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PARAMETER ANALYSIS OF A REMOTELY CONTROLLED HOME MONITORING SYSTEM USING MOBILE ROBOT VIA CAMERA

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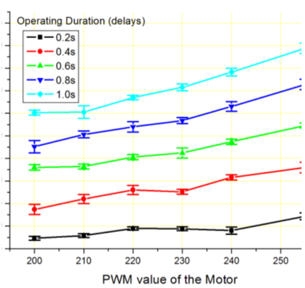
Graphical abstract



Abstract

In this paper, the performance and prototype of a remotely-controlled home monitoring mobile robot for security and surveillance purposes were discussed. Home monitoring system has been one of the basic infrastructures that is being used in most of the residential compound. However, traditional CCTV system, which requires supporting surfaces and high equipment cost, has forced human to search for an alternative. Thus, this project provided a more flexibility and mobility to the home monitoring system, which consisted of an obstacle detection system and a camera. After discussing the conception of the project, as part of the experiment aspect method, experiment setup and result were presented. In this paper, the objectives also looked into the sensitivity of the obstacle avoidance system, to design and develop a remotely-controlled home monitoring robot, to design and develop a networking system for long distance robot control and to analyze the performance of the motor in terms of pulse width modulation (PWM). In conclusion, the experimental result proved that the proposed project was successfully developed with detailed supporting data.

Keywords: Remotely-controlled, home monitoring system mobile robot, obstacle detection system

Abstrak

Dalam kertas ini prestasi dan prototaip robot mudah alih bagi pemantauan kawalan jauh di rumah untuk tujuan keselamatan dan pengawasan dibincangkan. Sistem pemantauan di rumah telah menjadi salah satu kemudahan asas yang sedang digunakan di kebanyakan kawasan kediaman. Walau bagaimanapun, sistem CCTV tradisional, yang memerlukan sokongan permukaan dan kos peralatan yang tinggi, telah memaksa manusia untuk mencari alternatif lain. Oleh itu, projek ini menyediakan kelebihan dari segi fleksibiliti dan mobiliti kepada sistem pemantauan di rumah, yang terdiri daripada satu sistem pengesanan halangan dan kamera. Setelah konsep projek dibincangkan sebagai sebahagian daripada kaedah percubaan, persediaan eksperimen dan hasilnya telah dibentangkan. Dalam kertas ini, objektifnya adalah menganalisa sensitiviti sistem kawalan robot di rumah dalam mengelakkan halangan, merekabentuk dan membangunkan sistempemantauan kawalan jauh di rumah, merekabentuk dan membangunkan sistem rangkaian kawalan jarak jauh menggunakan robot dan seterusnya menganalisis prestasi motor pergerakan dengan menggunakan modulasi lebar denyut (PWM). Kesimpulannya, hasil eksperimen membuktikan bahawa projek yang dicadangkan telah berjaya dibangunkan dengan data sokongan yang terperinci.

Kata kunci: Kawalan jauh, sistem pemantauan robot mudah alih, sistem pengesanan halangan

1.0 INTRODUCTION

Home monitoring system has been one of the basic infrastructures that are commonly used in most of the residential compounds in this modern era. Moreover, closed-circuit television (CCTV) has become the trend in replacing security guards to look after houses and asset. However, flexibility and mobility issues of the existing CCTV system have been one of the limitations that has yet to be solved by the engineers in reason years. Generally, all CCTV systems require supporting surfaces such as ceiling or wall to hold the video camera. Although some of the camera models are able to provide tilt and turn function, the viewing angle is still limited as compared to a moving camera which enables user to travel to the desired location. Thus, in this project, the combined of systems which includes mobile robot system and CCTV system were developed, which enable to provide sufficient flexibility and mobility as compared to the traditional security system. The scopes of this project will be focusing on producing a remotely-controlled home monitoring mobile robot for long distance control, analyzing the sensitivity of the obstacle detection sensor, designing and developing a suitable networking system for the project and lastly, analyzing the performance of the motor in terms of pulse width modulation (PWM). Meanwhile, the ideas of developing such project were generated from the high property crimes rates in our country and the limitation of the existing surveillance system.

