“I hereby declared that I have read through this report entitle “Vision-Based Mobile Robot” and found that it has comply the partial fulfillment for awarding the Bachelor of Mechatronic Engineering.”

Signature : ………………………………………………

Supervisor’s Name : Mr. Muhammad Herman bin Jamaluddin

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VISION-BASED MOBILE ROBOT

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This Report is Submitted in Partial Fulfillment of Requirements for Bachelor of Mechatronic Engineering.

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APRIL 2010

“I declare that this report entitle “*Vision-Based Mobile Robot”* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.”

Signature : ………………………………………………

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Date : ………………………………………………

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ABSTRACT

This project is about a vision-based approach for line following mobile robot to follow red line on different background colors. The vision sensor is a Complementary Metal-Oxide Semiconductor (CMOS) sensor, interfaced with an 8Mbits FIFO independent memory for image buffering and microcontroller for mobile robot movement control. This project is categorized to three main parts which include electric circuit, mechanical design and microcontroller programming. The main objective of this project is enabling the automatic mobile robot to follow the desired trajectory such as line tracking according to real-time image from CMOS sensor. For further implementation of other desired trajectory such as landscape image or object can be obtained by comparing reference image with current image taken by CMOS sensor. The program can determine movements of mobile robot by differentiating the line color and the background color under different lighting conditions. The program used to process the data is using C language. C compiler will execute the HEX file which is downloaded into the PIC chip. The mechanical motion of the robot is controlled by differential drive by two DC motors.

ABSTRAK

Projek Sarjana Muda ini berkenaan dengan pergerakan robot mengikut garis merah menggunakan aplikasi visual. Visual sensor iaitu CMOS (Complementart Metal-Oxide Semiconductor), berinteraksi dengan 8Mbits FIFO memori tungal untuk penyangaan imej dan mikropengawal untuk mengawal pergerakan robot tersebut. Projek ini dibahagikan kepada tiga bahagian penting iaitu, litar electrik dan elektronik, struktur mekanikal, dan program mikropengawal. Objektif utama projek ini ialah membolehkan robot automatic untuk mengikut garisan panduan yang dikehendaki. Untuk implementasi selanjutnya, laluan yang dikehendaki berpandukan object atau landskap boleh dicapai menggunakan konsep perbandingan imej semasa dengan imej rujukan. Program tersebut akan menentukan pergerakan robot dengan membezakan warna garisan panduan dan warna latar belakang dalam kecerahan cahaya yang berbeza. Program yang ditulis adalah dalam bahasa C. Penyusun bahasa C akan menghasilkan fail HEX untuk dimuatturunkan ke dalam cip PIC. Pergerakan mekanikal robot dikawal oleh panduan pembezaan oleh dua motor DC.

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ABBREVIATION

APS	-	Active Pixel Sensor
ASCII	-	American Standard Code for Information Interchange
CAD	-	Computer-Aided Design
CIF	-	Common Intermediate Format
CMOS	-	Complementary Metal-Oxide Semiconductor
CPU	-	Central Processing Unit
DC	-	Direct Current
FAT	-	File Allocation Table
FIFO	-	First In-First Out
FPS	-	Frame Per Second
FYP	-	Final Year Project
GUI	-	Graphical User Interface
Hz	-	Hertz
IR	-	InfraRed
JPEG	-	Joint Photographic Experts Group
LED	-	Light Emitting Diode
LCD	-	Liquid Crystal Display
MMC	-	MultiMedia Card
ns	-	Nanoseconds
PDIP	-	Plastic Dual In-line Package
PWM	-	Pulse Width Modulation
RAM	-	Random Access Memory
RGB	-	Red-Green-Blue
ROM	-	Read-Only Memory
TTL	-	Transistor-Transistor Logic

ABBREVIATION

UTeM	-	Universiti Teknikal Malaysia Melaka
WMR	-	Wheeled Mobile Robot

CHAPTER 1

INTRODUCTION

This chapter will introduce the objective, problem statement and scope of the project of vision – based mobile robot. This project is categorized to three main parts which include electric circuit, mechanical design and microcontroller programming.

