Autonomous Mobile Robot Using Vision System and ESP8266 Node MCU Board

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Abstract

This paper proposes an automated mobile robot indoor system. A web camera sensor is equipped to detect the current location of the vehicle. The web camera is located above to capture the object and environment for mapping. The images come from the web camera via a USB interface to the computer. The image processing method is used to determine the position of the mobile robot for giving the input of path planning. The microcontroller obtains interactive actions with the combinations of image processing and suitable path planning to control the direction of the mobile robot. The experimental results show that the vision system can interact with the microcontroller. The robot can move automatically from the starting point to the goal.

Keywords: vision system; autonomous vehicle; mobile robot; microcontroller; image processing
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1. Introduction

Nowadays, service transportation indoor systems repeat passages that involve traveling short and these are controlled by humans. It is necessary that service transportation systems can recognize traffic signals and signs on the way [1]. Operators control the vehicles enabling the vehicles to get to their targets safely [2, 3]. Many researchers have been trying to create technology that can make transportation more convenient [4] and part of this has been the creation of autonomous robots that can travel to the destination safely [5] and improve the lifestyles of their users [6]. There are different systems that can be used to make self-driving vehicles [7] in order to replace human operations. The system is controlled by an interactive interface and reaches autonomous navigation by extracting the appropriate mapping information [8] for better convenience, safety, and efficiency on the road [9]. A sensor is one important part that measures physical input from its environment to convert into a signal for the perception of a vehicle if the sensor is suitable to handle these tasks. It is able to complete the identification [10 -12] and allows a vehicle to go to the target with precision [13]. Considering the key role of self-driving in the automatic mobile robot, it seems that the perception sensors are necessary for a mobile robot to automatically self-drive [14]. These types of systems also need improved vehicle navigation system [15], location system [16], electronic map, path planning [17]. Furthermore, better vehicle speed control is crucial for overall vehicle control [18].

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Speed control is complex due to the large amount of information that needs to be dealt with, and usually a single sensor is unable to efficiently perceive the mass information. However, an additional performance of the automatic mobile robot based on those factors is necessary.

In order to develop a self-driving mobile robot for indoors, choosing a suitable method for mapping is very important for the navigation of an autonomous driving robot [19]. There are several methods to guide the mobile robot to reach the goal [20]. Magnetic tape is an easy way to guide the mobile robot for tracking. It is attached to the floor and helps the robot to identify the surrounding area for navigating mobile robots. The mobile robot often seems to be confused about moving when something is obstructed on the road or when the magnetic tape is lost. Lidars are often used and they play an important role in system navigation. Many researchers use a Lidar to perceive the surrounding environment and establish the electronic map [21-23]. Lidar is a remote sensing method that uses light in the form of a pulsed laser to measure ranges to the object. It is not appropriate for some tasks that are too sensitive to laser light and the laser beams may harm the human eye in cases where the beam is too powerful. A vision system is one innovation that can be applied in visual perception [24, 25]. To provide more information than conventional sensors [26, 27], the accuracy of data collected can be improved by methods based on image processing advanced sensory tools [28], particularly with respect to physical measurement [29]. Vision system helps to automatically locate [30], navigate [31], judge motion [32], and perform path planning [33] for the mobile robot on the way to its destination. Such vision systems can provide better convenience, safety, and efficiency for transportation systems.

This paper presents a mapping method with image processing that identifies the current position of the mobile robot for path planning. The autonomous mobile robot is controlled by an ESP8266 Node MCU board. The microcontroller interfaces with the vision system to control the direction of the mobile robot for autonomous driving. The computer shows electric graphic mapping in real-time. The system is also designed for path planning for navigation of the mobile robot on the computer [34]. The vision system not only provides a graphic map via the image processing method but it also navigates and guides the robot to the goal based on the path planning. The system also helps autonomous mobile robots reduce the use of multiple sensors and is considered to be one of the best options to reduce production costs [35].

2. Materials and Methods

2.1 The operation system

This section describes the design of an autonomous mobile robot for indoors. Considering the key role of the components in self-driving vehicle, the system consists of three parts, as follows: 1) a navigation system that requires the current location of the vehicle and position of destination, 2) a path planning facility, and 3) vehicle control. In this research, the vehicle system consists of two parts: 1) a vision system and 2) a mobile robot system as shown in Figure 1. The whole process of the system consists of four steps.

