Obstacles Detection for Electric Wheelchair with Computer Vision

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Abstract—**This research aims to present the detection system of an obstacle for electric wheelchair using computer vision in order to facilitate for disabled persons and reduce the possibilities of accidents. In this system, the distance threshold is set to alert when a wheelchair is approaching an obstacle. The alert system consists of the smartphone's camera attached to the back of a wheelchair. The YOLOv3 model was used for object detection. The researcher has developed an algorithm to detect obstacles such as pillars, doors, or edge of the wall with edge detection method to enhance the detection efficiency of the system. Therefore, the usage of two algorithms enables the system to choose the obstacle detection between objects and edge detection. The research found that the system can choose the algorithm to detect obstacles with an accuracy of up to 80%. Moreover, the experiment revealed that the system can alert warnings before collisions with an accuracy of up to 90%. Further, this system can also calculate the approximate time prior to the collision.**

Keywords-Computer Vision, Obstacle Detection, Edge Detection, Electric Wheelchair, Time to Collision

I. INTRODUCTION

Nowadays, the number of disabled persons is constantly increasing. One of the most common types of disability is physical or movement disabilities. Therefore, wheelchairs are widely used as assistive devices for disabled persons because it can reduce the limitations in the daily routine of disabled persons.

In general, there are two types of wheelchairs; manual wheelchairs and electric wheelchairs. Manual wheelchairs, using hand to control movement, is suitable for users with muscular strength. On the contrary, electric wheelchairs, the user can easily control the wheelchair by using automatic button without exerting force.

Although wheelchairs facilitate the movement of disabled persons, it is frequently found that the primary obstacle in using wheelchairs is the encountering of obstacles. From the difficulties of body movement of disable persons, in the case of wheelchair moving backward, in particular, disable

the wheelchair user to see the obstacles behind. Thus, these circumstances may increase the possibilities of an accident.

From aforementioned problems, this research aims to present the detection system of an obstacle for electric wheelchair with computer vision in order to facilitate for disabled persons and reduce the possibilities of accidents occurrence. This system measures the distance between the obstacle and the camera attached to the back of a wheelchair. If the measured distance is lower than the specified threshold, the system must warn users prior to the collisions to an obstacle. This method enables the system to be embedded to the mechanism of electric wheelchairs.

II. RELATED WORK

Assistive devices for the disabled persons has been continuously developed and applied with the progressive technology of each era. The usage of assistive devices aims to increase usability, facilitate users, and reduce problems or defects caused by various applications. Each type of devices has been developed with different technologies to comply with the problems encountered by the users.

The work in [1] developed manual wheelchair to smart wheelchair using various hardware devices and sensors to the wheelchair. A camera embedded in the front of the wheelchair detects people and objects obstacles. Another work [2] developed a smart wheelchair with obstacle detection systems and human detection algorithms with basic techniques of computer vision using cameras and lasers attached in front of the wheelchair to estimate the distance and location of obstacles.

The team in [3] used ultrasonic distance sensors with a walker for people with visual and mobility impairments. The study found that camera obstacle detection is more accurate than ultrasonic distance sensors. However, the usage of ultrasonic distance sensors in a low light environment or at night with low

visibility may reduce the efficiency in obstacles detection.

For research [4] related to electric wheelchairs, we found that designed and developed electric wheelchairs with automatic reverse sensors using hardware devices comprising of microcontroller, ultrasonic sensors, and buzzer for sounding the alarm. If the obstacles are within the specified range, the system will alert the movement. These devices can be used to estimate the distance between the wheelchair and obstacles efficiently with in low budget.

Research of [5] developed shoes with sensors and actuators which are embedded to navigate the visually impaired persons by enabling the detection of surrounding objects and effectively alerting the user. They compared the performance of the algorithms used to detect obstacles comprising of Faster R-CNN, Fast YOLO, YOLOv1, YOLOv2, YOLOv3, and SSD500, and found that YOLOv3 showed the highest performance.

The research [6] developed a real-time obstacle avoidance system for an autonomous wheelchair by using stereo camera for severely disabled people. A stereo camera is embedded in front of the wheelchair, and a camera calibration method is applied from a 3D perspective to a pinhole image model to calculate the differences. The usage of the Sum of Absolute Differences (SAD) correlation method is applied for detecting landmarks and estimate distances.

The work in [7] presented the collision avoidance system for autonomous navigation by using a simple camera as a main sensor and optical flow as the primary vision technique for obstacle detection. Optical flow is a method that is used to detect the motion of pixels between pairs of images. If the clusters of like-colored pixels of an object move in a similar direction, the object is in a relative motion.

