OPTIMIZATION OF VISION-GUIDED MOBILE ROBOT NAVIGATION USING DUAL CAMERA

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Robotics and Automation) (Hons.)

by

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2017

DECLARATION

I hereby, declared this report entitled "Optimization of Vision-Guided Mobile Robot Navigation using Dual Camera" is the results of my own research except as cited in reference.

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Date	: 22 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Robotics and Automation)(Hons.).

The members of the supervisory committee are as follows:

………………………………………………………………

(Supervisor) – Signature & Stamp

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ABSTRACT

The main purpose of this project is to optimize the vision-guided mobile robot for navigation. The vision system for mobile robot is optimized by using dual camera. Two units of Pixy cameras are used as a vision sensor to the mobile robot for navigation. This idea is used because of dual camera has wider vision than single camera. The idea is validated through several experiments to improve that vision system is optimized by using dual camera. Three different layouts are used to conduct the experiment of comparing the ability between dual camera and single camera. Time taken and response time for each experiment is collected. In addition, the behaviour of mobile robot during performing task also is observed. The collected data from the experiment conducted is analysed by calculating the efficiency of each layout. From the analysis that has been made, positive result is obtained. So, from the result, can be conclude that using dual camera is more efficient than single camera. Suggestion for future work is also included in this report.

ABSTRAK

Tujuan utama projek ini adalah untuk mengoptimumkan robot mudah alih untuk navigasi berdasarkan sistem visi. Sistem visi untuk robot mudah alih dioptimumkan dengan menggunakan dua kamera. Dua unit kamera Pixy digunakan sebagai sensor penglihatan kepada robot mudah alih untuk navigasi. Idea ini digunakan kerana dua kamera mempunyai visi yang lebih luas daripada kamera tunggal. Idea ini disahkan melalui beberapa eksperimen untuk meningkatkan sistem penglihatan dioptimumkan dengan menggunakan dua kamera. Tiga kondisi yang berbeza digunakan untuk menjalankan eksperimen untuk membandingkan keupayaan di antara dua kamera dan kamera tunggal. Masa yang diambil dan masa tindak balas bagi setiap eksperimen dikumpul. Di samping itu, tingkah laku robot mudah alih semasa melaksanakan tugas juga diperhatikan. Data yang diperolehi daripada eksperimen yang dijalankan dianalisis dengan mengira kecekapan setiap kondisi. Daripada analisis yang telah dibuat, keputusan yang positif diperolehi. Jadi, dari hasil yang diperoleh, kesimpulan yang dapat dibuat ialah menggunakan dua kanera adalah lebih cekap daripada kamera tunggal. Cadangan untuk kerja-kerja masa depan juga dinyatakan di dalam laporan ini.

DEDICATION

Specially dedicate to my beloved mother, my beloved father, my beloved family, supervisor, lecturer, seniors and friends who have guided and inspired me through my journey in education. Also thank you to their support, beliefs and motivation.

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LIST OF ABBREVIATIONS

3D	-	Three Dimension
AC	-	Alternate Current
AGV	-	Automatic Guided Vehicle
CMU	-	Carnegie Mellon University
COM	-	Component Object Model
CPU	-	Central Processing Unit
DC	-	Direct Current
DSP	-	Digital Signal Processors
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
FAT	-	File Allocation Table
FPGA	-	Field-Programmable Gate Arrays
fps	-	Frames Per Second
I2C	-	Inter-Integrated Circuit
ICSP	-	In-Circuit Serial Programming
IDE	-	Integrated Development Environment
LCD	-	Liquid Crystal Display
LED	-	Light-Emitting Diode
MISO	-	Master In Slave Out
MOSI	-	Master Out Slave In
MVA	-	Multiple Visual Agent

PWM	-	Pulse width modulation
SCK	-	Serial Clock
SCL	-	Serial Clock
SD	-	Secure Digital
SDA	-	Serial Data
SLAM	-	Simultaneously Localization and Mapping
SPI	-	Serial Peripheral Interface
SRI	-	Standford Research Institute
SS	-	Slave Select
UART	-	Universal Asynchronous Receiver/Transmitter
USB	-	Universal Serial Bus

LIST OF SYMBOLS

$\bar{x}$	-	average
KB	-	kilobyte
mA	-	miliAmpere
MHz	-	mega hertz
mm	-	milimeter
V	-	volt
ε	-	efficiency

CHAPTER 1

INTRODUCTION

1.1 Background of study

Robot is an electromechanical machine that is commanded by a computer program or electronic circuitry. There were many types of robot such as mobile robot, medical robot, robot arm, service robot, educational robot, industrial robot and other. All those robots were controlled and programmed based on their function.

