VISUAL BASED SENSOR CART FOLLOWER FOR WHEELCHAIR BY USING MICROCONTROLLER

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VISUAL BASED SENSOR CART FOLLOWER FOR WHEELCHAIR BY USING MICROCONTROLLER

By

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LIST OF ABBREVIATIONS

AC	Alternating Current
CCW	Counter Clockwise
CW	Clockwise
DAC	Digital Analog Converter
DC	Direct Current
FOV	Field of View
GPS	Global Positioning System
IDE	Integrated Development Environment
IR	Infrared
LED	Light-Emitting Diode
PWM	Pulse Width Modulation
RGB	Red Green Blue
UART	Universal Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
Vin	Input Voltage
Vout	Output Voltage

VISUAL BERASASKAN PENGIKUT SENSOR CART UNTUK KERUSI RODA DENGAN MENGGUNAKAN MIKROPENGAWAL

ABSTRAK

Kepada pengguna kerusi roda, adalah sukar untuk mereka membawa bagasi ketika melancong. Ini kerana sukar untuk mereka membawa bagasi sambil mengemudi kerusi roda mereka dengan lancar. Sensor troli pengikut berdasarkan penglihatan adalah inisiatif yang boleh meringankan beban untuk pengguna kerusi roda. Kaedah untuk mewujudkan projek ini adalah dengan menggunakan CMUcam5 ™, sensor ultrasonik, Arduino MEGA 2560 R3, pemandu motor, motor servo dan motor didorong. The CMUcam5 ™ adalah bahagian utama dalam projek ini kerana ia menyediakan keupayaan penglihatan mudah untuk sistem terbenam kecil dalam bentuk sensor pintar. Sensor ultrasonik digunakan untuk menghalang troli daripada bertemu apa-apa halangan seperti dinding dan manusia dan menjaga kereta itu dalam jarak tertentu. Pemandu motor digunakan untuk mengawal pergerakan motor yang dipandu. Sudut luas meter servo ditetapkan dari 60 ° ke 120 ° dan penting untuk memandu troli itu. Visual-sensor troli pengikut boleh membantu pengguna kerusi roda untuk perjalanan lebih mudah sambil membawa bagasi mereka.

VISUAL BASED SENSOR CART FOLLOWER FOR WHEELCHAIR BY USING MICROCONTROLLER

ABSTRACTS

For the wheelchair user, it's difficult to carry their luggage when travelling. It's difficult for themselves to carry luggage while handling their wheelchair to navigate it smoothly. The vision-based sensor cart follower is the initiative that can lighten the burden for wheelchair user. The method to establish this project by using CMUcam5™, ultrasonic sensor, Arduino MEGA 2560 R3, motor driver, servo motor and driven motor. The CMUcam5™ is the main part in this project since it provides simple vision capabilities to small embedded systems in the form of an intelligent sensor. The ultrasonic sensor is used to prevent the cart from bump any obstacle such as wall and human and keep the cart in certain distance. Motor driver is used to control the movement of the driven motor. The wide angle of servo meter is set from 60° to 120° and important to steer the cart. This visual-based sensor cart follower can help wheelchair user for easier travelling while carrying their luggage.

CHAPTER 1

INTRODUCTION

1.1 Background

The increases number of mobile robot nowadays give the big impact to the manufacturing area. The technologies of mobile robot keep on evolving from originally that made for war now become common things for hospitals, offices, and factories usage (Ahmad et al. 2016). The concept of mobile robot is basically suggested whereby mobility is free-roaming robots move about with an integrated multifariousness fostering even more preponderant returns in extra range or application surpass that of the typical factory floor (Abdullah Sani 2014).

The aim of this thesis is to help the disabled person especially wheelchair user to lessen their burden and can go anywhere without no worry. To accomplish this goal, cart follower is to be designed to carry the user's luggage. Besides that, it would be an innovative approach because there are few initiatives that help disabled people during their daily workout in current society.

The visual-based sensor cart follower is more compatible to the wheelchair user since the ability that can track and follow their user by put the marked on the back of the wheelchair. Besides that, the cart also does not have any attachment between the wheelchair and the cart. This function can help the user without having any energy to the person.

1.1 Problem Statement

Problem faced by wheelchair users is difficult to carry luggage from one place to another. They have their difficulty when they should carry their luggage while use their hands to contolling their wheelchair. Eventhough they hang their luggages to their wheelchair, they will carry the burden of their luggage that can slow their movement. Besides that, for the normal wheelchair, there is no additional space for them to carry their luggage.

1.2 Objective

1. To develop a cart follower for wheelchair user by using visual-based tracking technique that can use as a luggage. This cart contains motor and visual based sensor to follow the user.
2. To design smart cart that can detect the obstacle and object moving while moving. The cart must contain ultrasonic sensor that can detect the obstacle and have some distance with the wheelchair to avoid the collision.

1.3 Research Scope

This research covers the speed of the cart and the usage of the cart. The maximum speed of the cart is limit to 3m/s since the normal speed for wheelchair user around 1.6km/h. Besides that, the usage of the cart is limit for the indoor usage like airport, shopping complex and other indoor places. The uneven surface at the outside makes the cart difficult to move.

1.4 ThesisOrganization

This thesis is divided into five parts; which are introduction, literature review, methodology, result and discussion and lastly conclusion.

Chapter 1 explains the background of this research, the problem faced by wheelchair user in our daily life. Besides that, the main objective to achieve and research scope of the project also get explain in this chapter.

Chapter 2 shows the literature review on different journals on the subjects which utilize different techniques to achieve the objectives respectively. Moreover, a summary on the advantages of some of the previous work will be discussed and used in Chapter 3.