1) A web camera captures the images and sends the information to a computer.

2) A computer determines the vehicle location which is obtained by image processing. The vehicle location and destination position are inputs of path planning to guide the robot to go to the goal. The path planning signal is sent to a microcontroller.

3) The microcontroller receives the path planning signal and converts it for wheel control of the mobile robot. There are four functions as follows: Forward, Turn Left, Turn Right, and Stop.

4) The mobile robot is moved from starting to reach a goal by command of the microcontroller.

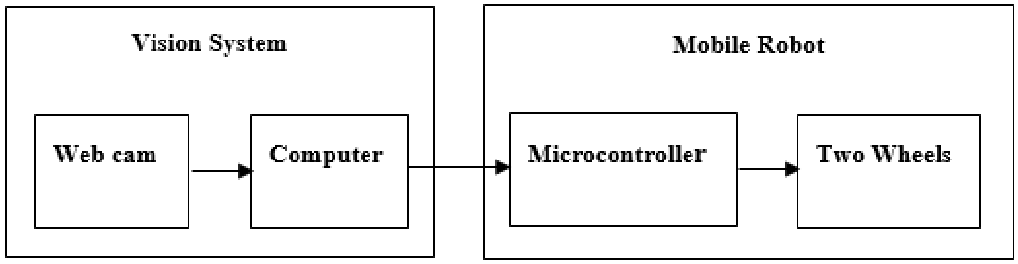

Figure 1. Block diagrams of the design of an autonomous mobile robot system

2.2 Vision system

The vision system consists of a web camera and a computer. The computer is used for image processing and designed path planning for the mobile robots. The computer is the central interface between the web camera and the microcontroller.

2.2.1 Web camera

The web camera is attached to a tripod stand. The web camera is installed from above as shown in Figure 2. The tripod stand is 127 cm high. The field of view (FOV) of the camera covers the area in 1280x960 pixels (122 × 32 cm). The configuration of the web camera is set up. There are brightness, contrast, exposure, sharpness, saturation, and white balance settings. The resolution of the web camera is 1600X896 pixels with 30 fps for capturing. The information is sent to the computer and the image is processed using the image processing method with LabVIEW software.

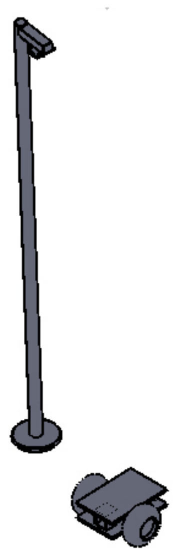

Figure 2. An autonomous mobile robot system

2.2.2 Object extraction from red plane

The RGB color image is an input signal of the computer. RGB (Red, Green, Blue) is the basic physical color of the object. The color of the robot is orange. This characteristic is distinguished from the scene. The object is separated from the scene by using red plane extraction and then the information is sent to thresholding.

2.2.3 Thresholding

Thresholding plays an important role in segmentation techniques and involves the separation of the object from the scene. The scene is changed to black color background. The object becomes more distinct. This process quickly determines the object and leads to finding the correct object.

2.2.4 Image matching

The image matching technique is used to evaluate the effect of the object by comparing the source image and the input image. The image matching process finds the existence of a pattern within a source image and it proceeds via the four steps as follows:

1) The object is captured as a source image to identify and reference patterns for matching

2) The web camera captures the image to send to the computer. The input image is compared across the source image to identify similar features that provide a matching of pairs between the source image and the input image.

$$(A1, B1) \leftrightarrow (A2, B2) \tag{1}$$

Where (A1, B1) is a feature in the source image and (A2, B2) is a matching feature in the input image.

3) The angle orientation parameter is set up to allows an automated way to detect images of an object in 360 degrees

4) The graphical interface is set up, and the trajectory of the robot is displayed in the graphic map. The computer updates the current location of the vehicle movement and reports the current position to the path planning.