Mobile robot is an automatic machine. It is capable to move from one point to another point and are not set to one physical condition. Mobile robots can be autonomous mean they are competent of navigate an uncontrolled environment without the need for physical or electro-mechanical guidance devices. These mobile robots are widely used and become more common place in commercial and industrial settings.

Arduino is one types of microcontroller. It is an open-source electronics platform based on easy-to-use hardware and software (Richard.B , 2010). The Arduino board is programmable using Arduino IDE. There are other types microcontroller used for robot such as Raspberry Pi.

Previous project for this topic was done by senior student which he developed and optimize the vision system for Arduino Robot. The development that has been made was attaching the camera CMUcam5 (Pixy) to the robot. The camera used as vision to mobile robot to follow line and obstacle avoidance rather than using infrared sensor and ultrasonic sensor. Besides, this new development also can detect colour image and path switching. The comparison of efficiency between vision sensor (camera) and basic sensor (infrared sensor and ultrasonic sensor) is made. The comparison made by taking the average time taken for robot to perform the task.

The new development of this project will continue by optimize by propose the efficient vision system to the mobile robot. Generally, this mobile robot will detect object in indoor environment with wide view of vision system. Two units of camera CMUcam5 (Pixy) will attach to the mobile robot to wider the vision system and navigate this mobile robot.

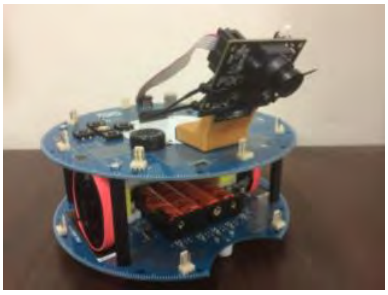

Figure 1.1: Developed Arduino Mobile Robot

1.2 Problem Statement

The previous version of Arduino mobile robot that has been developed only have a CMUcam5 (Pixy) as their vision system. It means that this Arduino mobile robot has basic vision-guided system that only can navigate line following and avoiding obstacle. The ability for this mobile robot is limited. Thus, based on the observation and checklist made, the problem that has been found are:

i. Arduino Robot has limited ability of navigation system.
ii. The vision systems for the mobile robot are basic and narrow
iii. An autonomous mobile robot navigation requires better vision system to perform tasks accurately.

1.3 Objectives

The objectives of this study are:

i. To propose efficient vision system using dual camera on a mobile robot for navigation.
ii. To validate the proposed vision-guided mobile robot for navigation and object detection.

1.4 Scope of Study

i. Purpose the new development of vision-guided system for mobile robot based on ATmega328P microcontroller.
ii. Study and develop the programming code to navigate the mobile robot using Arduino IDE software and PixyMon software.
iii. Conducting experiments to prove the proposal of efficient vision system using dual camera on a mobile robot for navigation in indoor environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provide some information knowledge about the mobile robot and other components that related to my case study. Mostly, all the information and knowledge were obtained from the articles, journals, books and other related sources. There were some facts and working principles been explained in this literature review.

2.2 Vision System Navigation

Vision for mobile robot navigation is one of the major topics in both robotics and computer vision research (N. Sawasaki et. al., 2006). There were many mobile robots produced used vision based system for navigation. The navigation system plays very significant part and demand competence for mobile robot (M. Saifizi et. al., 2012). Using vision system for navigation is more effective and consume less response time instead of using sensor such as ultrasonic sensor and infrared sensor. The development of vision system for mobile robot navigation is increasing and more advance. Vision system is a system which consists of the hardware and software necessary to emulate functions of an eye. The information that captured by function of an eye is processed and passed on to a processor.