Chapter 3 discuss about the methodology on which techniques are to be implemented on the thesis. Besides, design and development of the luggage carrying cart will also be discussed completely.

Chapter 4 explains the result and discussions on all the aspect on the cart. It also including the details on the method used for wheelchair following effectively.

Lastly, Chapter 5 concludes the overall research and recommending the development that can be done in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Luggage cart follower must have some basic functions in order to deem this project a success. Firstly, the wheelchair following cart must be able to identify and follow the target which in this project use colour pattern that located at the back of the wheelchair using visual-based tracking technique. Secondly, motor with a large torque is required to move the wheelchair following cart. Thirdly, the cart will follow the wheelchair and maintain a specific distance between them to prevent collision to occur. This cart can follow the user while they handle their wheelchair without having any attachment by using vision-based sensor. This cart following robot will follow the user without need any extra control by a human and indirectly can minimize the workload of the stuffs. Furthermore, this could also comfort the wheelchair users (Hoo, 2016).

This important focus is to make sure that the cart can be rotated 180° and follow the user path. However, to accomplish this project need consider many factors to make sure the wheelchair bound is comfortable. There are many commonly implemented in the hospital or the airport as helpers. Basically, research in the following application involves several types of things or object to be followed. Example of the robot are like line or path following, leader following, human following, and wall following. Most of them can be describe as following mobile robot. (Noridayu, 2014).

2.2 Following Robot

In this part, the following robot is described in the field of mobile robot. A following robot is a part of robotic that can do the task of following (Noridayu 2014). There are many ways that method to achieve the task following. The following robot is depending on information that it gets from the tracking device through many types of sensor or device that being used.

2.2.1 Line or path following

Line follower robot can be said the well-known following task robot. The Line follower robot is a robot that detect the line or path and follow the line that already drawn under the floor. This robot is function by sense the line that using infrared (IR) that is install under the cart.

Sensors that are implemented with Infrared Ray (IR) are commonly used in the line following robot. The IR sensors will be set up and distributed to its place and signalling the present of the line for controlling the direction (Pakdaman and Sanaatiyan 2009).

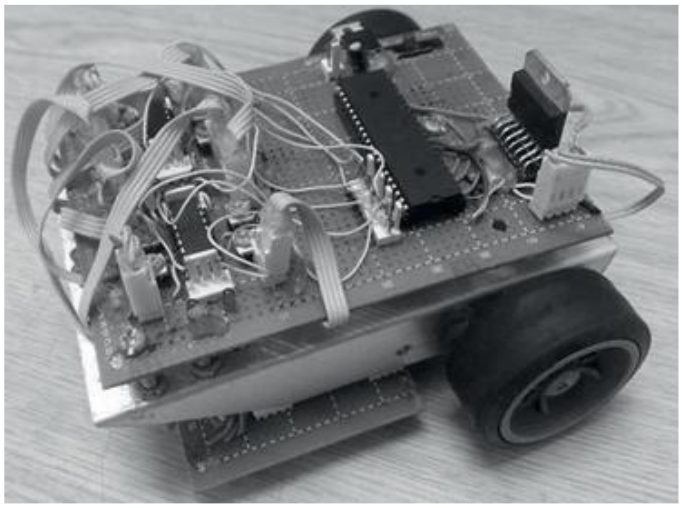

Figure 2.1: Designed line follower robot (Pakdaman & Sanaatiyan 2009)

2.2.2 Leader Following

Leader following robot is designed to follow the leader at certain distance by using visual information about position of leader robot. The leader will have a pattern mounted on its back that can observed by follower to obtain information by using camera. The information will be used to control their position as follower (Soria et al. 2006)

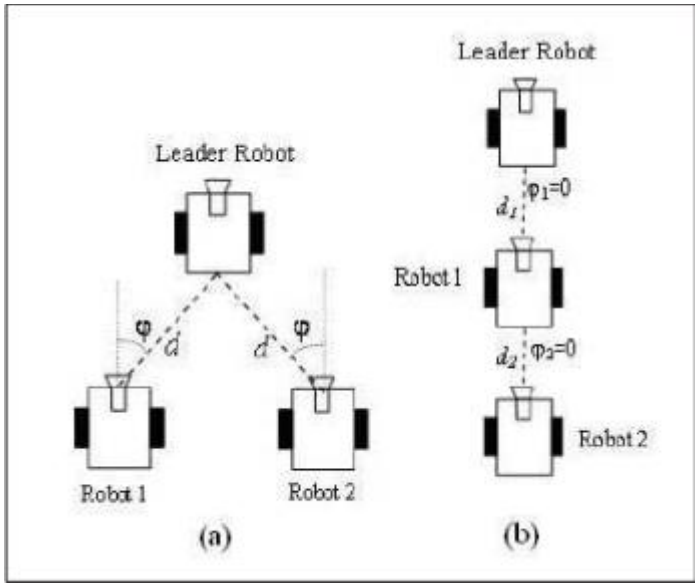

Figure 2.2: Coordinated control of mobile robots based on artificial vision (Soria, et al. 2006).