2.2.5 Navigation system

The main purpose of the path planning is to guide the robot to its goal by locating the mobile robot’s position relative to the destination position. The current position of the mobile robot is obtained by image processing. The mobile robot’s position and the destination position can be derived by using the parameters as follows:

$$[(Xd - Xc), (Yd - Yc)] \leq \pm 100 \tag{2}$$

The design path planning consists of four terms as follows:

1) The mobile robot goes straight in the Y- axis direction until the distance between the mobile robot’s position and target position is less than or equal to ±100 pixels.

2) The mobile robot turns to the right when the result of distance in the Y axis direction between the target and the mobile robot (Yd – Yc) has a positive value.

3) The mobile robot turns to the left when the result of distance in the Y axis direction between the target and the mobile robot (Yd – Yc) has a negative value.

4) The mobile robot moves forward in the X- axis direction until the distance between the mobile robot's position and target position is less than or equal to ±100 pixels and then it stops.

The computer processes the information and sends data to the microcontroller at the same time, which requests for commands to be executed as mobile robot movement. The program displays the mobile robot trajectory graphic within a given position in the pixels of the monitor as shown in Figure 3. Therefore, the vision system not only shows a graphic map by the image processing method but also navigates to guide the robot to go to the goal as directed by path planning.

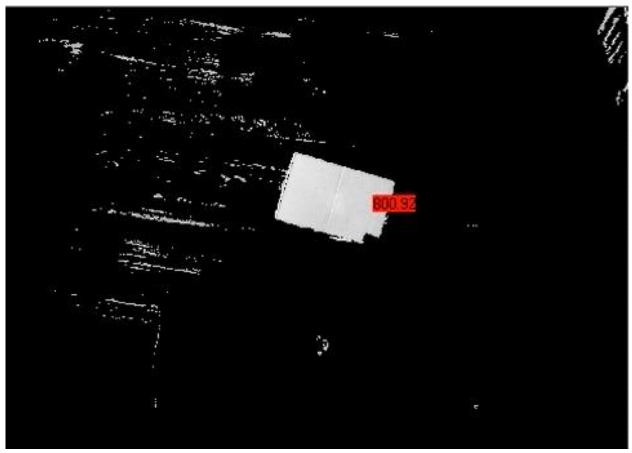

Figure 3. Tracking by using the image processing

2.3 Mobile robot system

2.3.1 The mobile robot's structure

The mobile robot's structural dimensions are 320 mm long, 250 wide, and 280 mm tall. The robot has an orange color for image processing detection. There are four wheels on the mobile robot. Two wheels of the mobile robot are attached to DC motors and the two additional wheels are attached to the rear of a vehicle to assist when the robot performs the turn. The DC motors are connected to a L298N board. The L298N board is used to generate a PWM signal from the microcontroller.

2.3.2 Microcontroller

The microcontroller mainly controls the speed and direction of the mobile robot. Generally, the function of the microcontroller is to receive the mobile robot's status perception from many sensors. The control signal carries directional information including environment perception to control the wheels and drives the robot to reach the goal. In this research, the ESP8266 NodeMCU microcontroller board is used to interface with the vision system. Starting point, path planning, and goal are fed as inputs into the vision system and then passed to the microcontroller. The microcontroller executes those instructions to control the mobile robot's direction and speed according to the path planning program. The ESP8266 NodeMCU is installed on the mobile robot to control the wheels. A diagram of all physical connections between the ESP8266 NodeMCU board and the several peripherals is shown in Figure 4. The described physical connections between ESP8266. This diagram obviously presents that the marked position is linked to I/O of the ESP8266 NodeMCU board.

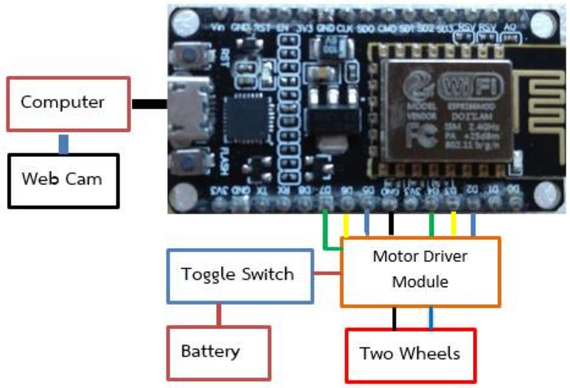

Figure 4. The physical connections between ESP8266 and each block of the proposed system

The path planning obtains information about the mobile robot's location and destination from image processing, which is designed to facilitate a car's movements and navigation from the starting point to the goal. The microcontroller utilizes path planning from the computer to control two wheels of a mobile robot into four functions: 1) Forward, 2) Turn left, 3) Turn right, and 4) Stop. The two wheels of the mobile robot are directly used for direction control in which four function datasets have been provided in Table 1.

