

Vision Aided Path Planning for Mobile Robot

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Abstract— Path planning is very important for autonomous mobile robots to navigate from the beginning to the ending position. Vision aided path planning for mobile robot system is discussed in this paper. The paper reveals the accounts from a historical overview and provides a study on how to develop a single vision system for a mobile robot, which implements an obstacle avoidance algorithm, detecting the objects by the colour. Also, we aim at highlighting and analyzing the use of single vision cameras such as webcam in providing data and useful information required for navigation purposes. The system is able to detect obstacles and provide position information from the image of indoor environment. The result is accurate enough to detect the static obstacles and avoid any possible contact with that obstacle. Thus, it is best suggested that the proposed colour approach would be significant as a navigational aid for the autonomous mobile robot.

Keywords—vision; path planning; mobile robot; obstacle avoidance; vision cameras; indoor environment

I. INTRODUCTION

Path planning is the determination of a path that a robot must take in order to pass over each point in an environment. The path is a plan of the geometric locus of the points in a given space where the robot has to pass through [1]. Basically, it is meant for mobile robot's navigation purposes. The efficiency of the path is based on the system used.

Path planning plays an important role in navigating a mobile robot, whilst navigation is a process of directing a route in order for the mobile robot to be able to move safely from one location to another without colliding with other objects. This requires the need for the robot to be well aware of its exact location. Generally, localization, path planning, and motion control are the problems of navigation of the mobile robot [2][3][4]. However, the path planning is the most important feature that we need to look on as it enables the selection and identification of a suitable path for the mobile robot in the specific workspace area. Admittedly, a mobile robot with vision ability will provide diverse services to humanity. Thus, this paper is aimed at proposing an effective visual tracking system that includes an object detection process to manipulate pixel colour count on deciding the existence of static objects. Therefore, the avoidance and tracking obstacle in real time application will enhance the effectiveness of path planning of a mobile robot [2]. Basically, the main objective for path planning is to search for an appropriate path with the pre-described environment provided with the given initial position and orientation, in order to reach the target position [5]. After a detailed background review of vision aided path planning for mobile robot system methods and

the numerous studies of it, our attention turned to the other parts that this paper consists of which includes, electrical part and mechanical part. The mechanical part consists of the system of the mobile robot employing differential wheel robot, which has two driven wheels and two free turning wheels. The speed of driving wheels can be varied independently. Motor control is done by the motor driver that consists of H-Bridge circuit. The amount of current required to drive the motors will be supplied securely through this component. Both motors are fully equipped with optical encoder to keep track of the intended movement. The mobile robot can operate at the speed of normal human walking speed (around 4-5 km/h). The mobile robot must have a minimum basic design of two decks:

- i. A base deck for the drive system and electronics components
- ii. An upper deck for mounting the laptop

The deck with the suitable diameter must be round. This is because the round disc shape will allow the robot to rotate without hitting anything as it is operating on the floor. All components mounted on the mobile robot must fit within the base deck. This includes the wheels. It will ensure its ability to turn freely in a clear space.

The electrical part consists of Lithium Polymer (LiPo) battery, which is meant to provide power for all mobile robot components, except for the laptop which is externally powered. It is used for the following devices:

- i. Motors
- ii. Motor controller

Meanwhile, the power supply from the laptop is also used for the following devices to ensure that the mechanical devices are using different sources of power with electronic devices.

- i. Proximity sensors
- ii. Robot I/O controller – Arduino board

II. RELATED WORK

The system is divided into four different branches, which are path planning, algorithms, image processing, and obstacle avoidance. Path planning is known as the determination of a path that a robot must take in order to pass over each point in the environment. Path planning is used to generate a collision-free path in the environment with obstacles and optimize it with respect to some criterion. Thus, it should be obvious to understand the path planning as path-finding problem possessed by autonomous mobile robot for its navigation in order to move safely from one location to another location without

getting lost or colliding with other objects. It somehow differs from the trajectory planning whose the path already scheduled or planned along the way [1]. Specifically in the context of autonomous mobile robots, path planning techniques have to simultaneously solve two complementary tasks at the same time. Basically, the main objective for path planning is to search for an appropriate path with the pre-described environment provided with the given initial position and orientation, in order to reach the destination goal position [5]. Therefore, it is extremely important that the autonomous mobile robot has an ability to manipulate the environment's model to understand the environment's structure. Then, it will be used for orders, plans, and execute paths. The algorithm chosen is definitely an important issue, as it will provide better and smoother mobile robot navigation. In addition, the algorithm must be matched with the configuration space used [3]. There are various types of algorithm that are commonly used. Anyhow, a path planning algorithm must need to meet several requirements as the resulting path should have the lowest cost to prevent any change in direction, it should be fast and robust, without interrupting the simulation process and it should not only optimized for specific map type. Therefore, the existing algorithms are being put in chronological order as in the Table I below:

TABLE I. EXISTING ALGORITHMS IN CHRONOLOGICAL ORDER

1980 - 1989	1990 - 1998	2000 - 2005
1. A* search algorithm 2. Visibility graph algorithm 3. Artificial potential field algorithm	1. Artificial potential field algorithm 2. Road map algorithm 3. Modified A* search algorithm 4. Genetic algorithm	1. Modified A* search algorithm • Physical A* algorithm 2. Stentz' Focussed Dynamic A* algorithm (Koenig's algorithm) 3. Depth first search algorithm

For A* Algorithm, this technique is the most suitable approach to control a group of robots as the A*-based path planning technique computes the paths for each of the robot individually and independently in the configuration time-space. In using this algorithm, the search area is divided into square grid which allows the analysis being done to individual grids. According to [6], A* algorithm is structured as follows: add the starting node to the open list, followed by repetitive steps and save the current path. The mobile robot will go backwards from the target square, go from each square to its parent square until the starting square has been reached. This is the most efficient path. The Genetic Algorithm is used in an unknown environment. It can work for a more complex problem in finding the satisfactory solution. In addition, it can work in a time varying system. Artificial Potential Field Algorithm, this algorithm helps in robot navigation, which has been used by previous researchers to allow real time robot operations in a complex environment. However, it suffers in minimum problem when operating in an environment that is packed with obstacles.

Roadmap Algorithm generates many random configurations of possible paths, while omitting the blocked path, and link adjacent free ones into a graph with line segments. The path planning process is performed by

linking the start and target points, then searching for a path between them. Therefore, Table II shows the comparison of strength for each type of path planning algorithm.

TABLE II. COMPARISON OF PREVIOUS PATH PLANNING ALGORITHM

TYPES OF ALGORITHM	STRENGTH
A* Algorithm	Time taken to find the best path is far less than the others. It finds a good path quickly.
Genetic Algorithm	- Works for complex problem - Can work with time-varying and unknown environment
Artificial Potential Field Algorithm	Help in robot navigation, however suffer in cluttered environments
Roadmap Algorithm	The algorithm builds its line segment graph to small enough to determine collision free path

Obstacle avoidance is the ultimate goal in this research. For general cases, the use of single camera vision is apparently enough to do this job for both stationary and moving obstacle avoidance. However, due to limitation of computing hardware, which requires high processing speed, the ultrasonic sensors can be utilized to detect moving obstacles [6]. While for the stationary obstacle, avoidance task can be done by using single camera vision.

III. METHODOLOGY

In this paper, the system consists of hardware and software parts. It involves two main stages which are designing the control algorithm, and hardware implementation in order to evaluate its performance in the real world environment.

The system of this mobile robot mainly reflects the useful function of Webcam in colour detection algorithm which can further be used with obstacle avoidance implementation. Fig. 1 shows the design overview of the system.

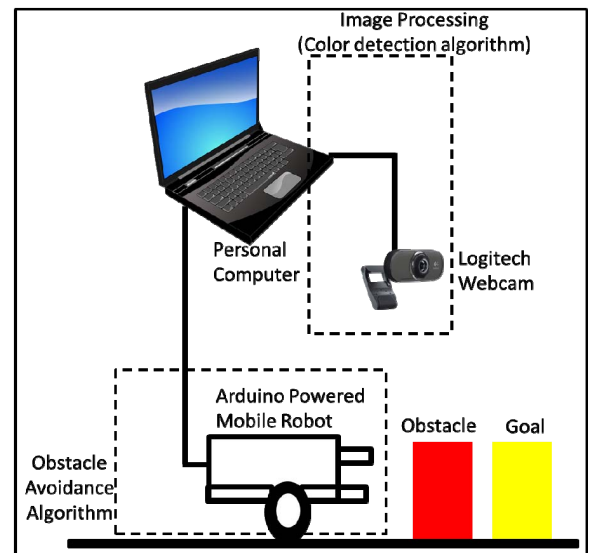


Figure 1. System Design Overview

A. Software

The softwares used are Microsoft Visual Studio 2010, OpenCV 2.4.0 Library, CMake 2.8.10, CV Blob Library and Arduino IDE 1.0.1. Microsoft Visual Studio 2010 acts as an Integrated Development Environment (IDE) to compile Open Source Computer Vision (OpenCV) library functions that were written in the C / C++ language. Moreover, the use of (CV Blob Library) is meant for computer vision to detect connected regions in binary digital images. CV Blob will perform connected component analysis (labelling process) and features extraction of an image.

The software system of this mobile robot divides the image processing process into four main stages; data acquisition, path planning algorithm, obstacle avoidance, and localization [7]. Fig. 2 depicts the image processing task done by the combination of an on-board PC and the microcontroller.