From all the research above, we found that most commonly found problem in the daily life of disabled people is about avoiding obstacles. Therefore, this research aims to present the obstacle detection system for electric wheelchairs backward. Using computer vision, the camera is embedded behind the wheelchair for detecting obstacles on the flat floor and specify the distance between the wheelchair and the obstacle. If it is closer than the specified distance, the system will alert users and report the time before the collision. This development aims to facilitate the users and reduce the chance of accidents.

III. METHODOLOGY

A. Device

This research develops an obstacle detection system for disable persons. Therefore, it is necessary to use a camera to record photos and videos. The researchers choose the smartphone's camera because of its high resolution to be used for computer vision work [8].

B. Workflow

The work process of the detection of an obstacle for electric wheelchair backward has been designed as follows.

Imports video data, extract imported data as an image or called as frame, detects objects in each frame using algorithm. The system will firstly use YOLOv3 to detect objects. In case the obstacles cannot be detected by this algorithm, the system will automatically switch to Canny edge detection to find obstacles instead. Calculation of the size of the object will be done to analyzes the direction of motion. If the same object in the next frame is larger, it shows that the wheelchair is moving closer to the object. The distance between the wheelchair and the object then calculated while the range of the distance near the collision has already been specified. If the object is within the specified range, the system will calculate the time before the collision and alert notification for warning as shown in Figure 1.
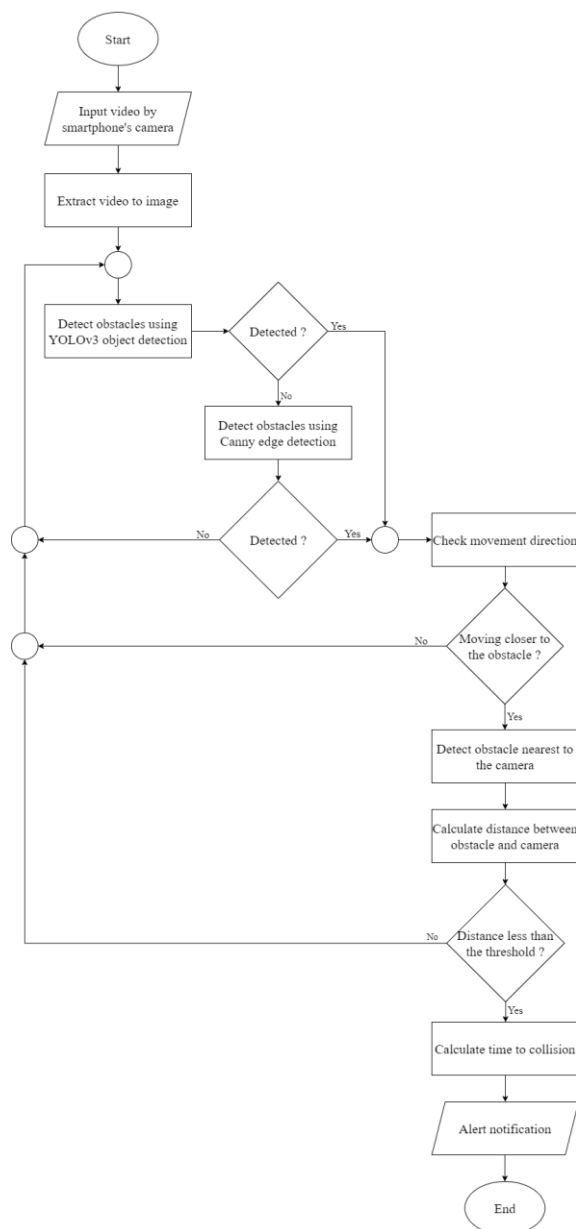

Figure 1. Flowchart of the obstacle detection algorithm.

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C. Distance Calculation

For the calculation of the distance between the wheelchair and the object. Firstly, set the distance threshold requiring the system alert before the collision. In this research, the actual distance from the wheelchair will be measured.
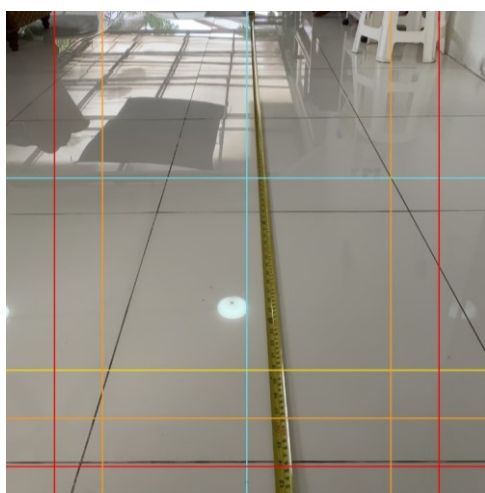

Figure 2. The yellow, orange, and red lines are used as alert threshold when any parts of obstacles reach each line. The horizontal lines are applied with object obstacles while the vertical lines are applied with pillars, doors or the edge of the wall.