Table 1. Control direction wheels of the mobile robot

Function	Left Motor	Right Motor
Forward	High (CW)	High (CW)
Turn Left	LOW	High (CW)
Turn Right	High (CW)	LOW
Stop	LOW	LOW

The stop toggle switch connects the digital inputs of the ESP8266 Node MCU board and the L298N motor driver module, which is used to stop in an emergency case. The ESP8266 Node MCU board is connected to the computer via a USB serial port. This whole process is summarized in Figure 5.

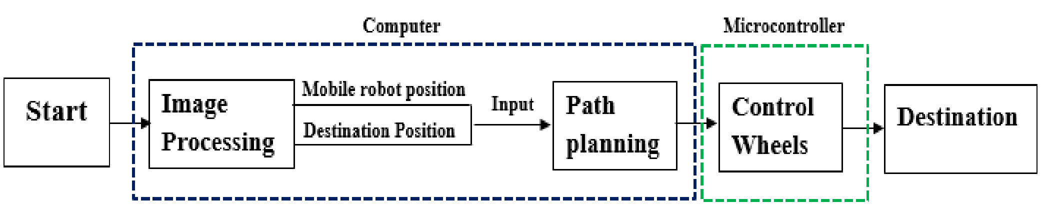

Figure 5. Blocks diagram of the mobile robot system

3. Results and Discussion

3.1 Test 1: Four corner of starting

There are four corners for starting: 1) The upper left corner, 2) The upper right corner, 3) The lower left corner, and 4) The lower right corner. The robot is required to autonomously execute a movement from four corners to the goal at point (800,400) as shown in Figure 6. A simulation was performed to evaluate the performance in order to reduce and eliminate errors before the test. The result of the trajectory to control the mobile robot is shown in Figures 7.

The image processing method used to determine the position of the robot by setting the web camera is attached above the mobile robot and the mobile robot executes the commands via the microcontroller. The trajectory of the robot is displayed in data as shown in Figure 8. The accurate trajectory followed the mobile robot movement. When the mobile robot is placed at the upper left corner (a, b) and the lower right corner (g, h), the mobile robot can go straight in the Y-axis direction then turn to the left and go straight to reach the goal by executing the command in range within ± 100 pixels. When the mobile robot is placed at the upper right corner (c, d) and the lower left corner (c, d), the mobile robot can go straight in the Y-axis direction then turn to the right and go straight to reach the goal by executing the command in range within ± 100 pixels.

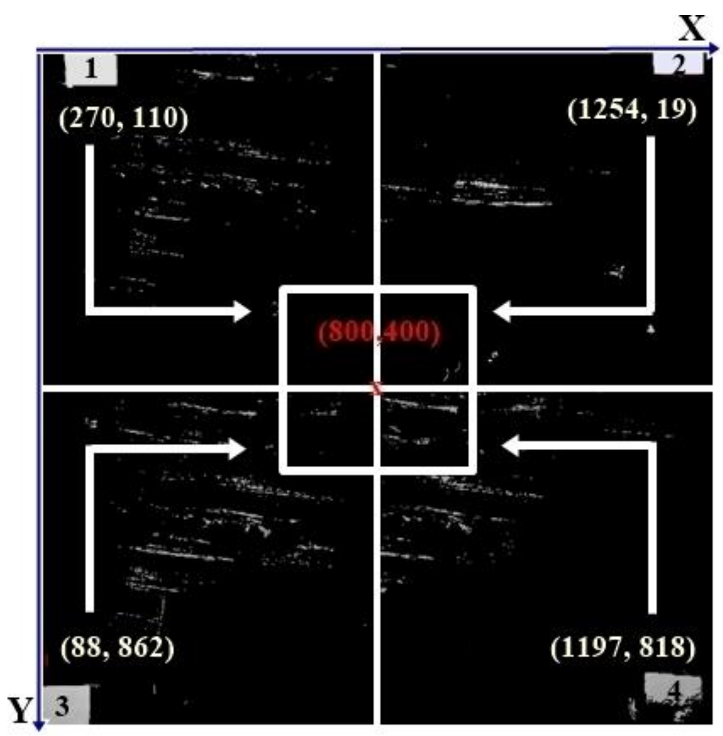

Figure 6. The trajectory of an autonomous mobile robot of four cornner of starting

