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CREC: Camera-Based Mobile Robot for Elderly Care

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ABSTRACT

Technologies that permits remote monitoring can be very helpful in reducing concerns of long-distance caregiving especially for elderly care. This work describes the design and development of a Camera-based mobile Robot for Elderly Care (CREC). A Pixy CMUcam5 camera is used as the main intermediary between the elderly and the movement of the robot. This camera uses a marker or tag to follow and monitor the elderly. Furthermore, a range finder sensor, Ultrasonic Sensor HC-SR04 is used as the main sensor to avoid obstacles as it is easy to inter-face and low-cost. An Arduino microprocessor is utilized to control the tyres of the mobile robot, so that the robot can follow the elderly with precision. In the current work, the robot is specifically designed to be used indoors. Several experiment have been carried out to show the usefulness of CREC. Experimental results demonstrated that CREC is capable to avoid obstacle and follow the marker tagged static and moving target successfully.

Key words: Mobile Robot, Range Sensor, Pixy Camera, experiment.

1. INTRODUCTION

The development of advance technologies have been progressing rapidly and has becoming important to many people. Electronic devices such as smartphones, laptops and tablets are essential gadgets and people cannot imagine a day without it. On the other hand, mobile robots have taken over various type of jobs in industrial setting because of its higher labor productivity compared to the companies that do not implement automation [1]. In the future, drone technologies will be capable to provide parcel delivery to humans anytime and anywhere [2]. Additionally, service robots that may give support in elderly care in home environment have been researches extensively [3].

A recent survey by United Nations Population Division shows that by 2050, the world's population aged 60 years and older is expected to be in total of 2 billion compared to 900 million in 2015 [4]. For elderly people, dangerous situation such falling can happen where it can lead to serious injury or worst death. The growing proportion of elderly people in society, together with recent advancement in robotics technology, makes the use of robots in elder care increasingly likely. Although there may be ethical issue arises, the benefits of robotics in elderly care cannot be neglected. In the future, many older adults need support and assistance with activities of daily living at some point. Therefore, service robots can potentially support in elderly home-based independent living. In several researches, it is found that elderly people have express deep satisfaction towards robots at home [5], [6].

Service robots in homes require to function in close proximity of people. It is well-known that current autonomous robotic technology still has many limitations in these challenging situations such as capability of simultaneously recognizing an elderly, follows him/her and at the same time avoiding obstacle. In order for the robot to recognize a human, it requires a mechanism that provides it information so that it can function accordingly. There are various methods in the literature that deals with issue on human detection for example the utilization laser scanner [7], real-time human face tracking [8], Kinect sensor [9], fusion of Bluetooth and Inertial Measurement Unit (IMU) [10] and RGB-D sensor [11]. These methods produced encouraging results in human detection, but majority of them require complex computational algorithm and high-end sensors that can possibly increase the cost of development. Furthermore, in these literatures, the ability of the robots to recognize a human target, follows the target and at the same time avoiding obstacle were not described in detail.

This paper describes the development of a mobile robot that recognizes and follows a human, and simultaneously avoid obstacles. The mobile robot is called CREC which is an acronym for Camera-Based Mobile Robot for Elderly Care. CREC is an integrated system that consists of human following system and obstacle avoidance system. A Pixy CMUcam5 is used to recognize and follow human target using colour signature algorithm which is easy to configure than other low-cost web camera. Furthermore, an ultrasonic sensor is used to detect obstacle in real-time.

This paper is organized as follows, the system design of CREC including object recognition and target systems are described in Section 2, followed by the experimental results in Section 3. Finally, the work is concluded in Section 4.

