MODIFIED STEREO VISION METHOD FOR AN UNMANNED GROUND VEHICLE

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This thesis is dedicated to my family and all my friends.

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Masoud Samadi

ABSTRACT

In recent years, automated robots are widely used in different fields of science and engineering such as industrial, rescue, surveillance and military applications. Among these automated machines, there are some robots which need to move around and navigate autonomously to perform their tasks. One of the crucial parts in these kinds of mobile robots which helps them to navigate autonomously is the environmental perception part. In order to retrieve information from the surroundings, a robot could use different types of sensor. Lately, stereo vision system has found its place in the environmental perception methods. This method has a great ability to provide 3D information of all the objects in the robots' path. The main goal of this thesis is to build a stereo vision-based mobile robot which navigates autonomously and explores an unknown environment while avoiding collision with obstacles in its path. Within the scope of this thesis, a modified version of standard Census stereo vision algorithm is proposed to reduce the processing time of the existing method. A stereo Vision-Based robot is designed and prototyped to implement and test the proposed stereo vision method. In addition, dynamic path planning algorithm is employed to provide a collision free path for the robot. The proposed strategy is able to navigate the robot from its current position to the defined destination while avoiding the obstacles throughout an estimated path. The details of design and prototype of the autonomous mobile robot such as hardware and software developments are extensively described. The results obtained are compared with standard benchmark dataset and the evaluation shows 3.36% improvement in terms of accuracy, while the speed is about two times faster than standard Census method. Therefore, based on the empirical observation, the proposed modified Census algorithm makes the robot able to reach the destination point without colliding with any obstacle throughout a planned path.

ABSTRAK

Sejak kebelakangan ini, robot-robot automatik telah digunakan secara meluas di dalam pelbagai bidang sains dan kejuruteraan seperti untuk aplikasi-aplikasi industri, penyelamatan, pengawasan dan ketenteraan. Di antara mesin-mesin automatik, terdapat sesetengah robot yang perlu bergerak bebas dan dikemudi secara autonomi bagi menjalankan tugas-tugas mereka. Satu daripada perkara penting di dalam robot-robot jenis bergerak ini yang membantu mereka dikemudikan secara autonomi ialah bahagian persepsi persekitaran. Untuk memperolehi informasi daripada persekitaran, sesuatu robot boleh menggunakan sensor yang belainan jenis. Kini, sistem penglihatan stereo sudah diketengahkan di dalam kaedah-kaedah persepsi persekitaran. Cara ini mempunyai kebolehan yang hebat bagi memberikan informasi 3D mengenai kesemua objek di dalam laluan robot. Matlamat utama tesis ini ialah membangunkan robot bergerak berasaskan penglihatan stereo yang berupaya dikemudi secara autonomi dan menjelajahi sesuatu persekitaran baru disamping dapat mengelak perlanggaran dengan halangan-halangan di dalam laluannya. Di dalam skop tesis ini, suatu versi yang dimodifikasikan mengikut standard algoritma penglihatan stereo Census dicadangkan bagi mengurangkan masa pemprosesan kaedah sedia ada. Robot stereo Berasaskan Pandangan direka bentuk dan diprototaipkan untuk melaksanakan dan menguji kaedah stereo penglihatan yang disyorkan. Disamping itu, algoritma perancangan laluan Dinamik diguna bagi menyediakan laluan yang bebas daripada perlanggaran untuk robot tersebut. Strategi yang dicadangkan boleh mengemudi robot daripada posisi semasanya menuju destinasi yang ditetapkan, juga dapat mengelak halangan sepanjang laluan yang dijangkakan. Perincian reka bentuk dan prototaip robot bergerak autonomi tersebut seperti pembangunan hardware dan software diterangkan dengan mendalam. Keputusan yang telah diperolehi dibandingkan dengan set data tanda aras standard dan penilaian menunjukkan kemajuan sebanyak 3.36% daripada segi ketepatan, manakala kelajuan meningkat kira-kira dua kali ganda berbanding dengan kaedah Census standard. Maka, berdasarkan kepada pemerhatian empirikal, algoritma Census yang dimodifikasikan membolehkan robot sampai ke poin destinasi tanpa melanggar apa-apa halangan sepanjang laluan yang dirancang.