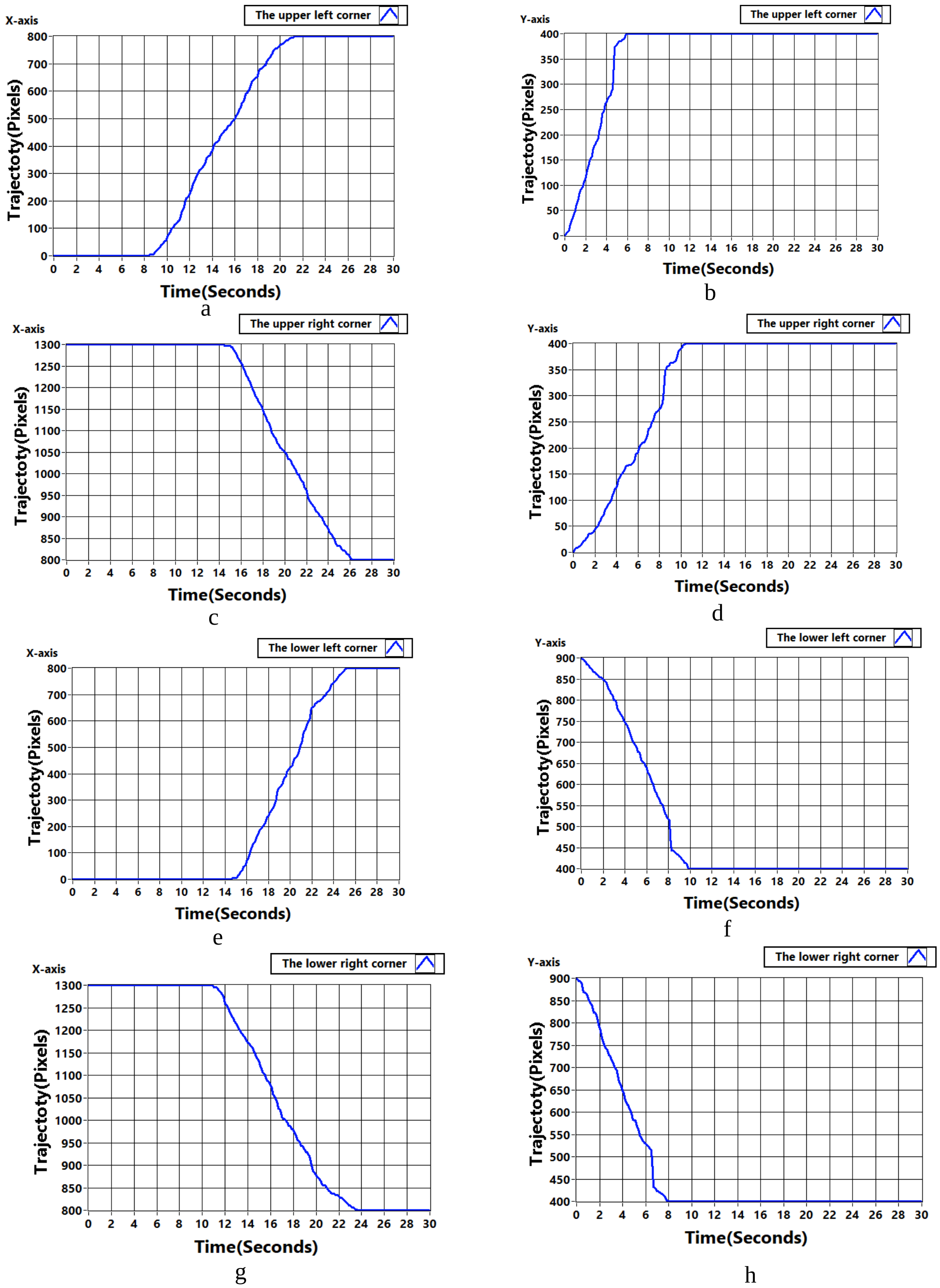

Figure 7. The trajectory simulation of an autonomous mobile robot at four corners