2.2.3 Human Following

This robot can accompany a person using vision based target detection and avoid obstacles with ultrasonic sensors while following the person. The robot first identifies an individual with its image processing system by detecting a person's region and recognizing the registered color and texture of his/her clothes (Yoshimi et al. 2006)

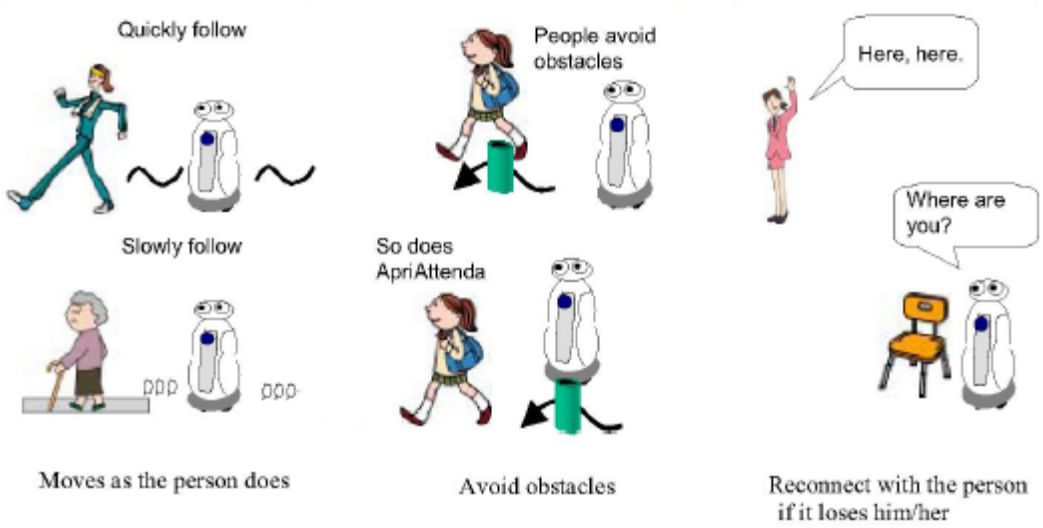

Figure 2.3: Functions of Person Following Robot ApriAttenda™ been used in several situations (Yoshimi et al. 2006)

2.2.4 Wall Following

Wall follower robot use wall as their guidance to navigate the destination. Project from Daniel et. al, 1996 in Constructing a Wall-Follower Robot for a Senior Design Project shows that the robot need to learn the environment first before it can navigate to a destination location.

In order for the mobile robot to navigate and learn the maze and avoid running into wall, it needs to have some sort of a sensor system. This sensor system will provide the robot with distance information, thus enabling it to stay a reasonable distance from the walls as well as determine where the openings are. This information, when fed into the micro-controller system, will help the robot to properly learn the maze (Daniel et. al, 1996).

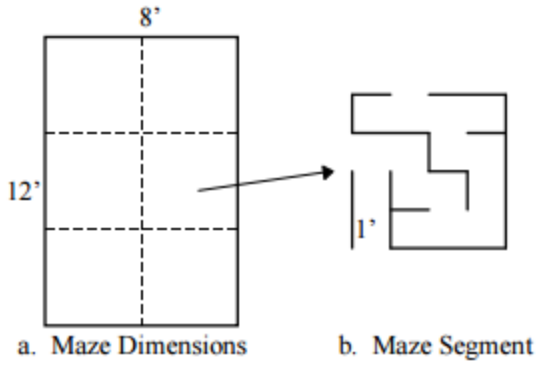

Figure 2.4: Example of maze segment (Daniel, Scott, George, and Pam Neal,1996)

2.3 Following Task Application

The following robot as above known as tracking. There are many methods had been used as visual perception. Most of the methods are using visual-based sensor, GPS Tracking system and obstacle avoidance such as infrared and CMUcam.

2.3.1 Vision-based Sensor

Vision-based sensors can be applied in a line following application. The main function of CMUcam5 is to provide simple vision capabilities to small embedded systems in the form of an intelligent sensor.

A visual based sensor is needed to fulfill the colour tracking technique. The cart will track and follow the wheelchair without any physical connection to the wheelchair since its only moved and follow the wheelchair if vision-based sensor (CMUcam5) detect according to colour pattern chosen. The colour pattern that placed at the back of the wheelchair will be tracked by CMUcam5 and the microcontroller will steer and drive the cart. The microcontroller will send the RGB colour information to tell the camera for the chosen colour pattern to be followed. Then, the camera will react back

based on the information and sent back for the position and collour pattern to the controller. The cart will in stationary untill vision-based sensor detects the chosen colour pattern that make the cart move forward or backward. However, there are several sensors being used to prevent the cart from colliding any obstacles or the wheelchair itself. When the target is moving away, the tracking angle will vary, and the servo motor will rotate to turn the cart around (Ahmad et al. 2016)In addition, the colour patternn technique can be improved by adding extra features like shape or object detection. This kind of features, can improved the better accuracy of the tracking method.

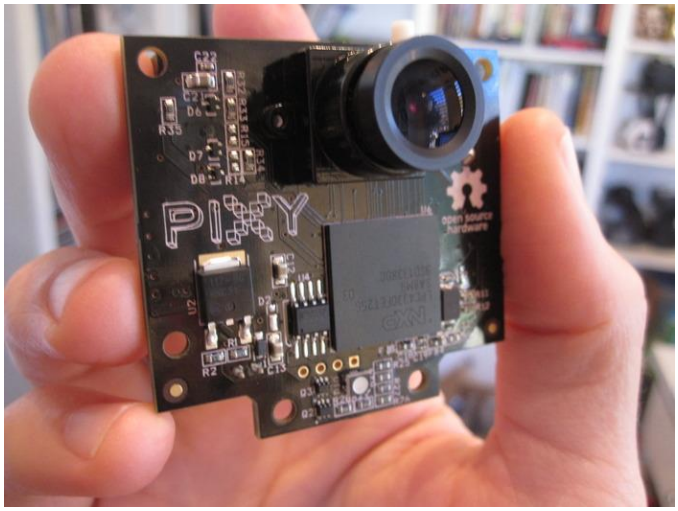

Figure 2.5 CMUcam5™

2.3.2 Obstacle Avoidance

Obstacle avoidance can be applied in following application. It is important since there are many obstacles such as wall, pole, human and others that can stop the robot from move. The sensor that are usually used are ultrasonic, or proximity sensor. Obstacle avoidance gives a priority to safety, goal convergence, and formation keeping that can avoid collision under all circumstances and make sure the robot move toward the goal (Lindhe et al. 2005)

2.3.3 GPS Tracking System

GPS tracking system is a way to approaches the following robot. By using GPS tracking system, robot will easily detect any ways that it need to choose. Navigation directions are computed within the network using value iteration. Using small low-power radios, the robot communicates with nodes in the network locally, and makes navigation decisions based on which node it is near (Batalin et al. 2004)

Although the GPS tracking system is well-known in approaches for following robot, it has several problems. One of the problem is the GPS tracking cannot detect any obstacle in front of the robot. Besides that, GPS tracking must always be updated if the routes are change or have a new shortcut route.

