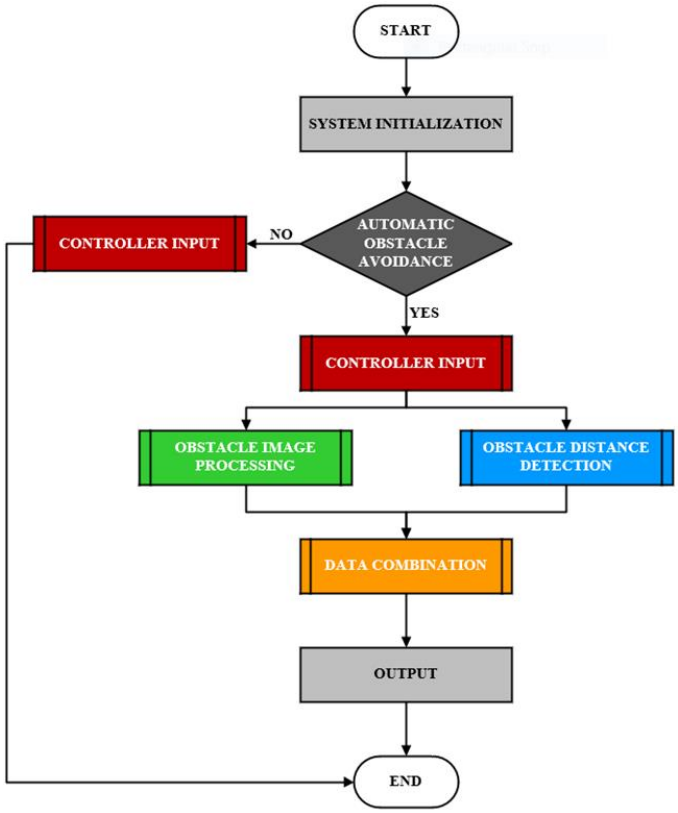


Fig. 1. The overall operation of the control system.

Moreover, the Raspberry Pi 4 provided with more USB port and more affordable price compared to other microcontroller, for example Beaglebone Black. The Raspberry Pi has larger community of developers than the Beaglebone, hence, it will provide more solution for any problems or questions. For the camera component, the Raspberry Pi Camera Rev 1.3 is used, and it is having the specification as 5 Megapixels resolution, 15 pin CSI interface and the most important issue is could directly plug in with the selected microcontroller unit which is the Raspberry Pi 4.

The joystick movement will determine the direction of the motor of the wheelchair. When the process starts, the controller will perform initialization to confirm that the controller could be used as shown in Fig. 2. The controller is constructed with 2 control outputs. The joystick controller will perform the movement direction of the wheelchair based on the direction of the joystick controller, while the rotate button, it enabled the wheelchair to rotate clockwise of counter-clockwise in the exact same point of location.

Next, Fig. 3 showed the obstacle distance detection which obtain from the ultrasonic distance sensor. The distance sensor that are based on LiDAR and Time of Flight (ToF) could provide better sensing ability and able to perform 3D imaging compared to the ultrasonic and infrared based distance sensor. The HC-SR04 sensor is used in the design due to the very affordable option compared to the others with decent ability performance of range and resolution. The specification of the component included the sensing range of 2-400 cm, power consumption 75 mW and resolution 0.3 cm.

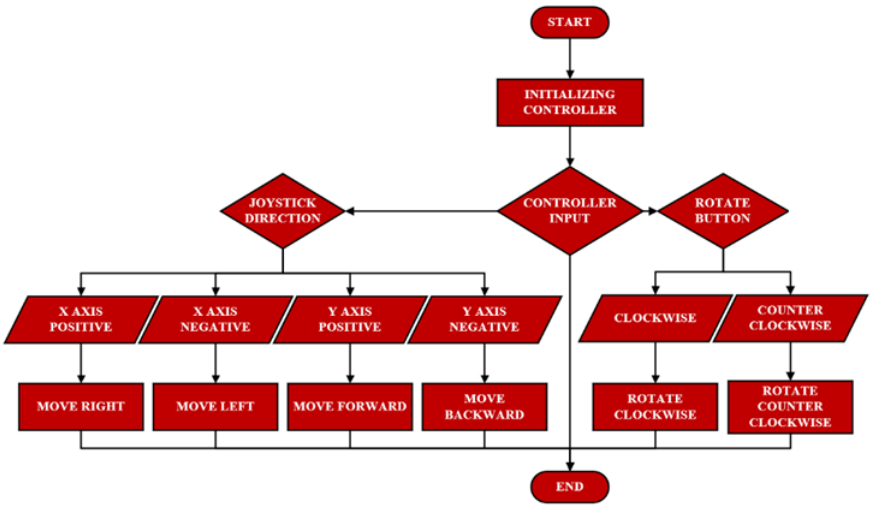


Fig. 2. The controller input.