Figure 2 shows the use of vertical and horizontal lines. The distance represented as a line threshold for alerting is comprised of blue, yellow, orange, and red lines respectively, details as follows.

- *Vertical line*: used for non-objects obstacles such as pillars, doors, or edge of the wall. If the obstacle is on the left side of the image, the system will use the threshold lines on the left side. Similarly, if the obstacle is on the right side the system will use the threshold lines on the right side.

- *Horizontal line*: used for objects obstacles that are detectable by the YOLOv3 model.

- *The blue line*: used to filter obstacles of interest. The system focus on the obstacles below this line.

- *The yellow line*: used to check whether the obstacle is below this line. The system will start calculating the time to collision when it is close to that obstacle.

- *The orange line*: used to serve as a warning criterion before the collision to the obstacle.

- *The red line*: used to serve as a warning criterion when there is a high chance of collision to the obstacle and occurrence of danger.

After setting the distance given threshold line, the system will find the nearest obstacle as obtained from the obstacle detection process by considering the size of the obstacle. If a part of the obstacle is within the specified distance, the system will alert notifications for warnings.

D. Obstacle detection

The most important part of this research is the algorithms used to detect obstacles. Therefore, in this research, the YOLOv3 [9] model was adopted because of its relatively high accuracy [10]. YOLOv3 (You Only Look Once, Version 3) is a real-time object detection algorithm that identifies specific objects in videos, live feeds, or images. YOLOv3 uses features learned by a deep convolutional neural network to detect an object. After the usage of YOLOv3, it found that YOLOv3 was able to detect humans and objects effectively. However, YOLOv3 was not able to detect the pillars, doors, or edge of the wall. Therefore, new algorithms to detect such objects have been developed by using the Canny edge detection [11,12]. Canny edge detection is a technique used to extract useful structural information from different vision objects. This technique significantly reduces the amount of data to be processed. The system will find the longest vertical line to be used to check whether the edge of obstacle is within a certain specified range in order to further notify the collision.
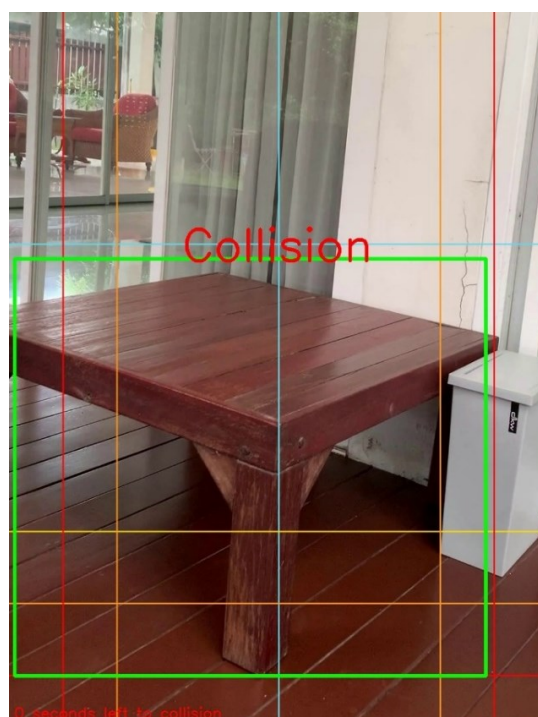

Figure 3. Obstacles that YOLOv3 can detect are outlined in green squares. In this figure, there appears an alert that means the table leg reaches the red line.

Figure 4. Obstacles that Canny can detect are outlined in the green line. In this figure, there appears an alert that means the edge of the pillar reaches the red left line.

E. Time to Collision Calculation

In term of the system that calculates the time before the collision. It is calculated whether the same object obstacle is in the next frame. It analyzes the number of pixels of movement approaching the camera. Then the system will analyze the size of the obstacle to find out the remaining pixels to reach the specified distance to the collision (the red line) in Equation 1.

$$|a - b| = Gap\ to\ Collision \qquad (1)$$

where a is the vertical position of the bottom of the bounding box of the obstacle.

b is the vertical position of the line of collision.

Calculate an average time of how many frames have elapsed for each pixel. It is used to determine the collision with the average frame rate per pixel. The time taken for the wheelchair to collision the obstacle can be calculated according to Equation 2.

$$\frac{|a - b|}{c} = Time\ to\ Collision \qquad (2)$$

where c is the number of frames that a move by one pixel.

IV. EXPERIMENTAL RESULTS

This research developed an obstacle detection system and calculate the time to collision system for an electric wheelchair. Therefore, to evaluate the performance of the system, the researcher divided the evaluation into two parts; the obstacle avoidance subsystem and the time to collision subsystem.