Based on some of the reviews from previous researches, the device used for remotely control [1-7] is the XBee Wi-Fi module. It is chosen due to the radio frequency for data transmission and has wireless coverage up to 100m. Secondly, it is regarding the mobile robot mechanical design, where in this project, wheeled mobile robot [8-9] is preferred rather than legged [10] and belt type [11] robot as wheeled robot enables high-speed movement and is easy to control. Moving on, DC geared motor is chosen amongst various types of motor due to its properties of continuous rotation and high torques. In various types of sensor [12-15] IR sensor [12] is used in this project as the obstacle detection sensor because IR sensor has a detection range up to 80cm and is low in cost. Furthermore, the most suitable network system for this project is local area network (LAN) [16-21] which operate under offline mode and is able to provide stable data transmission rate. Lastly, a Dlink cloud camera is used to provide live feed video to the interface.

2.0 METHODOLOGY

2.1 Mobile Robot Prototype

The design of the prototype is first drawn using SolidWorks software and then sent for fabrication. The prototype consists of upper deck and lower deck and four supporting poles. The material used for upper and lower deck is acrylic board with thickness 6mm, while the supporting poles are made of brass. Besides that, the prototype is moved by two identical DC geared motor attached to two identical 5 inch wheels. Moreover, the camera is positioned on the upper deck facing the front direction. There are four identical infrared sensors (IR) which are placed at front, left, right and back of the prototype to detect the surrounding obstacle. The main component of the prototype consists of Arduino Uno board, Motor driver, and XBee Wi-Fi module. Other than that, an external rechargeable 9V battery is used to power the motor driver to support the performance of both motor while the Arduino Uno board and Camera are powered by a power bank. Figure 1 shows the top view, side view, front view and overall view of the prototype.

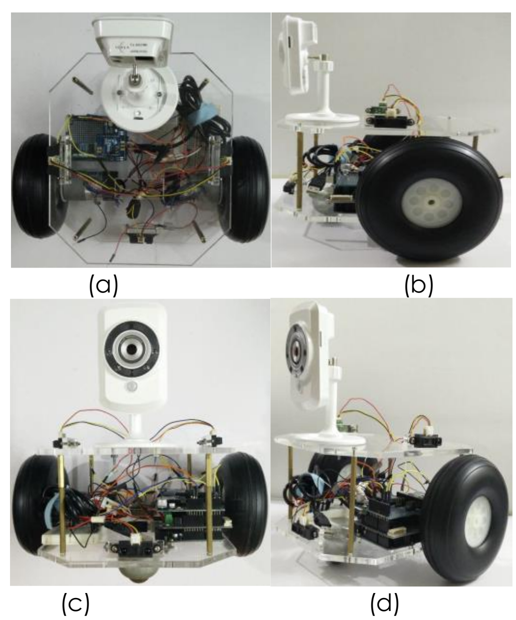


Figure 1 (a) Top view, (b) Side view, (c) Front view and (d) Overall view of the prototype

2.2 Networking System

Local Area Network system (LAN) is used to support the wireless connection between each of the components in this project. In this project, both cloud camera and Arduino Uno board will be linked to the Virtual Controller via different channels. For instance, cloud camera requires a router as a interlink party to complete the wireless connection. However, Arduino Uno requires XBee Wi-Fi module to support transmitting and receiving data signal from the virtual controlled via external wireless adapter. The project networking system connection is presented in Figure 2.