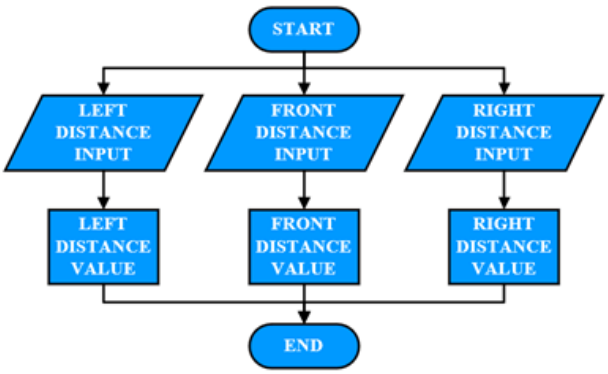


Fig. 3. The obstacle distance detection.

Figure 4 is the obstacle image processing which obtain from the mentioned camera. When the process starts, the system will receive live image input from the connected camera. Since the live image input will be in RGB format, the system will convert the live image become greyscale and blurring the input. Hence, the system could detect the canny edge clearer. After the canny edge detected, noise reduction filter will be applied to get clearer output, hence, the image will be able to segmentate in binary image black and white. Based on the colour output, the obstacle could be detected due to the black colour is the obstacle or the unwanted part of the input, while the white colour is the available pathway that are able to be travelled by the wheelchair. The obstacle data will be stored and used in the data combination process.

Figure 5 showed the data combination based on the result that has been obtain from obstacle distance detection and obstacle image processing. The system combined the data from the obstacle image processing and obstacle distance detection. Each of data will be convert into true or false condition, whereas the true value is 1 and false value is 0. The value of each process will be combined as an or gate, which mean either true value from either process will turn the output become true and only false output when both process is false value. When the output value is false or 0, the system will still follow the controller input process. However, when the output value is true or 1, the controller input will be deactivated, then the system will compare the distance value on left and right side of the wheelchair. The system will avoid the obstacle by choosing the biggest distance from either left or right side of the wheelchair.

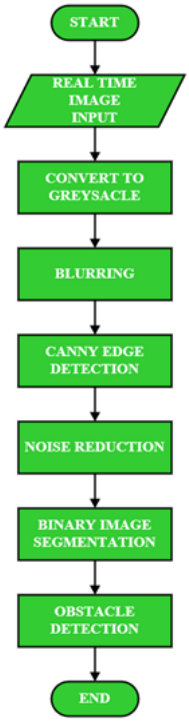


Fig. 4. The obstacle image processing.

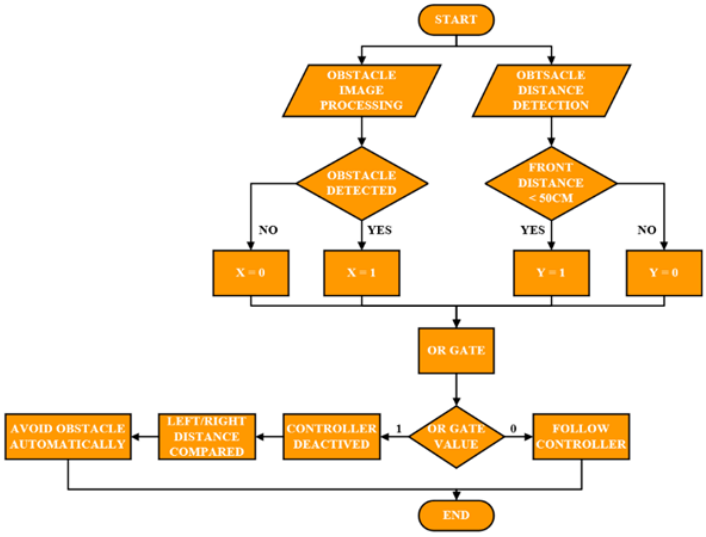


Fig. 5. The data combination.

4. Result and Discussion

The scope and the assumption of the design and develop is listed in Table 1, which included targeted user or group, user health condition, environment, and prototype sizing.

Table 1. Project assumption.

