Depth Estimation from Vision Based Wireless Monocular Camera Sensor for Soccer Robot Applications in MiroSot Middle League

by

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A thesis submitted in fulfillment of the requirements for the degree of Master of Science (Mechatronic Engineering)

School of Mechatronic Engineering
UNIVERSITI MALAYSIA PERLIS

2012

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Academic Session : 2011/2012

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ACKNOWLEDGEMENTS

I would like to thank Allah S.W.T for his blessing and guidance for me to finish this research and thesis successfully. Firstly of all, I would like to thank Assoc. Prof. Dr. Kenneth for his time and efforts to advises, guide, motivation, financial support and encourage me to finish this research.

Second, I would to thank Politeknik Tuanku Syed Sirajuddin (PTSS) and especially Mr. Mohd. Shahrom Bin Idris for their supports, assistances and permission to use all equipments needed for this research. I also would like to thank Mr. Sivadev Nadarajah for his support and cooperation throughout this research.

I would like to thank my parents and family for their endless love, advices and prayers. I also would like to express my sincere gratitude to my fiancée for her encouragement and supports in completing this thesis.

Then, I would like to express my sincere gratitude to my all members of Autonomous and Machine Vision (AutoMAV) Cluster and all people whom involve directly or indirectly this research. Without their support, this research work would never be successful.

TABLE OF CONTENTS

CHAPTER 2: LITERATURE REVIEW

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
AGVs	Automated Guided Vehicles
AI	Artificial Intelligence
BGR	Blue-Green-Red
CamShift	Continuously Adaptive Mean Shift
CCD	Charge Coupled Device
CSMACA	Carrier Sense Multiple Access Collision Avoidance
DSSS	Direct Sequence Spread Spectrum
DVR	Digital Video Recorder
FHSS	Frequency Hopping Spread Spectrum
FIRA	Federation of International Robot-Soccer Association
FPS	Frame per Second
GPS	Global Positioning System
GUI	Graphical User Interface
HSL	Hue-Saturation-Lightness
HSV	Hue-Saturation-Value
HuroSot	Humanoid Robot World Cup Soccer Tournament
IR	Infrared

ISM	Industrial, Scientific and Medical
KAIST	Korea Advance Institute of Science and Technology
LED	Light Emitting Diode
MAX	Maximum
MDP	Markov Decision Process
MIN	Minimum
MiroSot	Micro Robot World Cup Soccer Tournament
NaroSot	Nano Robot World Cup Soccer Tournament
OpenCV	Open Computer Vision
O-QPSK	Offset-Quadrature Phase Shift Keying
PAN	Personal Area Network
PWM	Pulse Width Modulation
R.U.R	Rossum's Universal Robots
RC	Remote Control
RF	Radio Frequency
RGB	Red-Green-Blue
RoboCup	International Robotics Competition
ROI	Region of Interest
SimuroSot	Simulator of Robot Soccer Tournament
UHF	Ultra High Frequency
USB	Universal Serial Bus
UWB	Ultra Wide Band
VHF	Very High Frequency

VS2008	**Microsoft Visual Studio 2008**
Wi-Fi	**Wireless Fidelity**
WiMAX	**Worldwide Interoperability for Microwave Access**
WPAN	**Wireless Personal Area Network**

ANGGARAN KEDALAMAN DARI PENGLIHATAN BERDASARKAN PENDERIA KAMERA MONOKULAR TANPA WAYAR UNTUK APLIKASI ROBOT BOLA SEPAK DALAM LIGA PERTENGAHAN MIROSOT