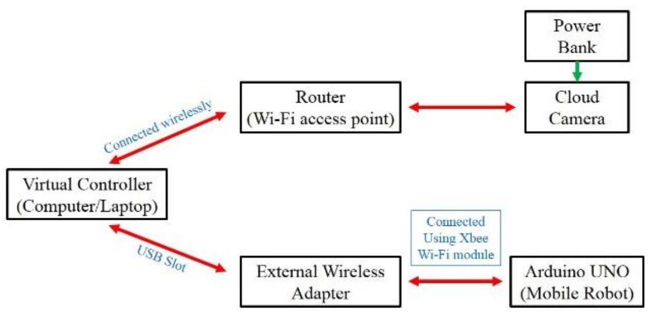


Figure 2 Project networking system

2.3 Mobile Robot System

The mobile robot system's main component consists of Arduino Uno board, Motor driver, DC geared motor and infrared sensor (IR). On the mobile robot, four identical IR sensors are being used as the obstacle detection system for the project, where all four sensors will be connected to different pin on the Arduino board. Meanwhile, a motor driver is also connected to the Arduino Uno board while the output pin of the motor driver is connected to left and right motor. Moreover, a 9V rechargeable battery is used to power the motor driver for supporting the performance of both motor while a power bank is used to supply the Arduino Uno board. Figure 3 shows the overall mobile robot system which is connected using wire.

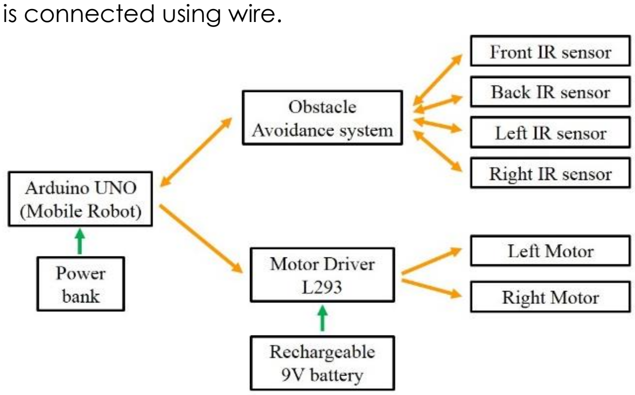


Figure 3 Overall Mobile Robot System

2.4 Process Operation

The operation process of the project starts from turning on the power of the mobile robot and router. Then, the cloud camera will automatically be connected to the router. Next, user will need to start up the virtual controller server. When the server is turned on, then the connection between laptop and router and between laptop and XBee Wi-Fi module is established. The next step is to open up the virtual controller HTML page using a web browser and then to insert the IP address of the cloud camera and XBee Wi-Fi module at the specific column located in the HTML page. When the device is linked up with the laptop, the system is ready to be used. At this moment, user can move the mobile robot to the desire position by pressing on the mobile robot's control button and the embedded live feed video will also be displayed on the video window in the virtual controller. If the system is not functioning, a troubleshooting process must be taken out by rebooting the connection between laptop and router or the connection between laptop and XBee Wi-Fi module. Lastly, the process flow of the whole system is completed. Figure 4 shows the operation flow of the project system.

2.5 IR Sensor Calibration Distance and Angle Test Experimental Setup

This experiment is divided into two parts, which are the distance test and angle test. First of all, the distance test will be conducted by placing an obstacle at 90° in front of the IR sensor while the distance between the sensors, in which the obstacle is varied from 0cm to 80cm with an increment of 10cm every interval. The test is also conducted using two different sizes of obstacle. Figure 5 shows the experiment setup of IR sensor calibration distance test.