The main objective of this project is enabling the automatic mobile robot to follow the desired trajectory such as line tracking according to real-time image from CMOS sensor. For further implementation of other desired trajectory such as landscape image or object can be obtained by comparing reference image with current image taken by CMOS sensor.

The concept of this project is using CMOS sensor for real-time image processing and comparing with reference image. The program can determine movements of mobile robot by differentiate the line color and the background color under different lightings condition.

1.1 Project Overview

Vision-based mobile robot is a project approach for line following of a white tape on different background colors. The vision sensor is a Complementary Metal-Oxide Semiconductor (CMOS) sensor, interfaced with an 8Mbits FIFO independent memory for image buffering and microcontroller for mobile robot movement control.

CMOS camera is known more as CMOS APS pixel in engineering term. Active pixel sensor (APS) is an image sensor consisting of an integrated circuit containing an array of pixel sensors, each pixel containing a photo-detector and an active amplifier. Each photo-detector in the array will produce voltage signal and send to integrated circuit to output a signal of current image. This signal will be used for navigation of the mobile robot.

1.2 Project Objective

The main objective of this project is to design and implement a vision-based mobile robot for navigation. To achieve this, the main objective is divided into several smaller and specific objectives as follows;

1. Design and establish basic mechanical structure.
2. To interface CMOS camera with computer.
3. To implement communication between CMOS camera and microcontroller.
4. To implement line recognition using CMOS camera and microcontroller
5. To implement navigation using CMOS camera and microcontroller under different lighting condition and background color.

1.3 Project Scope

The scope of this project is to design and implement a vision-based mobile robot for navigation. This project divides into three main parts which are, mechanical structure, electrical circuit and microcontroller programming.

The mechanical structure designed and establish for differential motor drive. The structure will install with 2 brushless DC motor with driver and 24Vdc battery pack. The support for CMOS APS pixel will be adjustable for further implementation such as object recognition.

The electrical circuit consist the connection for brushless DC motor driver with CMOS APS pixel and microcontroller. The microcontroller programming will be using C-language and will be downloaded into LP2106 Philips microcontroller. The microcontroller will be able to receive the signal from CMOS APS pixel and output a command to brushless DC motor for mobile robot movement.

1.4 Problem Statement

Most of the automatic mobile robot used in Robocon using Infrared (IR) sensor or fiber-optic sensor for navigation. This is no exception for Faculty of Electrical Engineering in University Technical Malaysia Melaka. This method of mobile robot navigation is vulnerable and dependant on environmental influences. Different lightning condition or event dusty environment will affect the performance of the mobile robot and will result an undesired trajectory. However, CMOS APS pixel will able to solve this problem because the signal produce by CMOS APS pixel consists of an array of photo-detector that will output more accurate signals. Even if there are any disturbances that affect some of the photo-detectors, the remaining photo-detector is still unaffected and still produce reliable and accurate signal.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is the summary of the literature review of the article that holds similar concept approach in mobile robot navigation. These articles give example on vision-based mobile robot control system and concept on implementing navigation in vision-based mobile robot.

2.2 First Review : Qualitative vision-based mobile robot navigation

This article is the effort of Zhichao Chen and Stanley T. Birchfield from Electrical and Computer Engineering Department at Clemson University, May 2006. In this article they presented a simple algorithm for mobile robot navigation. Using a teaching-replay approach, the robot is manually led along a desired path in teaching phase, and then the robot autonomously follows the path in the replay phase. The feature points of this article are automatically detected and tracked throughout the image sequence, and the feature coordinates in the replay phase are compared with those computed previously in the teaching phase to determine the turning commands for the robot.

The robot movement methodology is entirely using qualitative in nature. According to Figure 2.1(a), the robot is in position A and the destination of the robot is B. The image that is currently observes by the camera hold two important information; sign in $\pi^t = \pi^d$ and the distance between $u_i^d > u_i^t$. This two information will provide a confirmation of the mobile robot is in path and should move forward. For turning methodology, from figure 2.1(b), it's noticeable that the destination consist 2 u_i^d at left and 1 u_i^d at right (the center of the camera divide the left and right part). If the mobile robot is deviate from the correct path, such as in position A according to Figure 2.1(b), all u_i^t is in left part of the camera. Hence, its will turn left to achieve the correct amount of sign before moving forward.