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LIST OF ABBREVIATIONS

UGV	–	Unmanned Ground Vehicle
SAD	–	Sum of Absolute Differences
ZSAD	–	Zero-mean Sum of Absolute Differences
SSD	–	Sum of Squared Differences
MRI	–	Magnetic Resonance Imaging
FPGA	–	Field-Programmable Gate Array
PC	–	Personal Computer
RAVON	–	Robust Autonomous Vehicle for Off-road Navigation
SVBRC	–	Stereo Vision Based Robot Controller
WTA	–	Winner Take All
FPS	–	Frame Per Second
IEEE	–	Institute of Electrical and Electronics Engineers
DC	–	Direct Current
SDLC	–	Software Development Life-Cycle
CPU	–	Central Processor Unit
DSI	–	Disparity Space Image
NCC	–	Normalized Cross Correlation
BP	–	Belief Propagation
CDU	–	Computation Decision Unit
USB	–	Universal Serial Bus
RAM	–	Random Access Memory
HD	–	High Definition
RMS	–	Root Mean Square
GA	–	Genetic Algorithm

LIST OF SYMBOLS

ξ	–	Census
ζ	–	Differential

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CHAPTER 1

INTRODUCTION

This chapter presents an overview of autonomous robots, stereo vision and path planning while generally discusses several diverse application domains that employ the stereo vision techniques in autonomous robots. In addition, the general problems that undermine the performance and efficiency of the stereo vision algorithms, the main objectives of this research and the scope of the thesis are highlighted at the end of this chapter.

1.1 Overview

1.1.1 Autonomous Robots

Nowadays, computers and robots facilitate the daily life of humankind. Robots come in several categories and groups which are based on their serving fields and applications. An unmanned ground vehicle (UGV) is a robot which operates on the ground without any human piloting on its board. UGV robots can be used in a wide range of applications, especially where the presence of a human can be dangerous, inconsistent, or impossible for some reasons. The UGV robots are in contact with the environment by using several physical sensors such as temperature, humidity, ultrasonic sensors, etc. For decision making, two strategies exist, either the robot autonomously makes decision about its behaviours and actions, or sends the information to a human operator at a different location and receives commands.

An autonomous UGV is a robot which does not need to be controlled by a human. Instead, the robot develops a limited understanding of its environment by using the sensors mounted on it. Such a robot is also known as a mobile robot which is designed to work in an unknown environment. To operate safely and efficiently in the said environment, the realization from the physical environment must be sufficient and accurate [1]. For performing a task robustly in an unknown environment, the autonomous UGV robot needs to be equipped with a accurate obstacle detection and avoidance algorithm.

A simple function of the obstacle detection and avoidance is shown in Figure 1.1, in which the autonomous robot is programmed to detect some specified objects. If the robot is targeted to reach a destination, it must be capable of localizing all the objects and barriers which are blocking its path. In order to avoid collision with the obstacles and barriers, the robot might be compelled to change its direct path frequently. Therefore, a reliable data collection from the environment is necessary for a mobile robot [2]. Several methods have been introduced by researchers to retrieve precise information of the field such as ultrasonic sensors, infrared sensors, laser range finder, etc.; however, each of these methods contains its own limitations and difficulties [3].

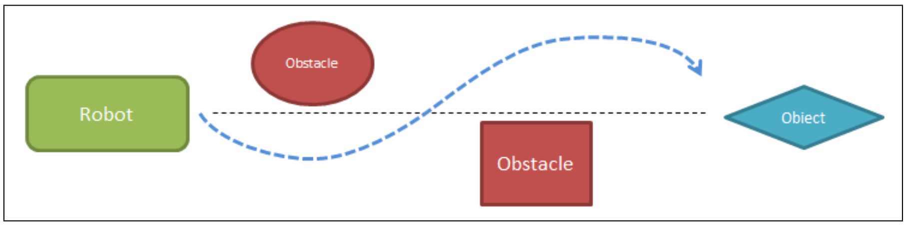

Figure 1.1: Obstacle Avoidance

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