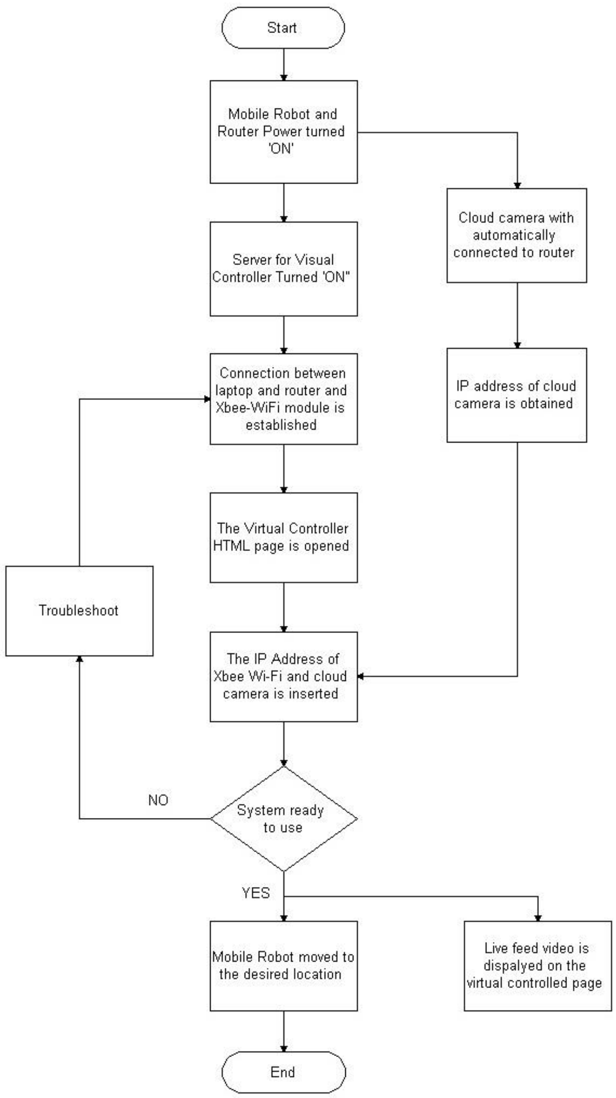


Figure 4 Project Process Operation Flow Chart

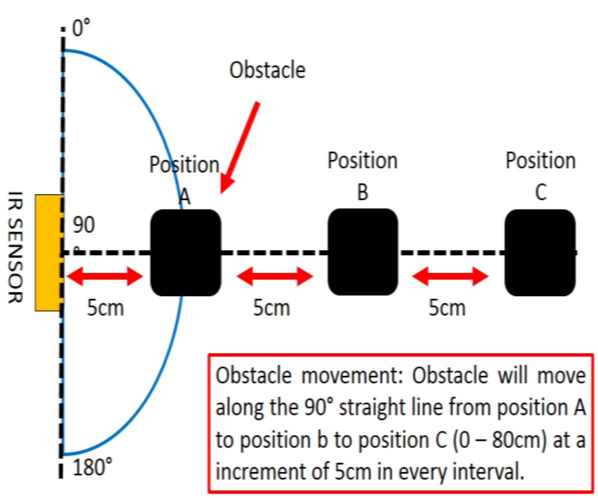


Figure 5 Experiment setup for distance test

Moving on is the IR sensor calibration angle test. In this test, the position of the obstacle will be varied from 0° to 180° with an increment of 10° every interval while the IR sensor will be located at the center point. Meanwhile, the distance between the sensor and the obstacle is varied from 10cm to 20cm and lastly 30cm. Two different sizes of obstacle are used throughout the experiment. Figure 6 shows the experiment setup for the IR sensor calibration angle test.

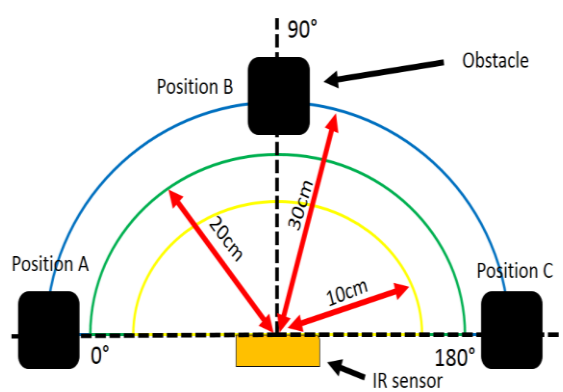


Figure 6 Experiment setup for angle test

2.6 Mobile Robot Turning Angle Control Experimental Setup

In this experiment, obstacles will be placed at 10cm and 20cm 90° in front of the prototype front sensor. The tests are divided into turning left test and turning right test. For turning left test, the left motor PWM will always be maintained at 0 while the PWM of right motor will be varied from 180 to 255, with an increment of 10 every interval. On the other hand, for turning right test, the right motor PWM will always be maintained at 0 while the left motor PWM will be varied from 180 to 255 with an increment of 10 every interval. Similarly, two different sizes of the obstacle are used throughout the experiment. Figure 7 shows the experiment setup for motor turning angle control.