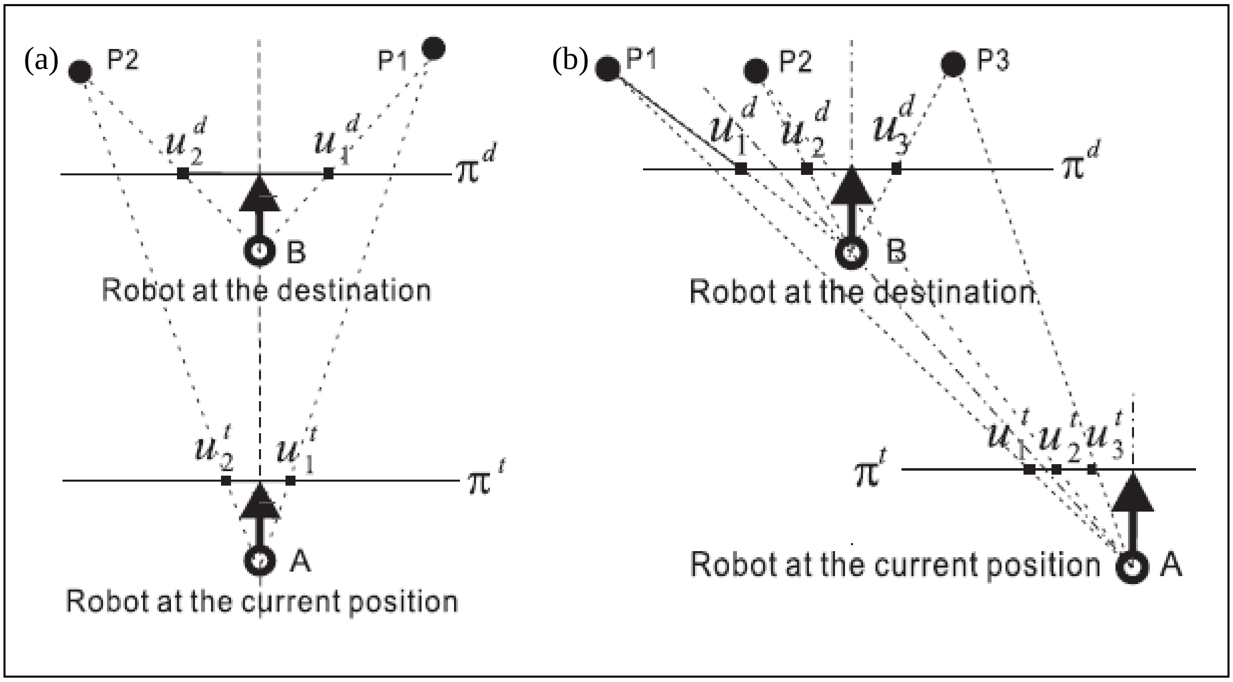

Figure 2.1: Position of Mobile Robot for moving methodology

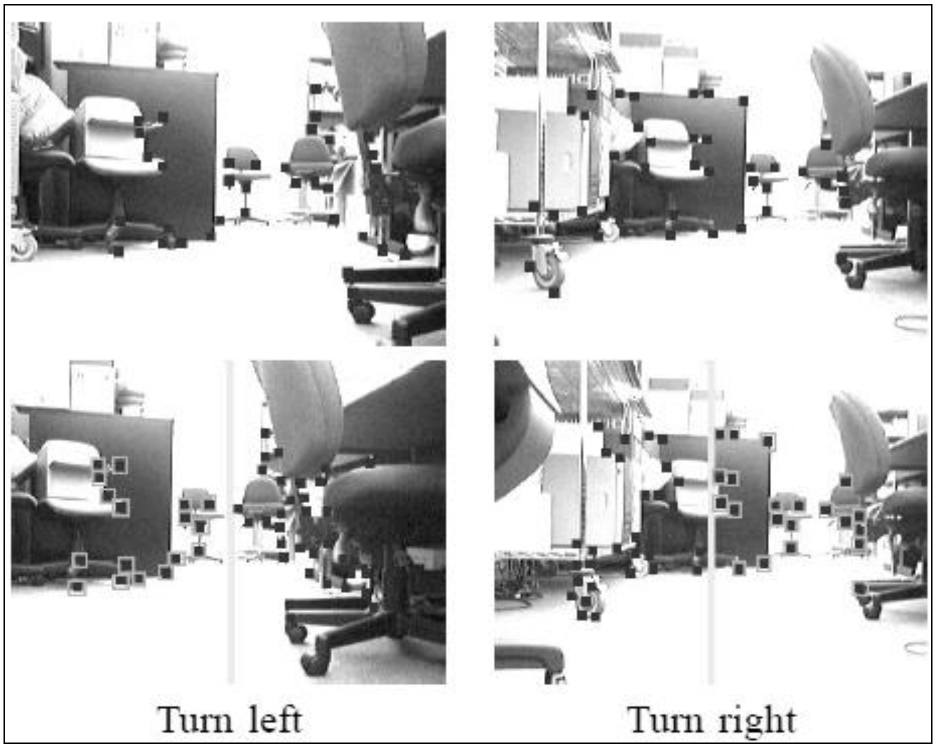

Figure 2.2: Image capture by camera during moving experiment

Figure 2.2 show the actual image capture by the camera in the situation such as Figure 2.1(b). The top picture show the position of destination, and the bottom show the current image taken by the camera. It's noticeable the sign (represent in red square) for both top and bottom image is different for both right and left side, hence the turning will follow the constraints were mentioned.

2.3 Second Review: Vision-based Navigation of Mobile Robot using Fluorescent Tubes

This article is about a vision-based mobile navigation method in an indoor environment for an autonomous mobile robot by Fabien Launay, Akihisa Ohya, Shin'ichi Yuta from Intelligent Robot Laboratory in University of Tsukuba. In this method, the self-localization of the robot is done by detecting the position and orientation of fluorescent tubes which are located above its desired path by a camera pointing to the ceiling.

Fluorescent tube is chosen as the landmark because absolute localization in indoor navigation using landmarks located on the ground or on the walls is not easy since different objects can obstruct them. The advantage of fluorescent tubes compared to other possible landmarks