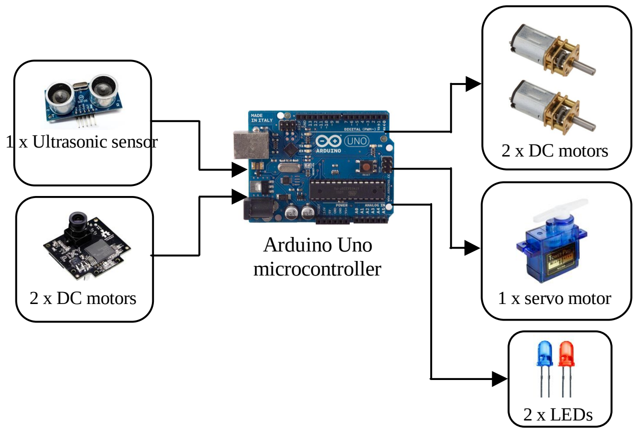


Figure 1: Block diagram for CREC electronic components

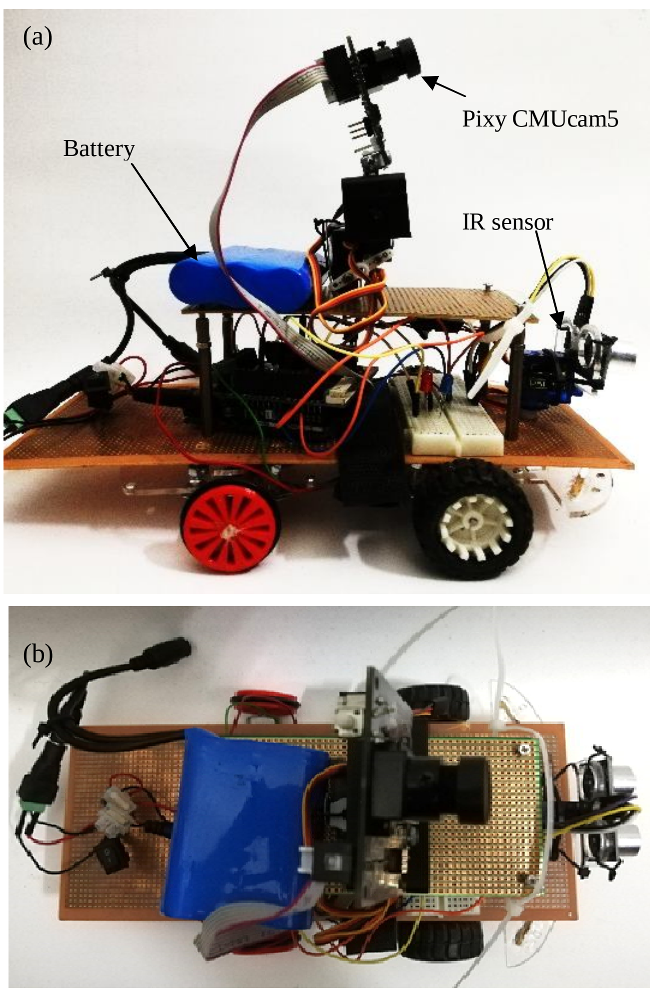


Figure 2: Prototype of CREC. Views from (a) top and, (b) side

2. SYSTEM DESIGN

2.1 System Overview

Figure 1 shows the block diagram of the electronic components of CREC. The input components consist of an ultrasonic sensor for obstacle avoidance system, and a Pixy CMUcam5 camera as main component for human target following system. Data from input components are sent to an Arduino Uno microcontroller for processing that produces output commands to output components that consist of DC motor that carry out the movement of robot, a servo motor attached with ultrasonic sensor to search for path and two (2) LEDs to indicate presence of obstacle. Figure 2 shows the actual prototype of CREC viewed from the top and side.

2.1 Obstacle Avoidance System

CREC utilizes an ultrasonic sensor to detect obstacle in front of it. The sensor works by emitting 40KHz sound wave which travels through the air. The wave will bounce back to the module if there is obstacle. Therefore, distance can be calculated by considering the travelling time and the speed of the sound based on emitting and receiving of the wave. The sensor's trigger pin was set on a high start for 10us in order to generate the ultrasound. That will send out an 8 cycle sonic bursts which travels at the speed of sound, and it will be received in the Echo pin. The Echo pin will output the time in microseconds the sound wave travel. Then Arduino will send data to motor driver and control DC motor according to the programmed instructions.