2.7 Slope and Different Surfaces Test Experimental Setup

This experiment is divided into two stages. The first stage of the experiment is the slope test. In the slope test, the prototype is tested to encounter different steepness of slope measuring from 0° to 8°. Furthermore, the distance of the slope is fixed at 0.6m and the slope surfaces are smooth surfaces made of plain wood. For this experiment, unlike the turning angle control, the PWM value for both motor will be given the same value in order to move the prototype in the forward direction. Besides that, the motor PWM is varied from 180 to 255 with an increment of 20 every interval. In the second stage of the experiment, the prototype will be tested on different surfaces including grass, tar road, sand road and carpet. For different surface tests, the level of the surfaces will be maintained at 0° of steepness. The chosen motor PWM value to be used for testing is 255, which is the maximum value that could be assigned. Figure 8 shows the experiment setup for slope test.

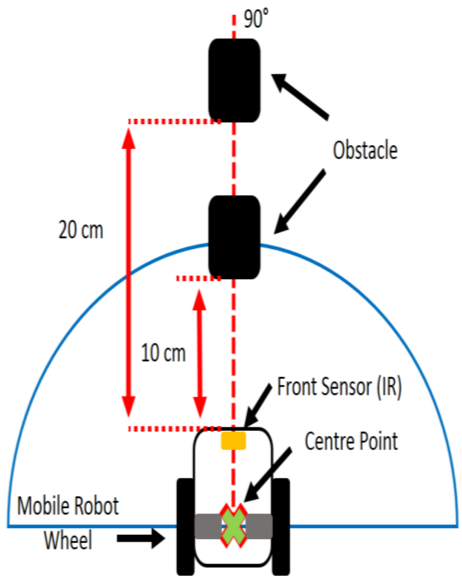


Figure 7 Experiment setup for motor turning angle control

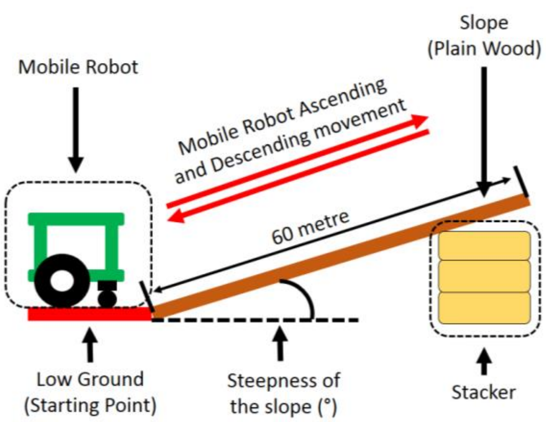


Figure 8 Experiment setup for slope test

2.8 Network System Experimental Setup

In this experiment, the wireless connection between the prototype and webpage interface is tested. First of all, the webpage interface will be operated using the internet browser. Then, the connection between cloud camera and the interface is established via router. At the same time, the XBee Wi-Fi module is connected to the interface via the external wireless adapter. When all the connection is done, the testing starts by giving the movement command and observing embedded live feed video. Figure 9 shows the experiment setup for the network system testing while Figure 10 shows the overall view on webpage interface.

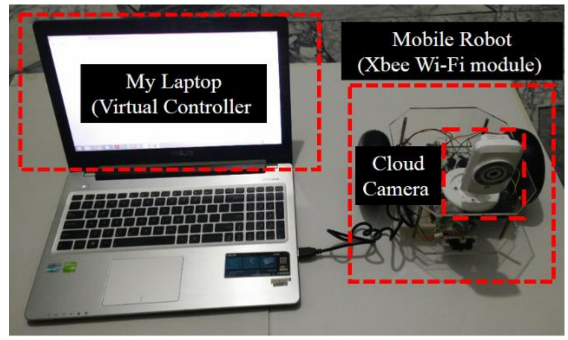


Figure 9 Experiment setup for network system test

Figure 10 Overall view of webpage interface

3.0 RESULTS & DISCUSSIONS

3.1 IR Sensor Calibration

3.1.1 Distance Test

The result shows that the data collected from experiment are similar to the datasheets. In conclusion, the detecting range of IR sensor is between 10cm to 80cm while reading less than 10cm an 80cm will provide an irrelevant finding. Figure 11 shows the results of IR sensor calibration distance test.