ABSTRAK

MiroSot ialah satu bidang dimana beberapaa bidang robotik seperti struktur mobiliti, kepintaran buatan, sistem penglihatan, agen-agen berbilang, komunikasi tanpa wayar dan gelagat berautonomi adalah sangat penting. Salah satu bahagian yang genting didalam keseluruhan sistem ini ialah sistem penglihatan. Sistem ini boleh menentukan faktor kemenangan ketika perlawanan MiroSot. Di dalam projek ini, kami melaksanakan sistem penglihatan lokal untuk mengawal pengerakkan and gelagat robot bola sepak berbanding sistem penglihatan global yang sedang digunakan. Disebabkan oleh had saiz robot mudah alih yang dinyatakan di dalam peraturan MiroSot, oleh yang demikian sedikit pengubahsuaian perlu dilakukan ke atas sistem penglihatan. Satu sistem penglihatan monokular telah digunakan sebagai alternatif kepada sistem penglihatan stereo yang lebih popular tanpa mengabaikan aspek anggaran kedalaman untuk menentukan jarak dan kedudukan bola. Dengan menggunakan algoritma CamShift dalam mengesan bola, kami menggunakan diameter bola bagi menganggarkan jarak bola dari robot mudah alih. Data tentu ukuran ini telah diuji dan memberikan bacaan yang tepat dalam jarak anggaran. Dengan menggunakan maklumat ini, robot bola sepak akan cuba mengelak sebarang halangan dengan melakukan satu pengerakkan-pengerakkan jujukan. Butiran terperinci tentang bagaimana kami memperoleh data tentu ukuran untuk anggaran kedalaman dan peringkat ujian turut disediakan didalam tesis ini. Kami turut menguji sitem kawalan kami dan kepututusan boleh didapati di dalam bab keputusan. Matlamat jangka panjang untuk projek ini ialah untuk mewujudkan satu sistem penglihatan untuk robot bola sepak yang diilhamkan secara biologi.

DEPTH ESTIMATION FROM VISION BASED WIRELESS MONOCULAR CAMERA SENSOR FOR SOCCER ROBOT APPLICATIONS IN MIROSOT MIDDLE LEAGUE

ABSTRACT

MiroSot is an area where robotics fields such as mobility structure, artificial intelligence, vision system, multi-agents, wireless communication and autonomous behaviour are of paramount importance. One of the most crucial parts of this overall system is the vision system. This system could determine the winning factor during a MiroSot competition. In this project, we are implementing a local vision system to determine the motion and behaviour of the soccer robot instead of a global vision system that is currently being used. Since there is limitation in the size of the mobile robot as stated in the MiroSot rules, hence some modification needs to be done on the vision system. A monocular vision system is used as an alternative to the more popular stereo vision system without neglecting the depth estimation aspect to determine ball distance and position. By using the CamShift algorithm to detect the ball, we use the ball diameter to estimate the distance of the ball. The calibration data has been tested and has shows that it gives accurate and precise distance estimation. By using this information, the soccer robot will try to avoid any obstacle by performing a sequence of movements. The details on how we obtained the calibration data for depth estimation and the testing phase have also been provided in this thesis. We also show how we test our control system and the results can be found in result chapter. The long term goal behind this project is to create a biologically inspired vision system for the soccer robot.

CHAPTER 1

INTRODUCTION

1.1 Overview

Micro Robot Soccer World Cup Tournament (MiroSot) is a competition of autonomous or semi autonomous mobile robots that mimics human soccer competition. This competition is divided into 3 categories which are the small league, the middle league and the large league which are played by 3 agents, 5 agents and 11 agents aside respectively. The mobile robot control is based on global cameras that are mounted at the top of the field as shown in Figure 1.1.