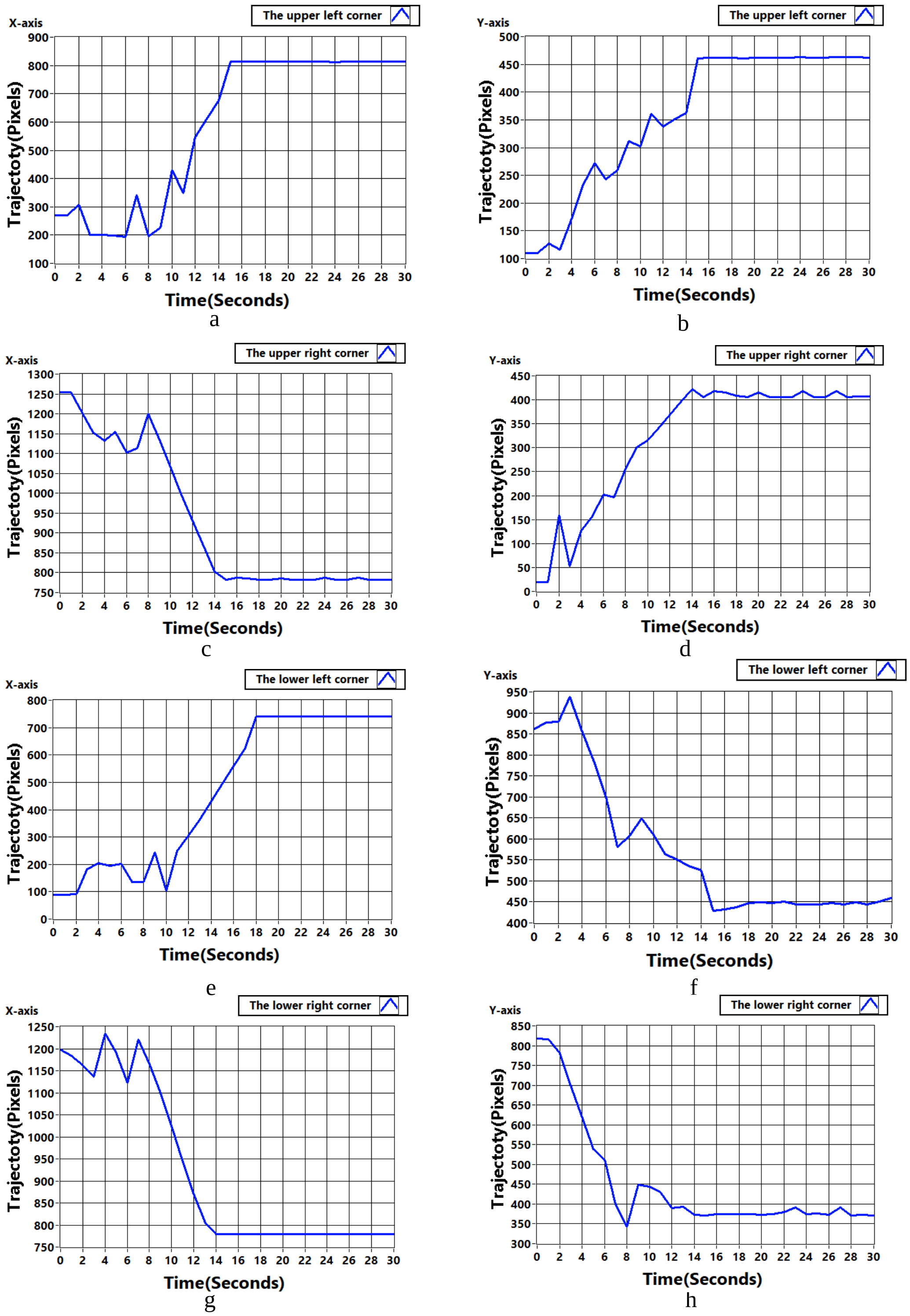

Figure 8. The trajectory of an autonomous mobile robot at four corners

3.2 Test 2: Two points of goal

To ensure that it confirmed the autonomous vehicle movement, the mobile robot was required to autonomously execute a movement from the upper left corner to the goal at point (300,800) and (110,450) as shown in Figure 9.