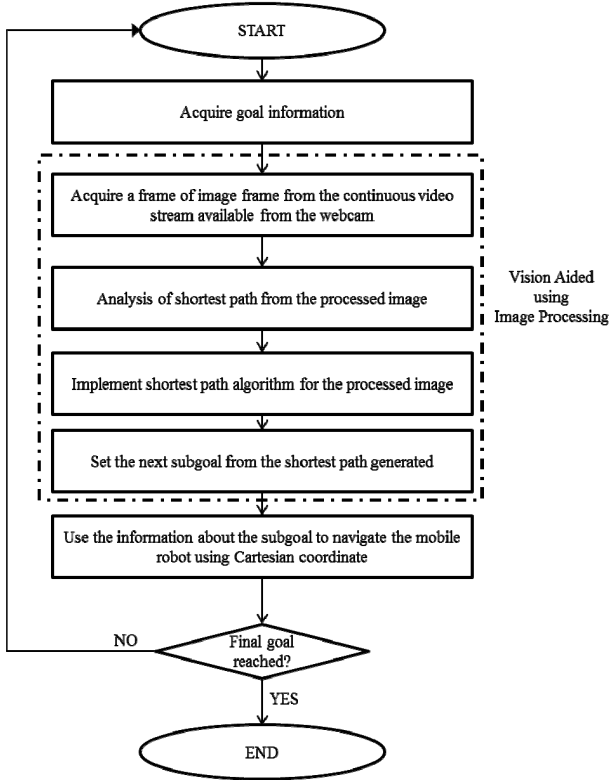


Figure 2. Flowchart of the Vision Aided Path Planning

In order to achieve this objective, the algorithm should be able to differentiate between the object in red or yellow colour. The obstacle in red colour indicates the obstacle which it needs to avoid, while the yellow colour representing the final goal.

On top of that, it should also be able to locate the exact position of the obstacle from the front view of the mobile robot. The colour detection process is shown in Fig. 3.

Firstly, the acquisitions of images are carried out by the web-camera. They were stored in a series of frames. The colour detection algorithm started with the conversion of the colour space. The initial colour space is in RGB colour space and converted to HSV colour space. This step is done in order to enhance the contrast level of each image.

The enhanced image is then converted into a binary image based on the red and yellow colour. The area with red colour will be assigned to '1' and the other area is assigned to '0'.

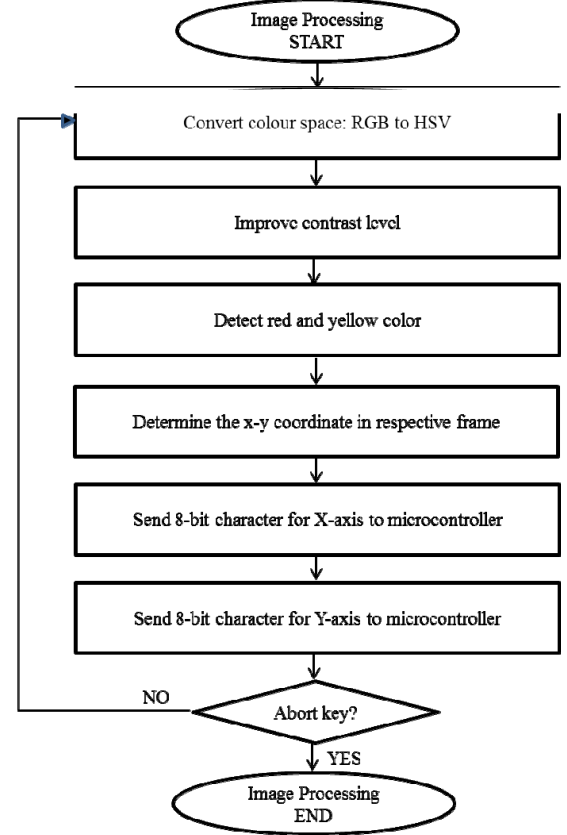


Figure 3. Colour detection algorithm

B. Hardware

The hardware part involves actuators 12V DC Motors with reduction gears attached to an encoders, differential wheels -15 cm (in diameter), Arduino UNO, sensors and Webcam -15 MP.

The mobile robot platform, basically, the operation of the mobile robot is shown in Fig. 4. Specifically, we are using actuators 12V DC Motors with reduction gears attached to encoders. The task output carried by this motor could be moving around on a smooth surface with obstacle avoidance functionality.