located on the ceiling is that once they are switched on, their recognition in an image can be performed with a very simple image processing algorithm since they are the only bright elements that are permanently found in such a place. Beside that, it is also free from problems such as dirt, shadows, light reflection on ground, or obstruction of the landmarks.

The mobile robot will correct its trajectory when a fluorescent tube is found. The mobile robot will position itself parallel with the fluorescent tube before moving to the next fluorescent tube.

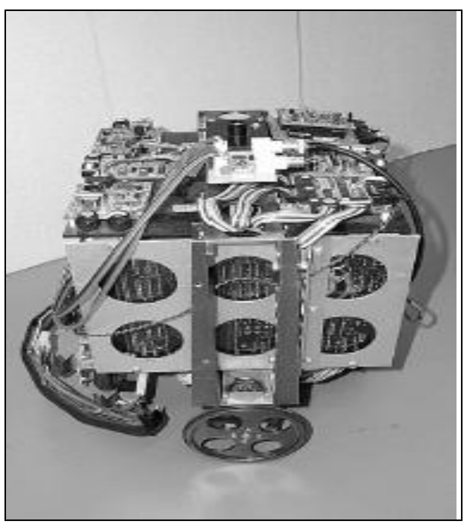

Figure 2.3: Mobile robot with camera pointing at the ceiling

2.4 Third Review: Path Tracking Laws and Implementation of a Vision-based wheeled mobile robot

This article is written together by Shiao Ying Shing, Yang Jui Liang, and Su Ding Tsair from Department of Electrical Engineering from National Chang-hua University of Education, Taiwan. This article provides an alternative way for vision-based approach navigation. The control objective for the vision-based tracking problem is to manipulate the WMR to follow the desired trajectory. This system is composed of a ceiling-mounted fixed camera whose outputs are connected to a host computer, and a WMR with two atop different color, round marks to differentiate the front and rear of the WMR as show in figure 2.4.