The simulations evaluated the performance as shown in Figure 10. The mobile robot moved straight from the upper left corner to go to the point (300,800) as shown in Figure 11 (a, b). When the goal has changed as shown in Figure 11 (c, d), the mobile robot was able to move straight along

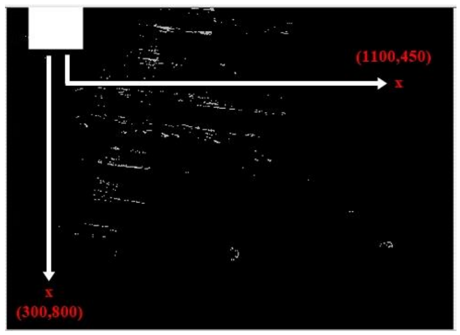

Figure 9. The trajectory of an autonomous mobile robot from the upper left corner to the goal

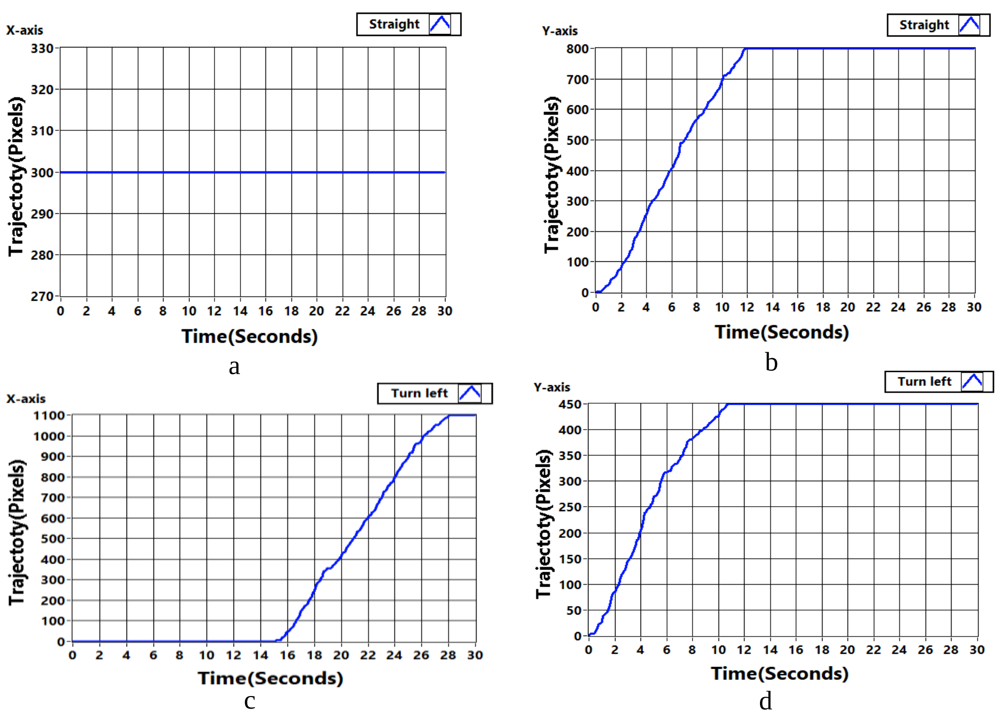

Figure 10. The trajectory simulation from the upper left corner to the point of goal