The system starts by adjusting the servo motor's alignment stacked with ultrasonic sensor to 90deg. Then, it will immediately search for any obstacle within 30cm range. CREC will move forward if there is no obstacle detected in front of it. In a scenario where there are obstacles detected, CREC will stop and change path. This is implemented by rotating a servo motor that rotates the camera to 170deg to capture the distance on the right side, and then rotate to 12deg to the left side. After capturing the distance on the right and left side, the system compares both distances to decide which path is the correct way to take. A simple 'if else' loop is used in the algorithm to determine the path by comparing both distances. If the distance on the right is greater than the left side, the system will recognizes that an obstacle is on the left side and it will turn right then move forward to the decided path. The algorithm repeats this procedure until it detected any obstacle.

2.1 Camera-based Target Following System

For this system, the main component is Pixy CMUcam5 where the camera uses a hue-based colour filtering algorithm to detect objects. The camera uses Serial Peripheral Inter-face bus (SPI) to communicate with Arduino and motor driver. The target object will be set as a signature by Pixy camera and it will calculate the blocks in the signature. The captured signature is according to previously set color using PixyMon software. After signature has been set, Pixy camera starts to calculate the initial area, maximum area and minimum area of signature's block. These areas later use to communicate with Arduino and motor driver to control the movement of CREC. The robot moves according to distance with the object tracked.

The movement of CREC corresponding to conditions of signature block's area in the captured image, where it calculates the new area of signature's block and compare to the initially calculated area. If the targeted signature block disappear from image, the robot will stop and start scanning for the signature again. The parameters set up to decide the action taken by the robot are x-axis position, height and width.

To follow the object, the robot is programmed with an algorithm consist parameters of width, height, x-axis and y-axis of the object tracked by the camera. The movement of the robot responded to the changes of the size and position of the signature. Area of the signature is calculated when the camera captured the image and set the signature. The area is set with range minimum (minArea) and maximum (maxArea) of ±1000, where

$$\text{area} = \text{width} * \text{height} \quad (1)$$
$$\text{maxArea} = \text{area} + 1000 \quad (2)$$
$$\text{minArea} = \text{area} - 1000 \quad (3)$$

When the object moves forward, the signature becomes smaller and new area of the signature (newArea) is calculated using the formula below:

$$\text{newArea} = \text{width} * \text{height} \quad (4)$$

Pixycam then compares the value of newArea with the range set for the maxArea and minArea. Using these values, CREC is capable of motions as described below:

- Forward motion: when the size of newArea < minArea the mobile robot moves forward. If the object moves backward, the signature become bigger and newArea is calculated.
- Backward motion: When the size of newArea > minArea the mobile robot moves backward. The minimum value of x is set to Xmin = 70 and max value is set to Xmax = 200. If the signature is within the range of minimum and maximum value of x, the mobile robot will stay forward.
- Turn left: The mobile robot will respond to position of the colour signature. Whenever the value of x < Xmin it will turn left.
- Turn right: Whenever the value of x >Xmax the mobile robot will turn right.
- Stop: The mobile robot will stop moving if the area and position of the signature is the same with initial value. CREC also stop moving when no signature is detected.

3. EXPERIMENT AND RESULTS

3.1 Experiment on Obstacle Avoidance System

For this experiment, the objective is to proof the algorithm in avoiding multiple obstacles along the path. From the experiment, the ability of the robot to reach the end of the maze from a point A to a point B will be analyzed.