2.4 Summary

In this project, line or path following robot is not practical since its only work in fixed line. It is difficult since the user is a person that using wheelchair that usually move randomly. So, it hard for them to move only in the line area. Therefore, line or path following method is not the best choice.

The leader following method is good but not acceptable since its only follow the leader without any obstacle avoidance. It only follows the leader by using vision-based sensor without having any awareness in its surrounding.

Method of human following is acceptable because its fulfill the requirement that needed for the vision-based sensor cart follower. The reason is it can track human and

have capability to avoid the obstacle. However, since it only tracked human, the disturbance might occur in the scenario lot of human and the sensor might not able to differentiate the real target.

The wall following method also not meet the requirement since the objective is to follow a dynamic object. It is also not suitable with following task because wall follower is designed to follow the wall that is stationary and static.

The application of vision-based sensor is very suitable for this project. This is because the requirement to establish this method is simple that need to identify the pattern or colour that can be attached at the back of the wheelchair. The CMUcam5 will detect and keep focusing the pattern or colour to follow the wheelchair movement. Besides that, vision based sensor is chosen because it has less interference from actual signal. However, vision-based sensor has several weaknesses that interference may occur when the colour or pattern is almost same to the surrounding area. However, CMUcam5 has a special ability called colour code that can track more than single colour. The colour code must have variant colour to overcome this problem. The camera will only detect and track when there is a combination of colour that being set.

Obstacle avoidance is important since we need to make sure that the cart is not having any accident during following. However, it is not accomplished our objective that need to follow the target. Obstacle avoidance just only prevent itself from hit any obstacle but it has no clear purpose to follow the target.

The GPS tracking system is a good navigation system since it reached some objective of this project. But it is not suitable for indoor use because it has a lot of magnetic field interference to be overcome.

Based on all review, vision-based sensor is chosen. The advantageous of this sensor is meet the objective of this project and a good choice for the real time colour tracking and following method. Using vision-based sensor, there is no need external power source to the wheelchair since the sensor detect passive type of target such as colour and pattern.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will explain in detail all the step about Visual Based Sensor Cart Follower for Wheelchair user. This project consists of cart design, hardware parts and software parts. For the cart design, it consists of two section that is upper section and lower section. For the upper section contains of microcontroller, motor and sensors while the lower section consists of battery and space for the luggage.

In the hardware parts, microcontroller that is Arduino MEGA is used to act as main components to control the overall system. The 12V 24AH rechargeable lead acid battery is the main power source that is directly connected to the DC motor. Besides that, other sensors like ultrasonic sensors are also used to detect the distance between the luggage cart and the wheelchair to prevent collision and for obstacles avoidance purpose.

The software part, it consists of two parts which are software for Arduino microcontroller and Pixy CMUcam5TM sensor. Arduino Mega microcontroller uses Arduino software IDE for programming while Pixy CMUcam5 sensor uses PixyMon program.

3.2 Project Implementation Flow

The step starts with collect all the information needed from journals, papers, and thesis. A basic design of the cart is included to fulfil the required specifications for the final model. Figure below show the project flow from start to compile the final report.