A. Obstacle Avoidance Subsystem Evaluation

To evaluate the performance of the obstacle avoidance subsystem, the researcher measured whether the system can choose an algorithm to detect object and non-object obstacles correctly, obstacle detection accuracy, and the system can alert when obstacles are detected within a specified collision distance.
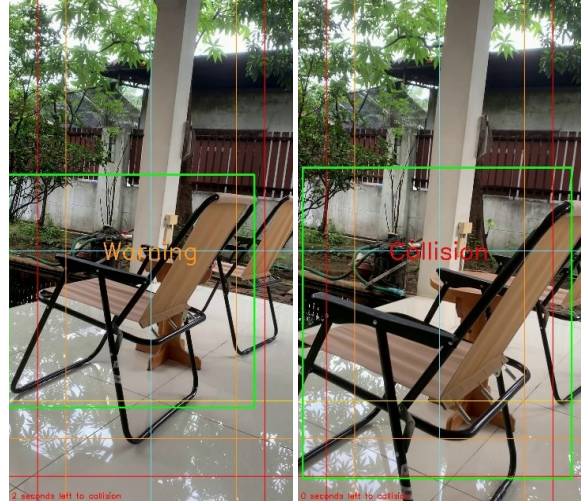

Figure 5. Two types of notification messages are displayed, with a warning indicating when part of the obstruction reaches the orange line and collision when part of the obstruction reaches the red line.

Figure 5 shows two types of notification messages. The warning message shows when obstacle is within the yellow line to the orange line ranges. Then, the system will display collision message when obstacle is within the red line below.

In this experiment, 20 videos were taken in an indoor and flat floor environment. The videos consist of the thirteen clips of footage that contain object obstacles and, the six clips of footage that contain non-object obstacles such as pillars, doors, or edge of the wall, and one video clip without any obstacles. For the reason that the videos were chosen in the experiment, in this research, we aim to mainly focus on detecting object obstacles that are motionless or lightly moving objects. From the videos used in the experiment, most of the obstacles are not moving. Besides, the appearance of each object is clearly different to test the diversity of obstacles. In term of the reason of selecting only one video without any obstacles, the researcher wants to test whether the system will not alert in the event that no obstacles are found. The object obstacle detection system also includes human tracking because YOLOv3 has a relatively high detection accuracy for both objects and human detection. For non-object obstacles, the system uses the edge detection method which increases the efficiency of the system. Thus, it can be used in a variety of environments. Table 1 shows the accuracy of system in choosing the algorithm for obstacles detection in each video. Also, the average accuracy for choosing detection model is accounted for 80% while the accuracy of alert notification before the collision is accounted over 90%.

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TABLE I.   THE ACCURACY OF ALGORITHM USAGE FOR OBSTACLE DETECTION AND NOTIFICATION FOR COLLISION

Video	Type of Detection		Notification
	Detected	Actual	
Video 1	Object	Object	True
Video 2	Object	Object	True
Video 3	Edge	Object	True
Video 4	Object	Edge	True
Video 5	Edge	Edge	True
Video 6	Object	Object	True
Video 7	Object	Object	True
Video 8	-	Edge	False
Video 9	Object	Object	True
Video 10	Object	Object	True
Video 11	Edge	Edge	True
Video 12	Object	Object	True
Video 13	Object	Object	True
Video 14	-	-	-
Video 15	Edge	Edge	True
Video 16	Object	Object	True
Video 17	Object	Object	True
Video 18	Object	Object	True
Video 19	Edge	Edge	True
Video 20	-	Object	False
Average Accuracy	0.80		0.90

B. Time to Collision Subsystem Evaluation

For the performance evaluation of the time to collision subsystem, the results showed that at every alert system, the system will be able to calculate the time before the collision. In case an obstacle is close to the collision, the system will adjust the time to zero second immediately. On the other hand, if the direction of movement is far from the obstacle, the system will not calculate the time in order to increase the system performance to run faster.

V.   CONCLUSION AND FUTURE WORK

This research is the development of the detection of an obstacle for electric wheelchair. A video of indoor environment was captured by a smartphone's camera. The research experiment found that the system can detect both objects and non-objects obstacles such as pillars, doors, or edge of the wall. The accuracy of detection system is accounted for 80% while the collision notification alert accuracy is 90%. Therefore, the algorithm is used to detect non-objects obstacles that can be improved and further developed to increase efficiency and accuracy to be able to use in an outdoor environment.

In the future, this research can be applied to other types of assistive devices for the disabled, or connected to an electric wheelchair to have an automatic braking system when an obstacle is detected at a certain distance, develop an application for display obstacles behind it to facilitate the user to see easier. including showing the time left to a collision so that users can slowly decrease the speed of driving to help reduce the chance of accidents.

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