Vision system navigation is a system used to visualize the data from vision system to help the mobile robot navigates itself into the environment. A mobile robot can be navigated by using camera or vision sensor as a vision system. Camera used can detect the object or interpret image from the environment. When the image is detected, the mobile robot will localize itself means know it's current position. Basically, if the camera detected the object or any other information, mobile robot will decide the movement whether to avoid or move forward. The movement of mobile robot is automated and programmed by the user.

2.2.1 Mono Vision

Mono vision image is captured by monocular camera which is one of the most frequently used ones, due to its being cheap in cost and rich in information (L. Xiao et. al., 2016). Using mono vision camera can detect the length and breadth of the obstacles (S. Mahajan et. al., 2013). Mono vision has the advantage of a lower image processing time. However, this mono vision with ingle camera makes it complex as no depth information is available to avoid obstacles (S.G Charan et. al., 2015). Object detection in varied real-time scenarios is a very difficult task. Object detection in irregular environment and varied angle of view is the problem to be settled.

An example for monocular camera is CMUcam5 (Pixy). This Pixy carry out a hue-based filtering algorithm is used to detect objects of a detailed colour (S. Lee et. al., 2015). It is small, easy-to-use, low cost and readily-available vision system. This camera is capable to find unique colours and return their image information to the microcontroller that used for controlling the mobile robot. The Pixy's on-board processor is compatible to external controller such as Raspberry Pi, Beaglebone and Arduino to perform the vision processing. They can be easily connected through a simple serial communication interface. The camera grants the microcontroller with clear pixel image value of the centre position and size information of the recognized objects in the image field of view. This information is gained based on image pixel value from the camera, can then be used to convert it into the real-world position of the mobile robot. All this useful information is applicable through one of several interfaces: SPI, I2C and UART, digital or analog output at 50 frames per second. The native resolution the Pixy's image sensor is 1280 x 800, but for higher frame rate of up to 50 frames/sec, and lower CPU and memory requirements the vision system actually uses 320 x 200 pixel resolution.

Figure 2.1: CMUcam5 (Pixy) (cmucam.org)

2.2.2 Stereo Vision

Stereopsis or Stereoscopic vision is the formation of alerting depth or distances to objects in the environment (Herath et. al., 2007). As a strand of computer vision research stereo vision algorithms have advanced apparently in the past few decades to a point where semi-commercial products are usable as off the shelf devices. Stereo vision naturally comes with high computational complexity, which previously restrained its deployment to high-effectiveness, centralized imaging systems. Conventional, high-performance stereo vision systems (Bramberger et al., 2006) commonly consist of a pair of high-resolution cameras and at least one processing powerful processor to derive stereoscopic information. Requirements of application is processing power and energy resources that can readily be chosen. They bind general-purpose processors with digital signal processors (DSPs) or field-programmable gate arrays (FPGAs) for demanding image processing tasks. Moreover, standalone, centralized stereo vision systems are example of typical unconcern for scalability and form factor. Their stereo vision tasks range from multi-target tracking, depth map generation, to visual hull reconstruction, which commonly need to be done in real-time, i.e., at frame rates of 15 or 30 frames per second (fps). Raw or pre-processed stereo image representations designed for human analysis and interpretation are the information that generated oftentimes.

Besides, this type of vision also has some problem due to noise. Noise due to stereo imbalanced is a serious problem (Murray et. al., 2000). Indoors scenes containing mirror-like surfaces, repetitive patterns, and time-varying light sources can cause errors that almost uniformly distributed across the imparity range of the stereo system. These imbalanced could be reduced with validation through comparing left-to-right and right-to-left best matches (P. Fua, 1993), the validation approaches by developing the number of cameras in a multi baseline system (T. Kanade et. al., 1996). However, even with a trinocular stereo system, these errors will appear. The error affect the quality of the map drastically and appear as "spikes" in the disparity image. Moreover, stereo vision demands a lot of processing time because it has complex task which is involves finding correspondence between images (M.I Arenado et. al., 2014).

2.2.3 Multiple Vision

Multiple Visual Agent, MVA concept proposed by (H. Ishiguro et. al., 1993) state that each agent of MVA has a camera controller and estimating resource for analysing the image data taken by its own camera and detecting the camera motion. In their development, they used four units of cameras with 4 cameras moving separately. Each agent studies the image data and controls the eye motion, such as fixation to a moving target, infatuation to a fix target for vision-guided navigation, or surveying a wide area to find obstacles.