No.	Aspect	Assumption
1	Targeted User	People with mobility disability that are could not walk but still able to control hand movement, lower limbs paralyzed, and elderly.
2	User Health Condition	Healthy with physical disabilities or at least still able to fully control hand movement.
3	Environment	One colour pathway with white lighting.
4	Prototype Size	1: 4

The prototype of the design was produced by using 3D printing with Polylactic acid (PLA) as the printing material and the overall design and dimension is showed in Fig. 6. Finite Element Analysis (FEA) was evaluated by using stress analysis module in SolidWork for the purpose of verifying the structural design and stability. The boundary condition (BC) of the analysis included the 50 N force applied on the pink arrow with fixed geometry on the green arrow as shown in Fig. 7. Analysis result showed the maximum stress is 0.41 MPa, and the minimum factor of safety (FOS) is 96.79, which justified the stability of the wheelchair structure.

Figure 8 showed the result of evaluating the image processing effectiveness by using the mentioned camera. The average accuracy of the obstacle image processing is 62.50 %, and when expose to a very bright lighting environment the accuracy can reached to 100 %.

The accuracy of the obstacle detection is 97.53 %, as showed in Fig. 9 within a range 3 cm to 63 cm with 6 cm increment. The result had ensured that the wheelchair is highly secure and safe when come to capturing objects within the sensing range.

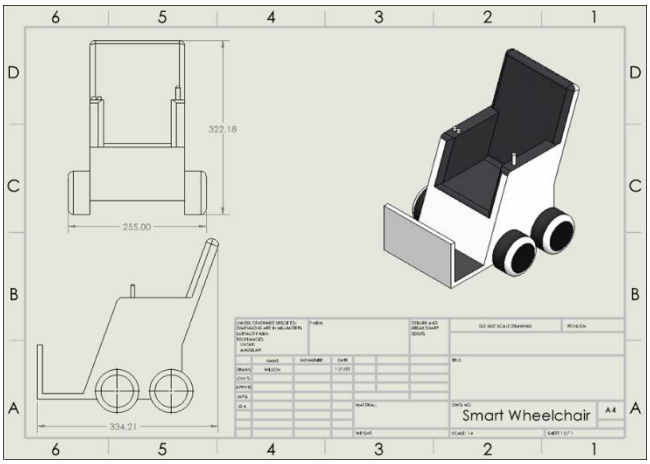
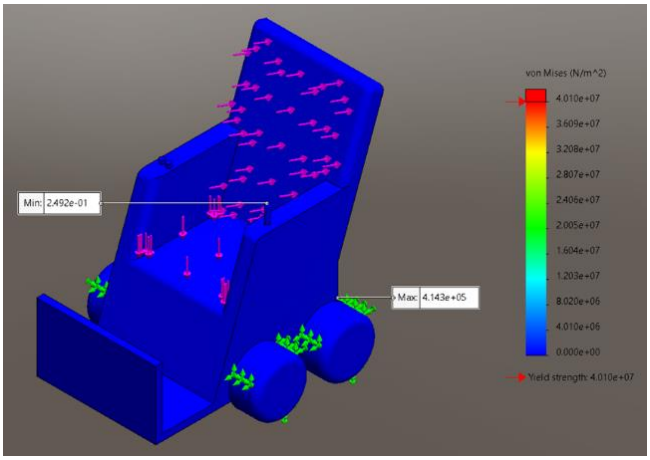
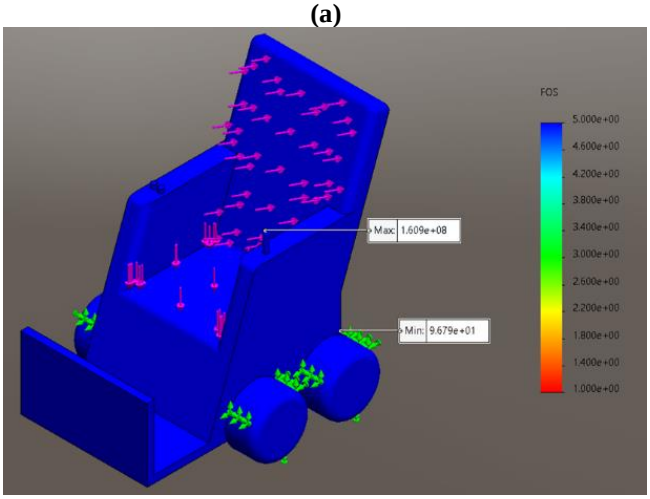


Fig. 6. Drawing of the wheelchair prototype.



(a)



(b)

Fig. 7. Stress analysis (a) von mises (b) safety factor.