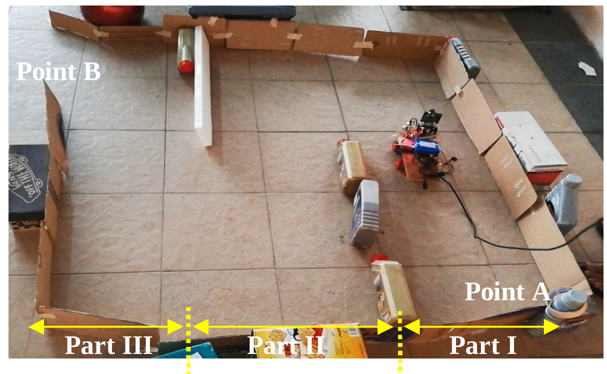


Figure 3: Experiment setup

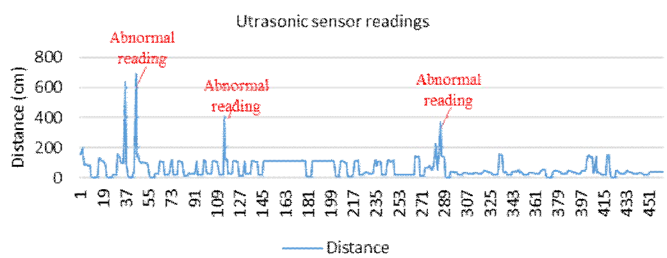


Figure 4: Distance detected by ultrasonic sensor

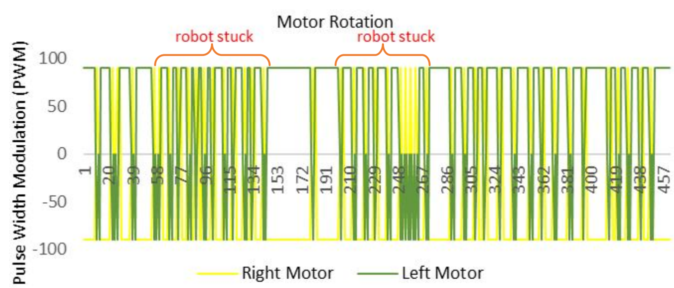


Figure 5: Motor movement corresponding to sensor

Figure 3 shows the experimental setup where the mobile robot is placed in a simple maze. Figures 3 and 4 show the results for distance detected and motor rotation respectively. In Figure 3, at reading 37, 45, 115 and 285 shows abnormal distance readings by the sensor at 638cm, 698cm, 407cm, and 370cm, respectively. The normal distances detected are within 90cm and 100cm and again this can be said that the performance of ultrasonic sensor may decreases when multiple components assembled. Corresponding to Figure 4, the robot wheel motors rotation results in Figure 5 shows the unsatisfied outcome where the mobile robot failed to solve the maze. From Figure 5, we can see at reading 57 precisely at t = 49s, the repetitive action of the mobile robot to turn left to second part of the maze. After a while, the mobile robot succeeded to turn to second part of the maze at t = 120s but had a hard time again to turn left and stuck at reading 253.

Several conclusions for the test can be made. First, the condition for distance to detect obstacle is not suitable to set at 30cm. It is because that the distance quite far and not suitable in narrow environment. There might be a time when a house is in mess and more obstacles possible thus, a shorter range is better. Second, the mobile robot is too heavy causing the motor hard to handle the robot to correct direction.

3.1 Target Following System

A. Case 1: Test-run in high presence of light

The objective of this experiment is to analyze the accuracy and performance of the camera in the high presence of light. Figure 6 shows the visual in PixyMon when the camera run in high presence of light. The signature is clear and set to 2 and the area of the signature is calculated.

Figure 7 shows the result of Pixy camera and DC motors during experiment in high presence of light. At reading 26 to 170 we can see the value of width and height decreasing because the target move forward. This causes the newArea calculated is less than initial area value. The rotation of the motor where PWM value for right motor and left motor is -70 and 70 respectively. The mobile will move forward. After that, the target turn to right and value of x-axis increase. Because of the value of x-axis do not exceed the maximum value which is 200, the mobile robot continues moving forward. At reading 526 the mobile robot goes backward because the value of width and height increased and newArea bigger than area. The robot will move backward to distance itself from the target. At reading 651, the robot stop because the size of area and position of x-axis are seemingly same with the initial value. The test result shows that the mobile robot move accurately because of the good performance of pixy camera in high presence of light.

A. Case 2: Test-run in low presence of light

The objective of this test is to analyze the accuracy and performance of the camera in the low presence of light. In this experiment, the light has been turned off to meet the condition of low presence of light. Figure 8 shows the visual in PixyMon when the camera run in low presence of light. The signature is not very clear. Only small part of the target is detected.