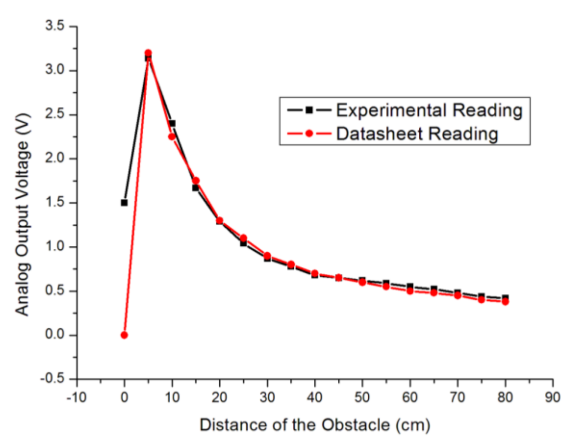


Figure 11 Results for distance test

3.1.2 Angle Test

The results show that the effective angle of detecting for IR sensor is 20°, which falls between angle 70° and angle 90°, while the most accurate reading collected is at 90° for obstacle distance at 10cm, 20cm and 30cm, Thus, this information has been used as our reference setting for the project's obstacle detection system. Figure 12 shows the results of IR sensor calibration angle test.

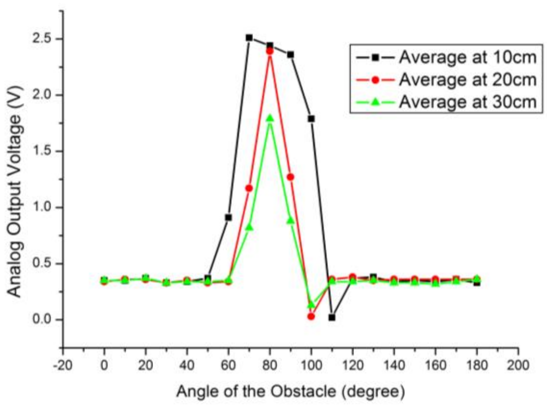


Figure 12 Results for angle test

3.2 Mobile Robot Turning Angle Control

The results from this experiment presented the most suitable combination of Motor PWM for turning left and turning right motions of the prototype for acquiring the required turning angle in avoiding the obstacle located at 10cm and 20cm in front of the prototype are shown in Figures 13 & 14. Thus, when one of the motor PWM value is 255 while another motor remains at 0, the turning angle is the largest for both turning left and turning right motions.

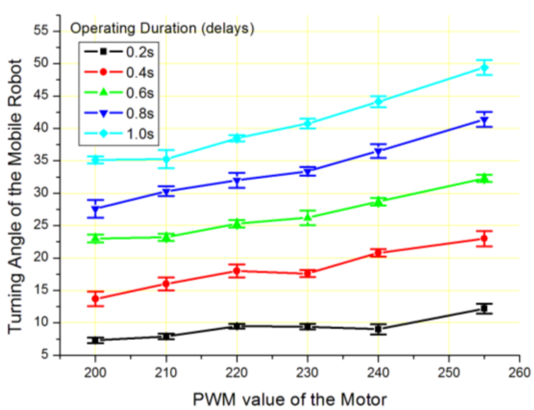


Figure 13 Result of turning angle test for turning right motion

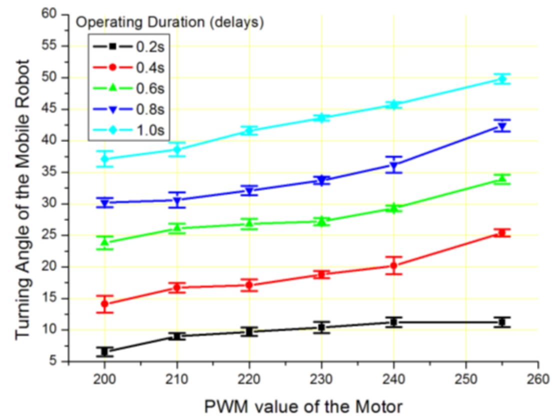


Figure 14 Results of turning angle test for turning left motion

3.3 Slope and Different Surfaces Test

The result shows that the performance of the prototype is out of the working range when encountering slope beyond 5° for ascending and descending orders. Meanwhile, at motor PWM 255, the prototype is able to travel the furthest distance. However, for different surfaces tests, the result shows that the prototypes are able to travel of tar road, sand road and carpet but unable to perform on grass surfaces. Figures 15 and 16 show the results of the slope test.