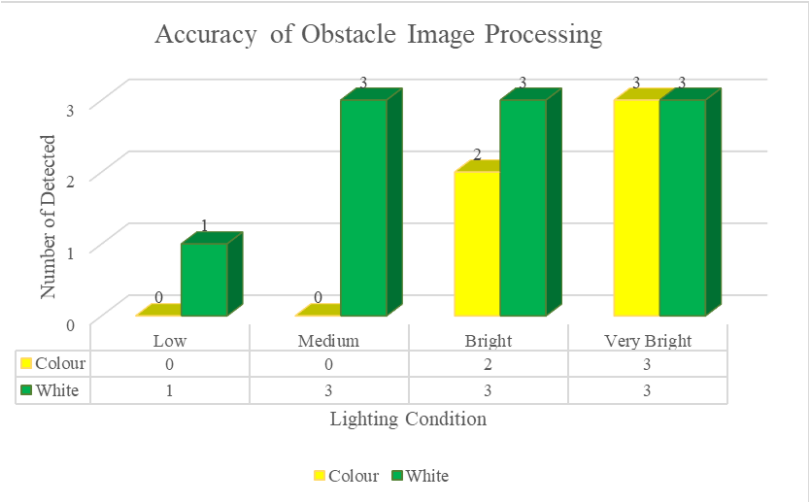


Fig. 8. Accuracy of obstacles image processing.

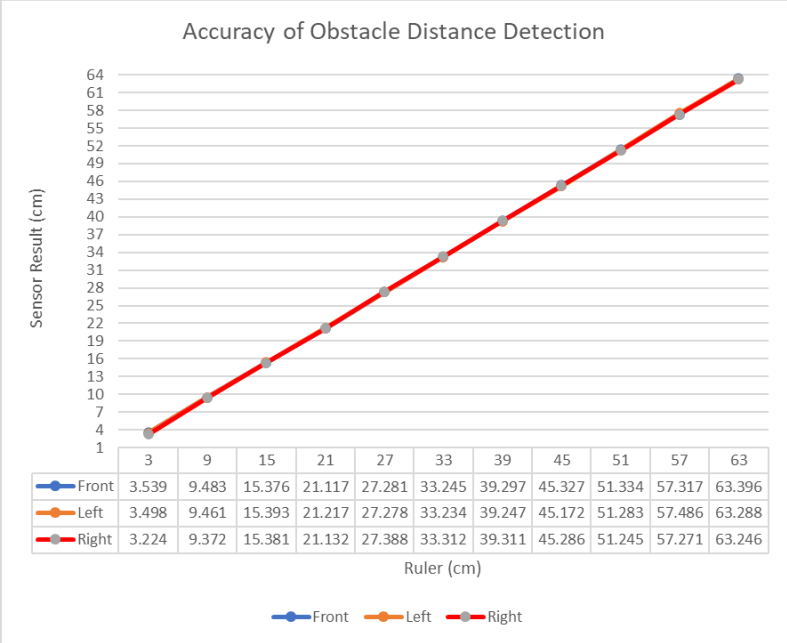


Fig. 9. Accuracy of obstacles image processing.

5. Summary

Wheelchair could be hard to be navigated, especially for the people with severe injury that are required a caretaker to assist them in navigating the wheelchair. Smart wheelchair has developed nowadays to overcome the problems in the conventional wheelchair. One of the developments is the implementation of camera vision technology to detect any obstacle and avoid them. Through this technology, the user could avoid any obstacle easily during the usage of the wheelchair. Further,

it could reduce the task of the caretake to navigate the wheelchair. Hence, the user could navigate the wheelchair by themselves without any intensive support from the caretaker. A prototype will be created for this project with Raspberry Pi 4 as the microcomputer to process all of the input output. The joystick will be used as the main controller input for the direction of the wheelchair movement. The camera and ultrasonic distance sensor will be used to assist the navigation to avoid collision with any obstacle and find better pathway. Hence, the smart wheelchair could be navigated semi autonomously.

6. Conclusion

To summarize, wheelchair is required for 131 million people in this world to support their mobility and most of it from the developing country. These lead to the aim of the project which is to develop a low-cost smart wheelchair which could avoid any obstacle with the aid of vision intelligence and sensors. Hence, smart wheelchair with obstacle avoidance system that are based on camera vision and sensors could be created to provide better mobility support for the disability people. In addition, there are limitations occur in the project. However, there are future enhancements to overcome the limitations and create a better outcome of the project.

7. Limitation

There are limitations that could be improved in this project. First, the wheelchair could not be fully automatic, the control input still required user input using joystick. Further, the image processing could only be processed accurately based on the lighting condition, brighter environment create better accuracy of the vision.

8. Future Enhancement

There are a lot of improvements could be made in this project. First, artificial intelligence in specify deep learning could be implemented and combined with vision technology to provide better accuracy of detecting obstacle. Further, brain computer interface could be the alternate option to control the wheelchair. Hence, the targeted user could broaden to people with severe mobility disability. Moreover, internet could be implemented to create location tracker as well as a monitor from the camera for the access of the caretaker.

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