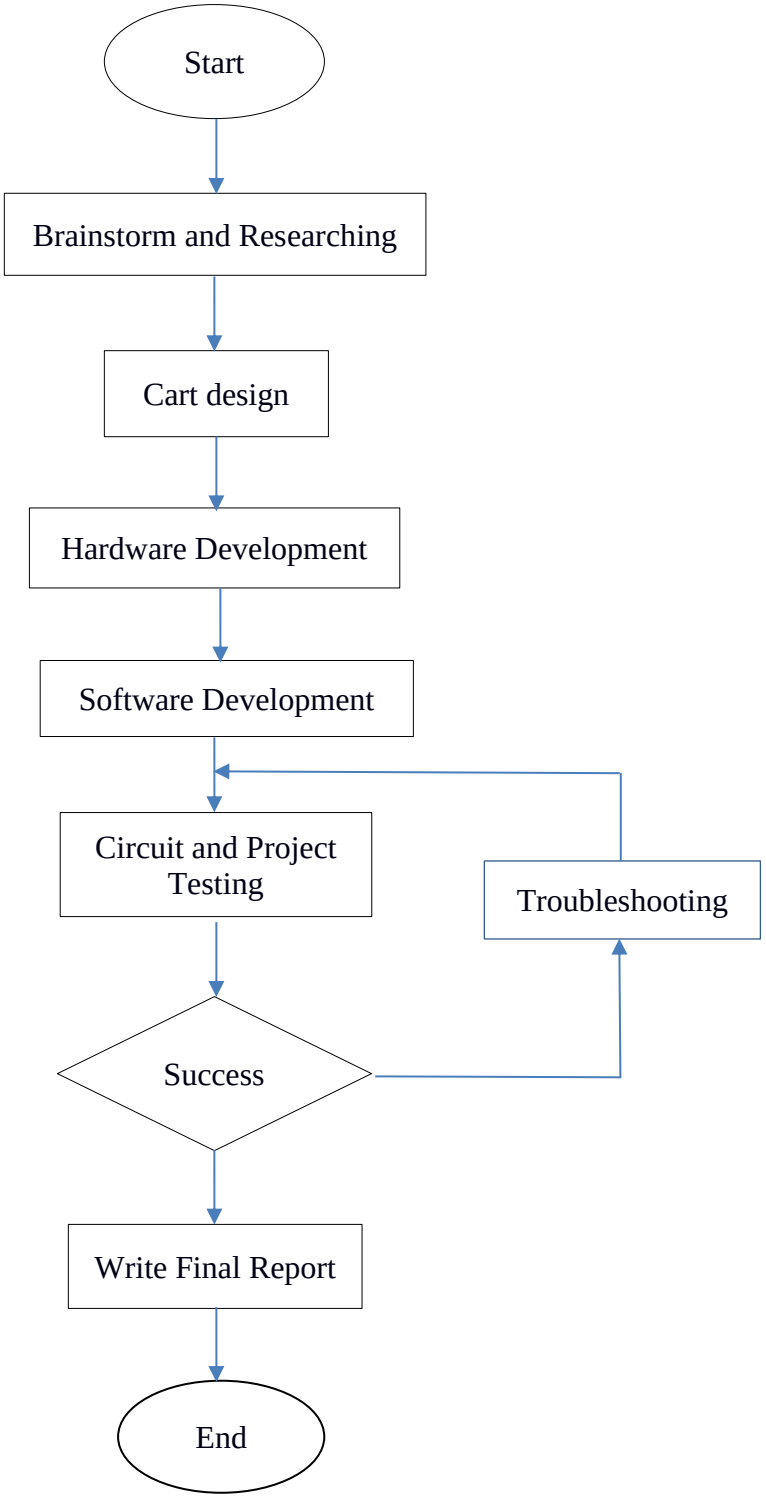

Figure 3.1: Project Implementation Flow

3.3 Project Requirement

This project required hardware and software part. The cart design and the specification also will be explained in this part.

For the hardware part, it contains microcontroller that are Arduino MEGA 2560, visual-based sensor, Pixy CMUcam5™, motor driver MD30B, servo motor HD-1051MG, transaxle motor PPSM63L-01 and ultrasonic sensor HC-sr04.

While for the software part, it contains Arduino IDE that use C and C++ language for the microcontroller and PixyMon program, the application for CMUcam5™.

3.3.1 Cart

In this part, there will explain about the design of the cart and the cart specification and function.

3.3.1.1 Cart Design

The cart divided into two parts, which are top part and bottom part. For the top part contains component such as microcontroller, vision-based sensor, ultrasonic sensor and servo motor while for the bottom part, it contains of battery and space for the luggage. The front of the cart is a bit higher than the back to make sure the cart is stable. Figure 3.2 shows the frame of the cart and figure 3.3 shows the casing of the cart.

Figure 3.2 Frame of Cart

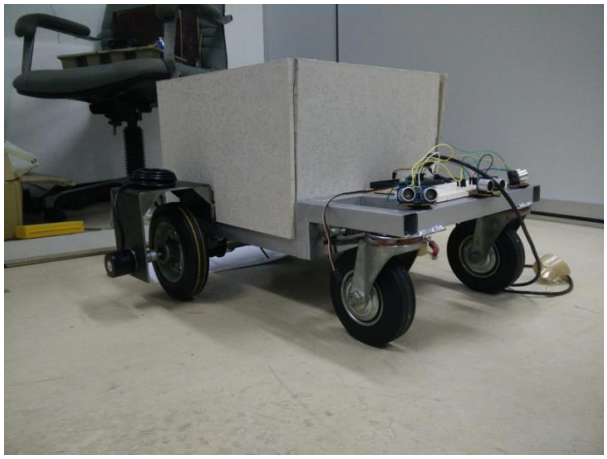

Figure 3.3 Casing of Cart

3.3.1.2 Cart Specification and function

The cart width is around 340mm and the length is 550mm and 255mm is the height. It weighs about 10kg and can lift to 50kg of luggage weight. The minimum speed of the cart is 9.99 cm/s and maximum speed is 88.7 cm/s.

The cart contains some hardware device including vision-based sensor Pixy CMUcam5™, microcontroller Arduino MEGA 2560, motor driver MD30B, servo motor to steer the direction, transaxle motor to move the cart and ultrasonic sensor that use to avoid the cart from any collision.

3.3.2 Hardware Part

The main component in this project is Arduino Mega that control the overall system. For the vision part, CMUcam5 was used to supply the input for the controller. To move the cart, motor driver play its roles for the speed and direction of the cart.

For the sensory part, it uses ultrasonic sensor that is important to make sure the cart and the wheelchair have some distance with the wheelchair and to avoid any collision happen.