Based on Figure 9, the mobile robot can perform well but less accurate at the start of experiment. It started to become out of control after several minutes. This is due to the loss of view of the detected signature. This result shows that the camera performed poorly in low presence of light causing the mobile robot to move out of control.

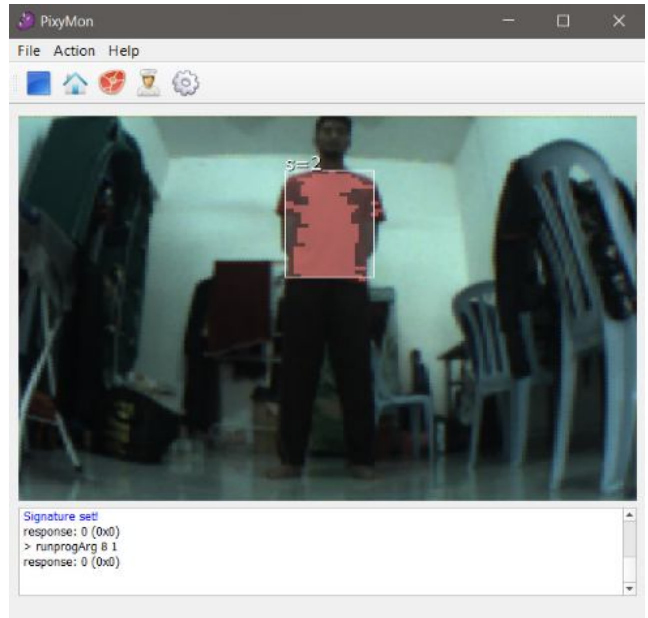


Figure 6: Pixy camera visual in high presence of light

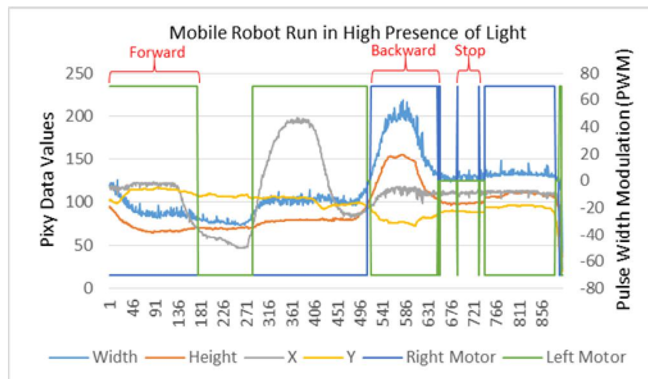


Figure 7: Result of mobile robot run in high presence of light

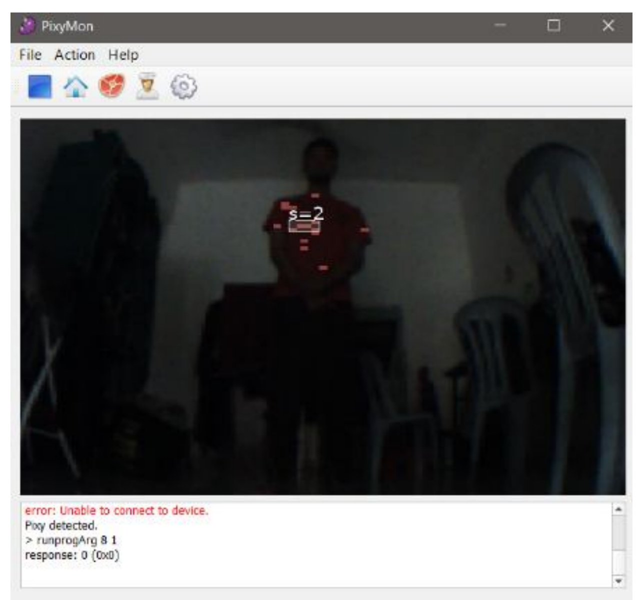


Figure 8: Pixy camera visual in low presence of light

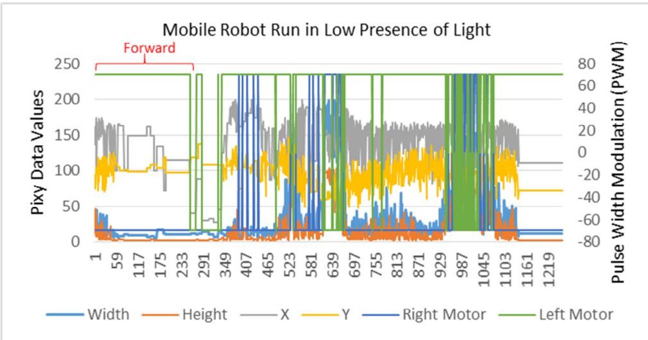


Figure 9: Pixy camera visual in low presence of light

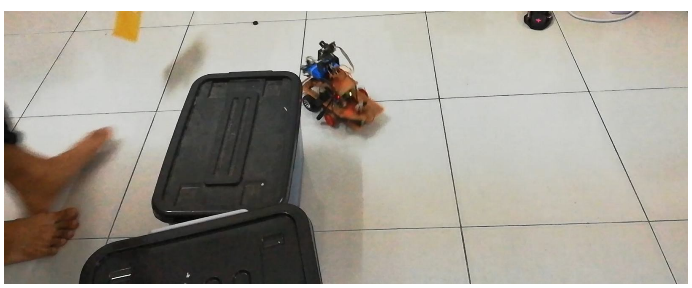
Figures 10(a)-(f) show the movement of the robot for the integration system of obstacle avoidance system and object following system. At t = 2s, CREC follows the object and detects the box. Then, CREC moves backward at t = 4s, and search for path. At t = 6s, CREC turns to the right and moves forward then continue to follow the object as shown in Figure 10(e) and Figure 10(f). The results show that CREC is able to simultaneously track an object and evade obstacles.

(a) At t = 0s, CREC detected object and follows it

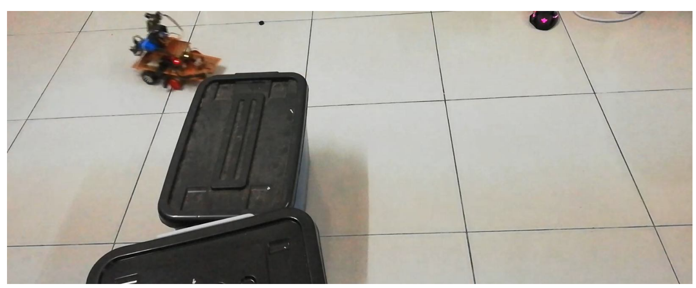
(b) At t = 2s, CREC follows object and detected obstacle

(c) At t = 4s, CREC moves backward and search for path

(d) At t = 6s, CREC turned right after confirming new path



(e) At t = 8s, CREC moves forward and follows object



(f) At t = 10s, CREC follows object and evading obstacle

Figure 10: Movement of robot over time

4. CONCLUSION

CREC is currently still in development process as there are several errors and failure in each experiments. The objective of this work is to build a mobile robot capable of avoiding obstacle and follow human target.

Multiple experiments have been done on each system to verify the performance and efficiency on performing tasks. For obstacle avoidance system, two experiments were conducted to test the algorithm implemented to the system and also to verify the performance of the robot in certain environment. The first case was to test the basic function and the results proved the accuracy of the motor movement when avoiding an obstacle. Second case was to test the capability of the robot to solve a maze. The result shows that further improvement need to be done to the implemented algorithm.

The experiment continues for human target following system to test the performance of the robot in high presence and low presence of light. The test concluded that CREC moved accurately because of the good performance of pixy camera in high presence of light. However, the camera performed poorly in low presence of light and causing the robot movement out of control.
After completing the experiments for both system, integration experiment was carried out to verify the performance of the complete integrated system. It was found that the system was functioning well for the functionality testing. However, the accuracy and the performance of the robot may decreased over time due to lightning condition.

As a conclusion, there is still room for improvements in the development of CREC. In the future, CREC will be a global needs to ease children worrying about their parents as the project will continue to be research and develop. Hopefully at the end of this work, the elderly monitoring robot will be able to follow elder autonomously and at the same time can avoid any obstacles.

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