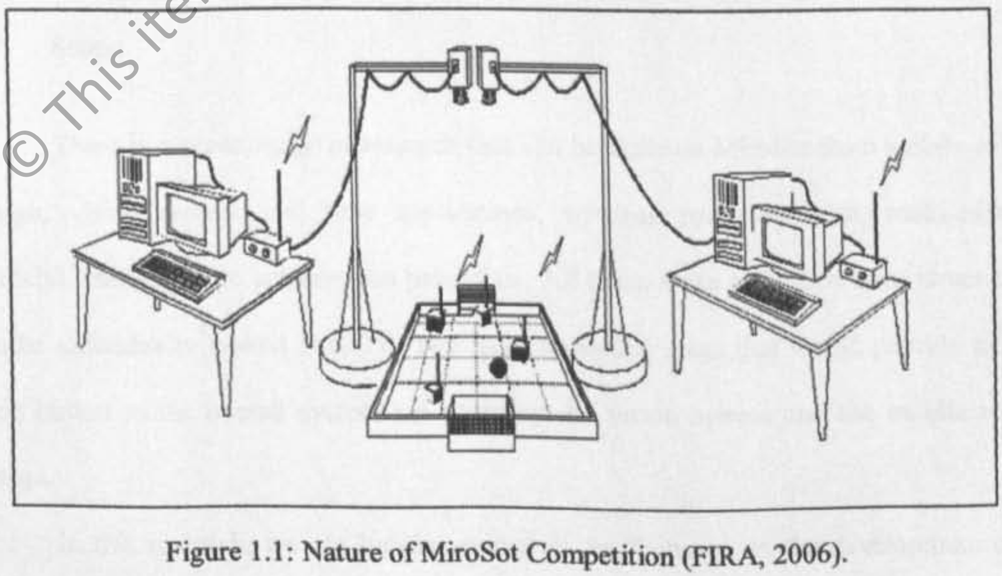

Figure 1.1: Nature of MiroSot Competition (FIRA, 2006).

This type of vision is good but the decision making is not similar to how human soccer is played. In this research, we are attempting to mimic the real human soccer by introducing local vision system to the agents. All decisions of the mobile robot are now based on its own vision system. However, with the limitation in size of the mobile robot given by the Federation of International Robot-Soccer Association (FIRA) which is bounded by a 7.5cm cube, implementation of a stereo vision may go against those rules. Hence, we are implementing a monocular vision system on the mobile robot and will try to solve several issues with this system.

Issues such as the accuracy of depth estimation and occlusion are several problems that will be tackled in this research. We will propose some solutions and conduct some experiments to test the methods that can overcome these issues. The global vision system is not used directly in this situation but rather we have changed its function instead to work as a supervision camera for global error correction and validation.

1.2 Scope

There is a broad range of research that can be done on MiroSot from mobile robot design, vision system, real time applications, wireless communication, multi-agents, artificial intelligence to autonomous behaviour. All these areas have their own issues that can be individually looked into. The two most important areas that would provide major contribution to the overall system are probably the vision system and the mobile robot design.

In this research, we are limiting ourselves by focusing on the development of a local vision system in order to attempt to mimic the human behaviour towards a real soccer game environment. By introducing a biologically-inspired vision system, we attempt to implement a local vision system on the mobile robot. Hence, every decision made is based on its local vision system. Since there is a limitation on the size of the mobile robot, we propose to introduce a monocular vision system with depth estimation capability that is similar to the stereo vision system.

We also intend to develop a manual movement interface for the mobile robot in order to familiarise ourselves with all the commands that are available to control the mobile robot. In the current state, all the commands can only be transmitted using a HyperTerminal application. This type of application may be difficult to be used for some people since it is not user friendly and hard to understand.

1.3 Motivation

Soccer is well-known as the most famous sports all over the world. The excitement and passion given to this sport is undeniable. FIRA is attempting to organise a soccer match between a team of robots and world cup winner of 2050. Hence they have decided to provide a few platforms, such as MiroSot, for completion between teams of robots in order to test their mechanical capability and artificial intelligence.

Normally in a MiroSot competition, every team use one global vision system as the only vision system to control the behaviour of its agents. We are attempting to introduce a biology-inspired vision system to this competition. This effort will make the agents behave as real humans during this competition since it has its own vision system. This vision system will control and determine the behaviour of agents during the game. It will mimic humans in the way of thinking and playing soccer.

Despite the fact that this research uses a monocular vision system instead of a stereo vision system, the accuracy in the estimation of distance is not neglected. This monocular vision system is not limited to applications for MiroSot competitions but can also be used in other types of robots such as navigation robots, surveillance robots, robot arms and military robots. The approach used in this research can be a reference to develop the monocular vision system.