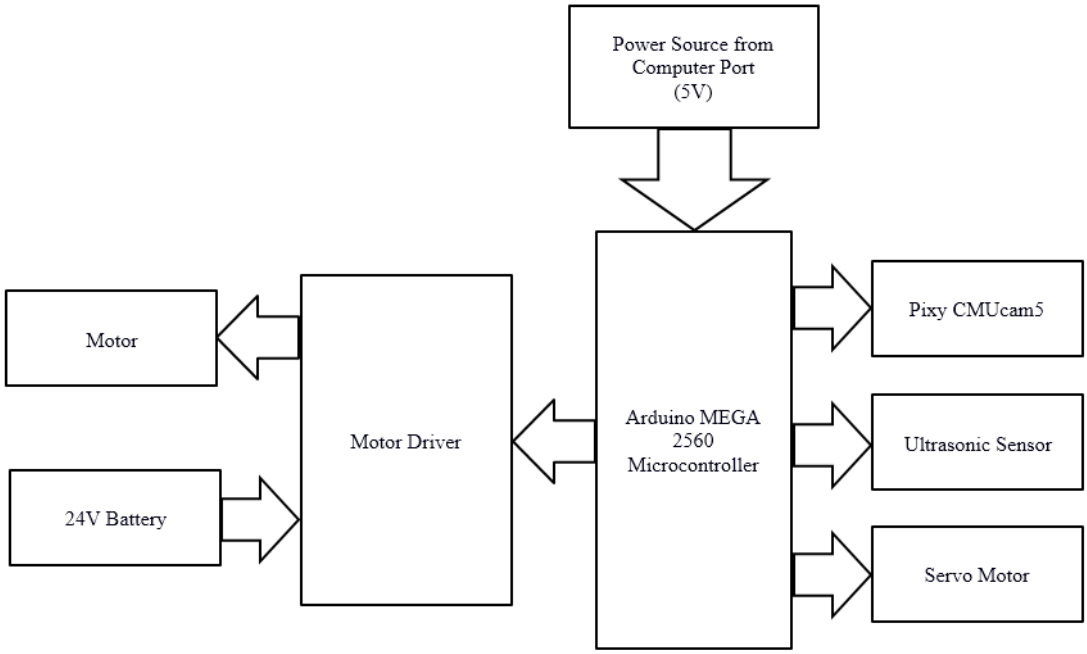

Figure 3.4: Overall Diagram for the Hardware process

3.3.2.1 Microcontroller

Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (arduino.cc, 2017). It has 54 digital input/output pins and 15 of it can be used as pulse width modulation (PWM) outputs, 16 analog inputs, 4 universals asynchronous receiver/transmitter (UART), a 16 MHz crystal oscillator, a USB connection to laptop or PC, a power jack for dc supply, an ICSP header, and a reset button (adafruit.com, 2013). It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

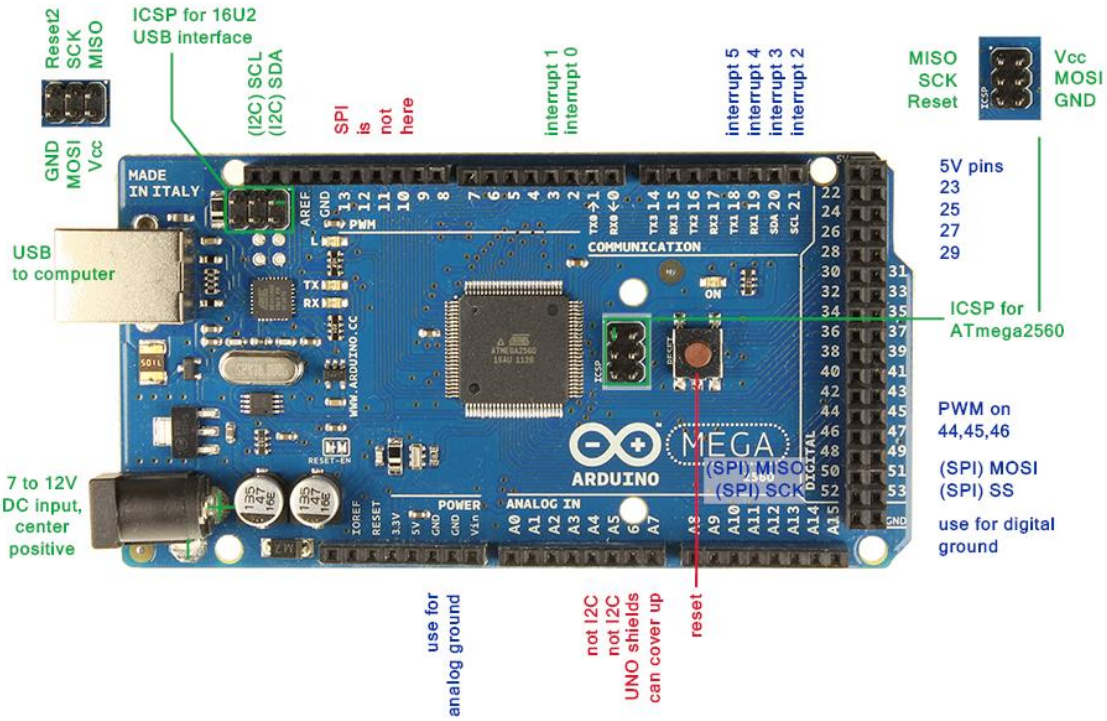

Figure 3.5: Layout of Arduino MEGA 2560 R3 and component description

(Arduino.cc, 2012)

3.3.2.2 CMUcam5™

This vision-based sensor is important since the task is to identify a targeted area. Pixy CMUcam5™ is chosen because its ability to solve the problem occurred when image sensors are used (cmucam.org, 2011). Furthermore, CMUcam5™ can be said as a well-known open source programmable low cost visual camera that has visual ability in embedded system to produce an intelligent visual sensor (CMUcam 2006). The figure below shows the Pixy CMUcam5™ that been used in this project. Besides the user can observe live-stream on its application, Pixy has a fast processor where it can process an entire 640x400 image frame every 20ms. The voltage input is 5V.