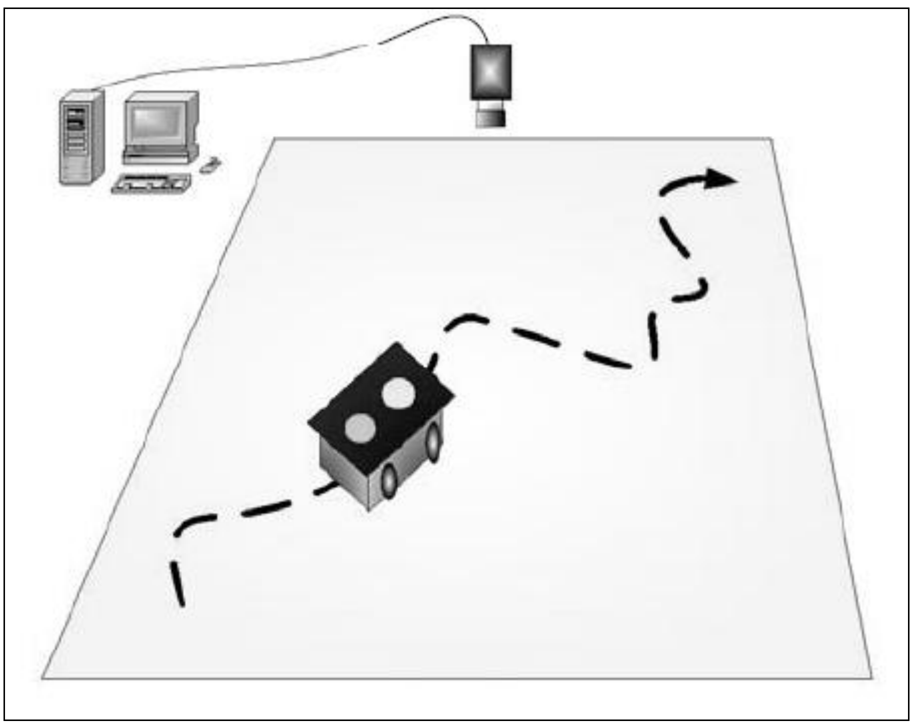

Figure 2.4: Layout of WMR and host computer in experiment field.

There is a wireless transmitter connected to host computer that will be transmit the signal for WMR movement. The camera attached to ceiling will constantly monitor the movement of the WMR. If the WMR is not moving in the desired trajectory, its will send signal to host computer and make correction in the control system that been developed in the computer. Then, the host computer will transmit the correction signal via wireless transmitter to the WMR and hence, correct the trajectory of the WMR.

2.5 Fourth Review: MINERVA – A Museum Tour-guide Robot

This article is written by Sebastian Thrun, Frank Dellaert, Dieter Fox, Charles Rosenberg, Nicholas Roy, and Jamieson from School of Computer Science in Carnegie Mellon University, Pittsburgh collaborates with Maren Bennewitz, Wolfram Burgard, Armin B. Cremers, Dirk Hahnel, and Cirk Schulz from Computer Science Department III in Univeristy of Boon, Germany. This article describes Minerva, a mobile robot designed to educate and entertain people in public places.

The movement of Minerva is determines by 2 types of maps, occupancy map and texture maps of the museum ceiling. Both maps are learned from 3 types of sensor data, laser scans, camera images and odometry readings during the learning phase. The occupancy map will be learned first for Minerva desired trajectory, while the texture map is used for real time position confirmation of Minerva.

The odometry reading is to keep track Minerva movement, however during the real implementation time, there will be crowd as obstacle and hence the odometry reading will deviate. Therefore, texture map of Smithsonian museum ceiling will determine the current position of Minerva and correct the odometry readings and provide a new trajectory for Minerva. The laser sensor will detect any obstacles during movement of Minerva in desired trajectory. If the desired trajectory is blocked by the crowd Minerva will avoid the crowds and wait for the alternative route that will be output from the correction after matching the results from texture map (camera image) and occupancy map (odometry reading).