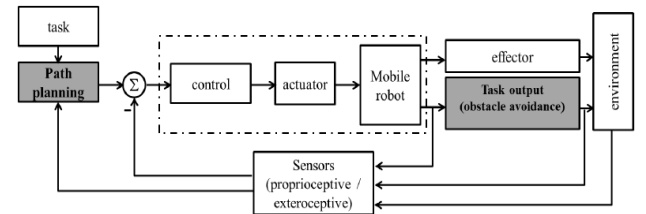


Figure 4. Block diagram of the mobile robot hardware

The sensors comprise of two types, which are proprioceptive, or exteroceptive. Proprioceptive act as a sensor that measure the internal state of the mobile robot. For example, the optical encoders can be able to determine its position on a map. On the other hand, exteroceptive can

measure the external variable or state outside of the mobile robot system. In this case, we could use a structured light sensor such as a CCD, or vision sensor such as monovision or colour vision camera. For control, it can be transmitted using a high or low level of communication. It needs to be feed forward (from the path planning) or feedback to the system. In this research, we would implement Field Programmable Gate Array (FPGA) platform by using the Altera DE1 Development and Education Board in order to control the mobile robot. Meanwhile the Arduino board is used to control the sensors and motor movement.

IV. RESULTS AND DISCUSSIONS

Experimental results are presented in this section. First, the result of obstacle recognition by using colour is shown. In some cases of obstacle avoidance, there are some common interested parameters such as colours, shapes, and sizes. Let say the obstacle is set to be yellow in colour, thus colour detection is needed in order to detect the obstacle. The obstacle can be differentiated from the surrounding environment through the use of a threshold. Fig. 5 shows the output of the program.

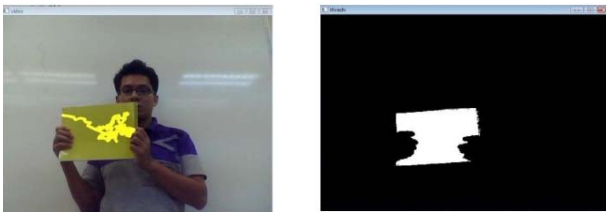


Figure 5. The threshold process upon yellow object

In addition, the implementation of A* algorithm in Fig.6 shows the two red dots are searching for the least movement cost to get to the yellow dot (smiley symbol), provided that the maze is depicted in the square grid form.

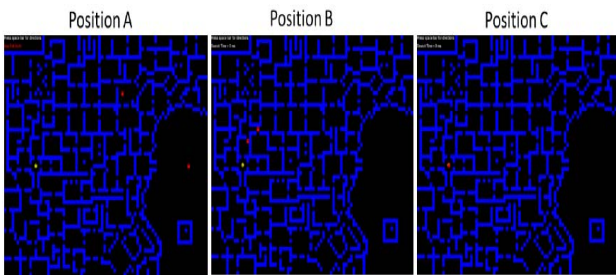


Figure 6. A* path planning algorithm on the maze

The mobile robot is expected to avoid yellow as yellow object represents the obstacle. Meanwhile, it is expected to find the red object which represents the target or the final decision. When the target is locked, the mobile robot is expected to find the shortest path to the target. In this paper, the robot updates the status by using the position coordinate. Thus, the colour detection algorithm needs to be equipped with the updated coordinate. The code is executed in order to calculate the position of the interested object in each frame, in this case, yellow-coloured object.

Based on the output, position (x, y) has two numerical numbers, indicating the x-position and y-position. Fig. 7 and Fig. 8 show the output of the program.

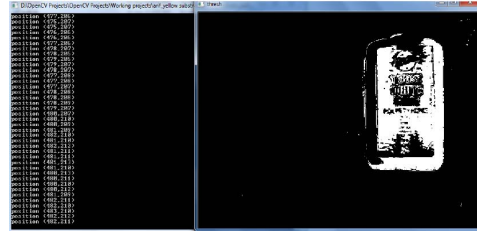


Figure 7. The coordinate of right obstacle is sent to microcontroller

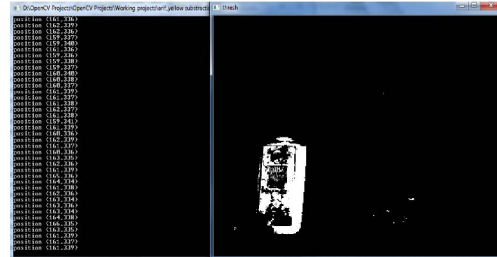


Figure 8. The coordinate of left obstacle is sent to microcontroller

V. CONCLUSION

This paper managed to provide a satisfactory result in vision-based navigational system for mobile robot by using colour detection. The ideas presented in this paper are implemented using data from image processing analysis. It is not only able to avoid obstacle but also able to plot trails by implementing the A* algorithm. In this case, the Webcam acts as a vision sensor to detect obstacles in detection area and other sensors, such as ultrasonic sensors are used to support the main sensor. Thus, we have created a navigational system that optimizes the use of sensors for continuous navigation in an indoor environment.

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