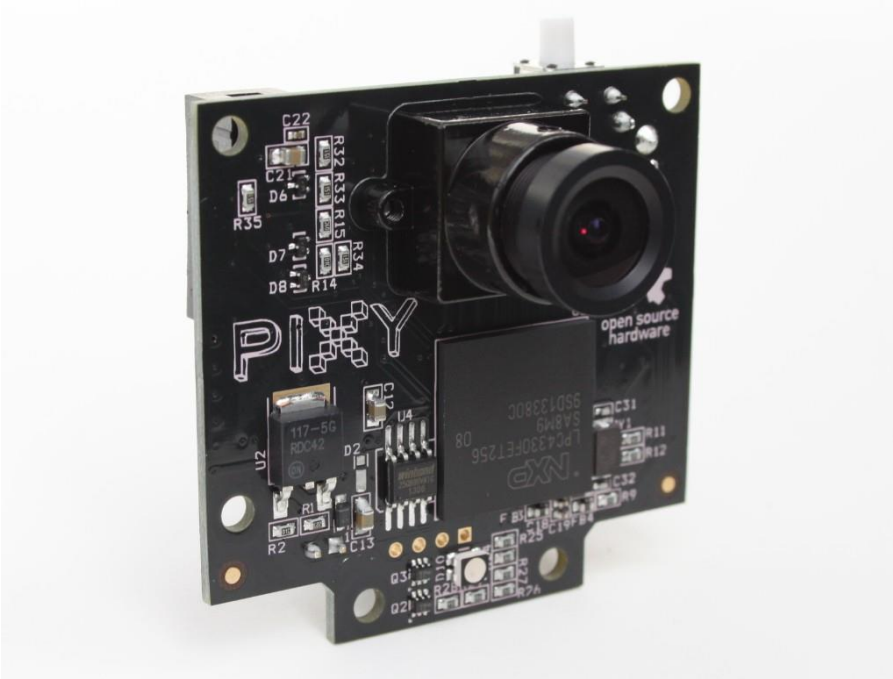

Figure 3.6: Pixy CMUcam5™

3.3.2.3.1 Field of view Pixy CMUcam5™

There are several mathematical concept that need to be used in order to find FOV of CMUcam5™. Figure 3.5 shows the CMUcam5™ in top view and wall perpendicular with camera. Equation 3.1 shows the basic trigonometric equations that need to find the FOV of the camera.

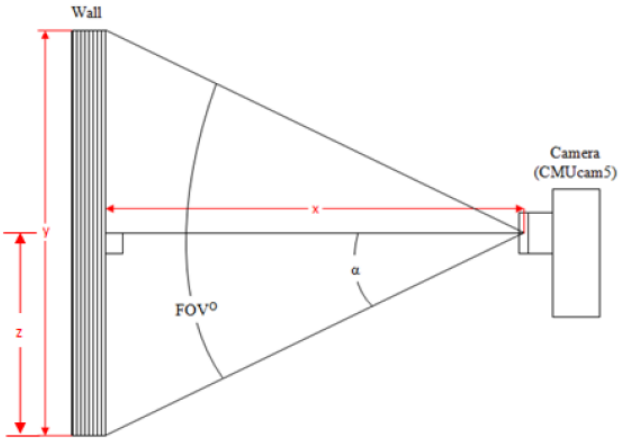

Figure 3.7 CMUcam5™ FOV setup top view

$$FOV = 2\alpha \tag{3.1}$$

$$\boldsymbol{\alpha = tan^{-1}\frac{z}{x}}$$

x = length between camera and wall

y = width of wall

z = width of wall/2

$$FOV = 2\,tan^{-1}\frac{z}{x} \qquad (3.2)$$

3.3.2.3 Motor Driver

A motor driver is a little current amplifier; the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor. Its play the important role to control the speed and direction of the motor.

The motor driver used in this project is MD30B Enhanced Motor Driver from Cytron. It was capable to drive up to 30 amperes peak motor current. There are 5 header pins jack typically for external connection with the microcontroller (Cytron 2008). MD30B is a full bridge motor driver intended for wide range of robotics and automotive applications. The dimension of this driver motor is 11.2cm x 6cm, which is almost the same size as the Arduino Mega board used.

The figure below shows the connection involving the microcontroller, battery and motor. The green LED will show the direction in clockwise (CW) while the red LED shows that the direction of the motor is in counter clockwise (CCW). The yellow LED is to indicate the power supply (Vin) in this motor driver.

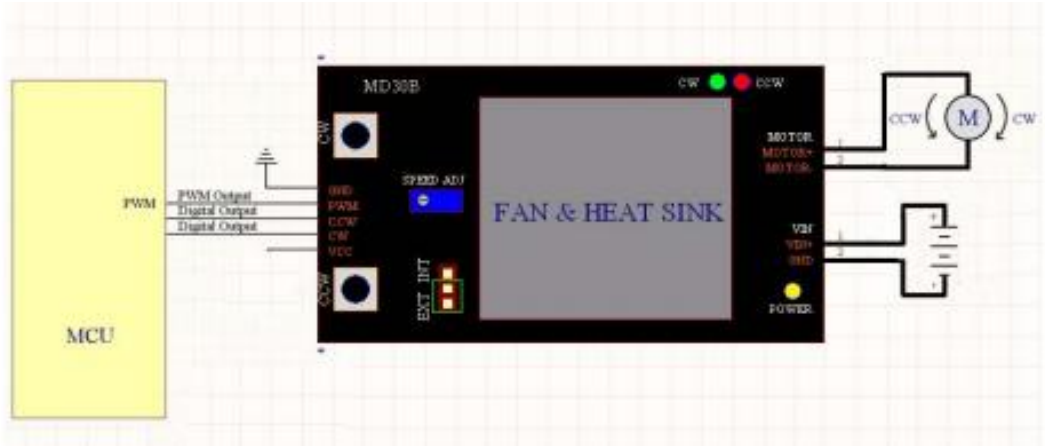

Figure 3.8: Pin connection layout to microcontroller, baterry and motor

3.3.2.4 Transaxle Motor

The transaxle motor is used as the main motor to move the cart. It required 24V DC with maximum input current 3.0A for the maximum output power 270W. Furthermore, the maximum speed that can achieved from this motor is 4700rpm.