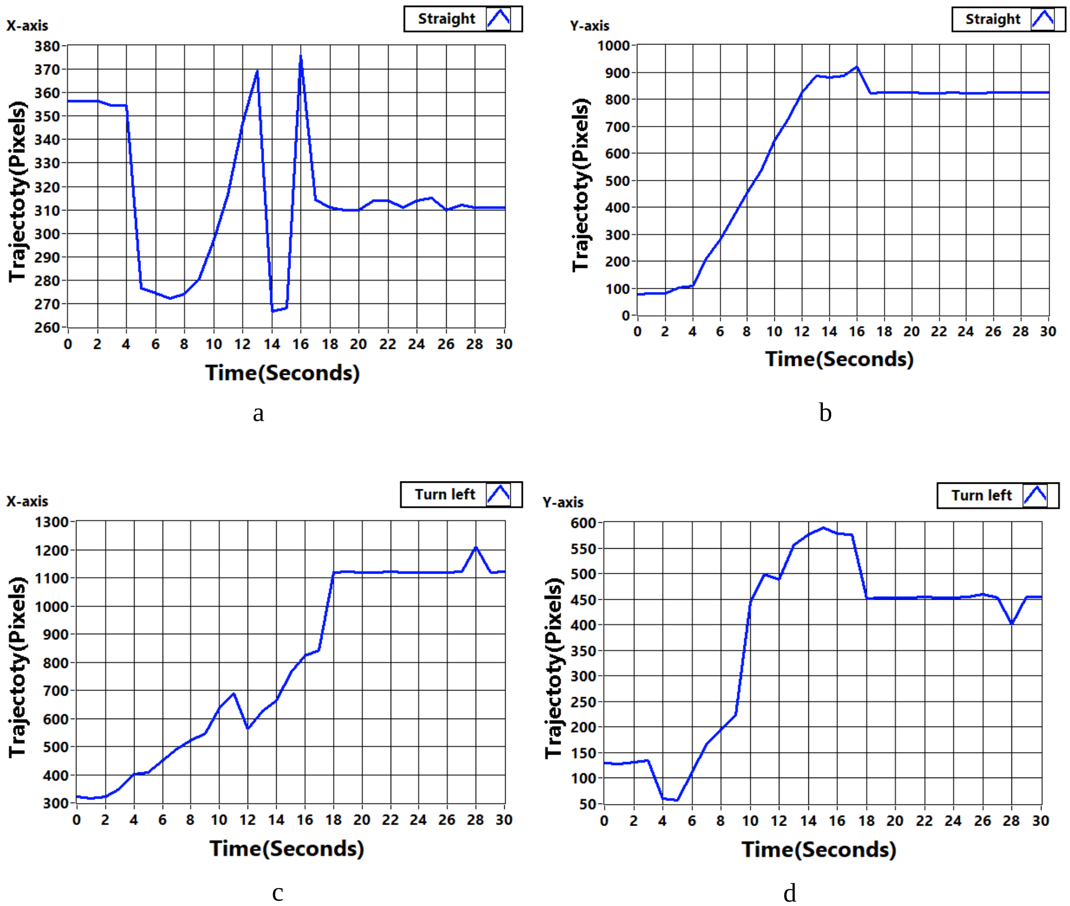

Figure 11. The trajectory of an autonomous mobile robot from the upper left corner

the y-axis direction then the mobile robot turned to the left on the x-axis direction and went straight to the point (1100,450). The overall trajectory was executed fully and autonomously, and the robot successfully arrived at the goal. These experiments with the automated mobile robot using the microcontroller under vision system navigation demonstrated that the system was sensitive and responsive enough to automatically move the mobile robot, which arrived at the goal successfully.

Table 2 shows that the movements of the mobile robot simulation and experiment had an average error rate of (X, Y) position of 7.51%, 1.63%, 9.00%, 4.26%, 3.01% and 1.18%, respectively. This indicates that the image processing method by setting the web camera above the robot interfacing with the microcontroller was able to take control of the autonomous vehicle movement.

Table 2. Function of movement the mobile robot

Function	X Sim (px)	Y Sim (px)	X Test (px)	Y Test (px)	AVG Error (%)
The upper left corner	800	400	813	462	7.51
The upper right corner	800	400	786	406	1.63
The lower left corner	800	400	740	444	9.00
The lower right corner	800	400	779	378	4.26
Straight	300	800	310	310	3.01
Turn left	1100	450	1119	453	1.18

4. Conclusions

These results confirm that the path planning can be programmed and designed for autonomous navigation in the vision system. The vision system can be interacted with the microcontroller to move the vehicle to the destination successfully. In this research, the area is limited to the coverage of the field of view of the camera. This method has been designed to support the system operation, enabling the mobile robot to automatically move to the destination by only using a web camera sensor. The mobile robot was enhanced and became more accurate upon the resolution of the camera, light intensity and light stability. The mobile robot system was not only controlled by an interactive interface but also achieved autonomous navigation by extracting the appropriate mapping information. In future work, we will develop and design a vehicle system that is able to avoid obstruction in various situations.

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