1.4 Problem Statement

The application of a global monocular vision system is unpopular among researchers due to its complexity and difficulty. All agents are controlled based on one global vision system which might slow down their movements since it needs to process everything at once. By implementing a local vision system to the mobile robot, every agent will be controlled based on its own vision system. The aim here is to have a biologically inspired vision system that is robust, fast, reliable and capable to be operated in a dynamic environment such as in MiroSot.

This research attempts to develop a monocular vision system based control for soccer robots using depth estimation from a single wireless camera mounted on mobile robot. This interface is planned to be employed in a MiroSot competition. The idea behind this application is to create an alternative for the current vision system used in MiroSot. However, the application of this idea is not limited within the MiroSot competition context. It could also be used in other mobile robot applications.

1.5 Objectives

The main objective of this research is to demonstrate the control of a soccer robot from a biologically-inspired monocular vision system based on a single wireless camera using depth estimation.

The sub-objectives of this research are as follows:

- To review the advantages and disadvantages of all technologies currently being used in MiroSot.
- To develop a manual movement interface for the mobile robot motion control.
- To determine the best position to mount a wireless monocular camera on the mobile robot.
- To develop a program to determine the depth estimation of the ball based on its measured diameter.
- To find a solution to calculate the diameter if the ball view is in an extreme condition known as occlusion.
- To integrate the mobile robot movement interface and the image processing unit to form an autonomous mobile robot with vision based control system.

1.6 Methodology

The general methodology adopted throughout this research will be discussed in this section. The details of all approaches are discussed in the following chapters. In general, this research is divided into three stages.

In the first stage, we will do a literature review on the development of mobile robot for applications in MiroSot. All current technologies and its alternatives that are used will be reviewed in this stage. We will cover elements of mobility structure, artificial intelligence, wireless communication, vision system and autonomous behaviour.

In the second stage, we will explain and discuss the details of the methods used throughout this research. There are two units that contribute to the overall system of this research which are the mobile robot control unit and the image processing unit. In the mobile robot unit, we will test the possible positions of wireless camera and the development of a manual movement interface. This will allow us to experiment with all the commands to control the mobile robot. In the image processing unit, we will implement the algorithm used to detect and estimate the object of interest. We will also develop the method used to obtain the calibration data for the monocular vision system.

In stage three, we will conduct the experiments and record the results in order to obtain the calibration data for the monocular vision system to estimate the depth. In the MiroSot competition, there is a situation where the mobile robot holds the ball and the ball obstructs the view of the wireless camera known as occlusion. We will model this situation geometrically and use appropriate mathematical concepts to solve this problem.

1.7 Expected Result

The main contribution of this research is the development of a vision based control for soccer robots using depth estimation. This requires the development of a manual control interface for the mobile robot used throughout this research. From this interface, we will implement all commands that are available to control the mobile robot. Hence, the movements of mobile robot towards the target and goal will be realised using a dictionary of motion commands.

Since this research is using a mounted wireless camera on the mobile robot, we will determine the possible positions for the wireless camera and the best position to acquire images with a view as far as possible. After that, we will develop an algorithm as a platform to process the images acquired. This algorithm will also carry out the depth estimation with the support of the calibration data obtained from several experiments. This coded program will be another contribution of this research.

After that, we will determine the method to integrate the image processing unit and the mobile robot control unit in order to ensure that the vision based control of soccer robot using depth estimation is successful. This approach hopefully will give some guidance to others to develop a monocular vision based control system.

1.8 Thesis Outline

The content of this thesis has been organised according to the scope, objectives and experimentations that have been done. Starting with this chapter, we will briefly outline the elements that contribute to this research. Chapter 2 will review the literature related to this research. In chapter 3, we will discuss all methods used throughout this research. Chapter 4 will discuss about the experiment results and also discuss on several issues that were observed during the experiments. Finally, we conclude in the final chapter some important issues regarding this project.