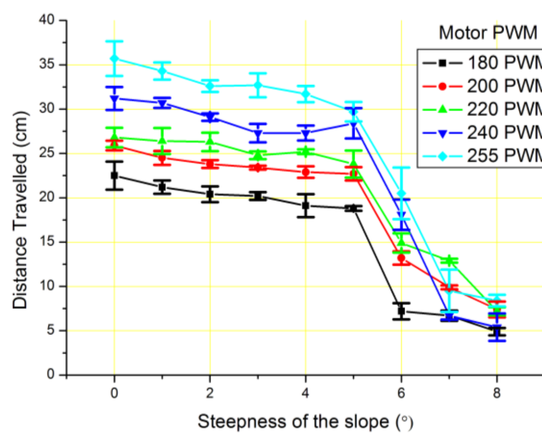


Figure 15 Results for ascending order

3.4 Network System Experiment

In this experiment, the signal data received by the Arduino Uno board from the Webpage interface are tracked using the serial monitor. The results show that the received signal data are exactly the same input command addressed in the webpage interface. As a conclusion, the connection between the webpage interface and the Arduino Uno is synced and the delays in data transmission are approximately 2seconds in average. Figure 17 shows the supporting evident of data received by the Arduino Uno using the Serial monitor.

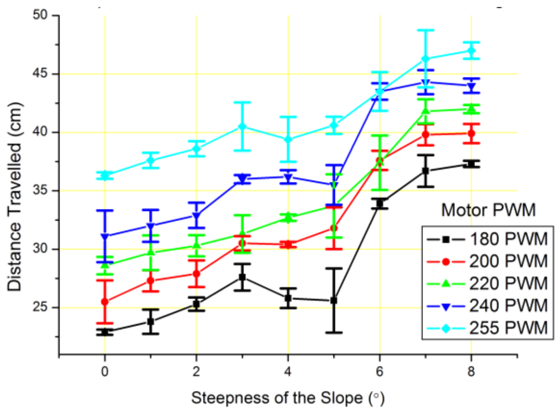


Figure 16 Results for descending order

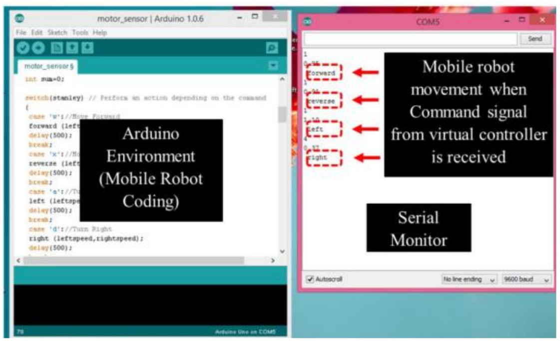


Figure 17 Results in Serial Monitor

4.0 CONCLUSION

In this paper, the performances of a remotely-controlled mobile robot for home monitoring purposes are discussed, which was able to operate within the resident compound wirelessly. The mobile robot is equip with an obstacle detection system for detecting the surrounding obstacle and a cloud camera for generating the embedded live feed video to the webpage interface. Moreover, the mobile robot is able to encounter slope with steepness less than 5° and travel on different surfaces. For future work of the current system, the improvement is to migrate the whole system from using local area network system to the third-tier cyberspace, where user can easily access to the system via webpage interface from anywhere in the world when internet access is available. This may simply increase the coverage of the mobile robot and also the application of the system. Furthermore, the face recognition system is useful to be implanted into the cloud camera operation to increase the security level of the home monitoring system, where the mobile robot itself may able to differentiate between family member and stranger.

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