The most important information will be the motor torque value which is 11Nm or equivalent to 112kg.cm. This mean a force of 112kg acting at a radius of 1cm would produce this amount of torque. This also means that this motor when using 1cm radius wheel can move cart that weight 112kg. The figure below shows the transaxle motor PPSM63L-01.

Figure 3.9: Transaxle Motor PPSM63L-01

3.3.2.5 Ultrasonic Sensor

The function of this ultrasonic sensor is to detect any obstacle via ultrasonic wave. In this project, the HC-sr04 ultrasonic sensor had been used because the ability to detect any obstacle or object from 2cm to 400cm in a correct matter. The operating principle for the ultrasonic sensor is similar with the bat's object detection which uses ultrasonic wave. The sensor sends out a 40-kHz radio frequency from the transmitter and the receiver will receive the reflected signal from the obstacle (Saadi 2014). The figure below shows the ultrasonic sensor HC-sr04 that been used in this project.

For this project, three ultrasonic sensors had been used to widen the area detection. This is because, each ultrasonic sensor only has field of view (FOV) angle about 60° that can't detect the obstacle or object incoming to the cart. Figure 3.11 shows the position of the three ultrasonic sensors to get the maximum angle front of the cart.

Figure 3.10: Ultrasonic sensor HC-sr04

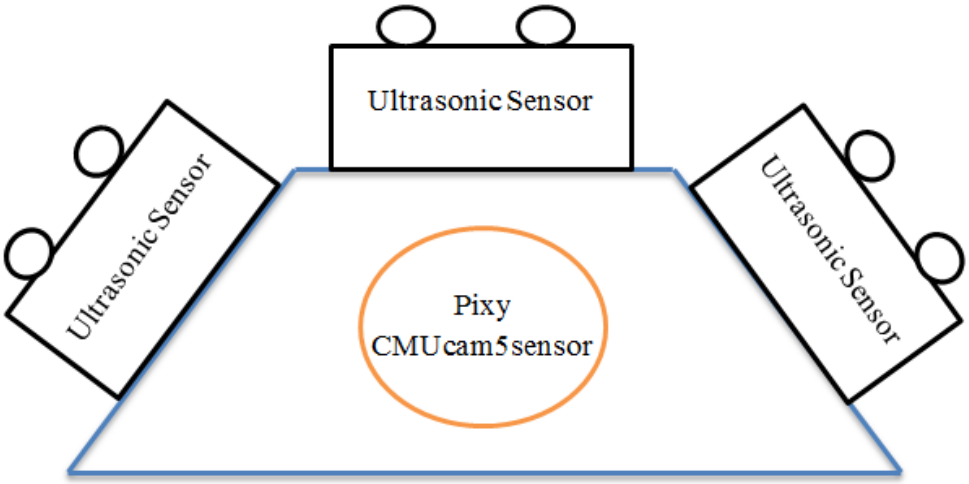

Figure 3.11: Position of the ultrasonic sensor in this project.

3.3.2.5.1 Time over distance in ultrasonic sensor

The ultrasonic sensor uses ultrasonic wave to detect the obstacle. Ultrasonic sensor sent the wave from the trigger pin and received at echo pin. From equation 3.1, time taken for the wave move from trigger pin to back at echo pin can get.

$$time\ (\mu S) = distance\ (cm) \times 58 \quad (3.1)$$

3.3.2.6 Servo Motor

The function of the servo motor is to steer the direction of the cart according to microcontroller. In this project, servo that being used is RC Servo motor with metal gear – code name HD-1501MG. This servo motor consists of 3 pins which are power pin (5V), ground pin and signal pin. Besides that, it has 17kg.cm or 1. 667N.m holding torque at 6V voltage supply (servodatabase.com, 2009).

When the 6V voltage is supplied, the rotation speed is 0.14sec per 60 degrees with no load with the current 500mA and if the voltage supply is 4.8V the rotation

speed at no load is 0.16sec per 60 degree with the running current 400mA. The figure shows the actual servo motor HD-1501MG while figure shows the dimension of the servo motor.

Figure 3.12: Servo Motor HD-1501MG

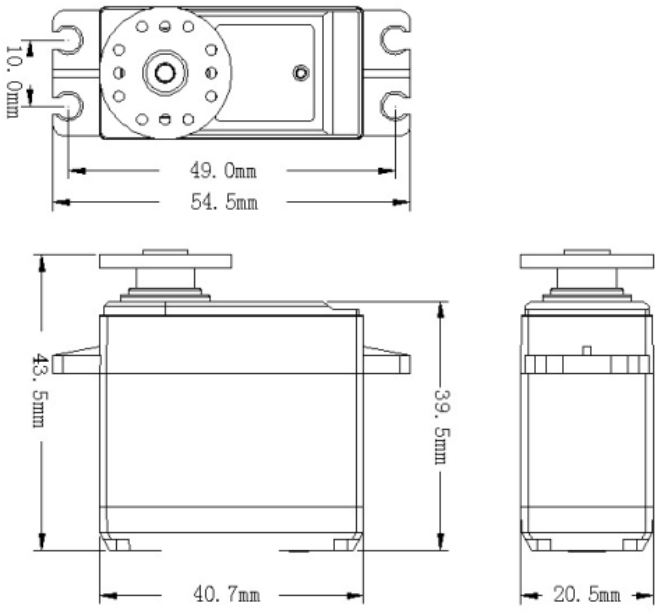

Figure 3.13: Dimension of the servo motor (pololu.com, 2009)