DEVELOPMENT OF A VISION-BASED MOBILE ROBOT NAVIGATION SYSTEM FOR GOLF BALL DETECTION AND LOCATION

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

February 2007

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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A significant challenge in the design of an autonomous mobile robot is the reliable detection of targets, obstacles and targets tracking. Many types of sensor are used for that purposes such as infrared, sonar, vision sensor and laser. Monocular vision is one of the methods used due to simplicity and computational cost compared to stereo vision. Based on current trends the autonomous mobile robot development, vision sensor is used as different functions such as target recognition, obstacles avoidance, and navigation.

To fulfill such demands the mobile robot should be able to estimate the distance of the detected targets and their angles from its current location. From the extracted information, the motions of the mobile robot can be done efficiently for targets retrieval task. This thesis addresses issue on golf balls localization. The sensor used for localization is a single color webcam. The experiment involves stationary golf balls localization at indoor and outdoor scene.

The objective is to localize golf balls at various locations to be retrieved by the mobile robot. The distance towards the golf balls are estimated based on their diameter. This is based on the perspective view concept where the golf ball sizes are inversely proportional to their distance from webcam. Golf balls detection is done using color segmentation in RGB (red, green and blue) color space. A vector, **a**, that represents mean value of the target sample is calculated. Then the mean and standard deviation of each color component is calculated. The threshold value lies in the range $\boldsymbol{\mu} \pm \boldsymbol{\sigma}$ which represents a square bounding box in RGB color space with a center at **a**. Every pixel in the test image is tested whether it lies within the bounding box which contributes to target pixel. The technique for segmentation can avoid high computation time for color image processing. The simple features such as diameter, *x*-*y* ratio and area are used as its inputs to the *k*-nearest neighbors (*K*-*NN*) classifier.

The software is developed in Visual Basic 6 with a laptop computer acts as a controller and for handling image acquisition and processing. The localization process takes less than one second to be completed. The technique has been tested at indoor and outdoor environment. The efficiency of the estimation is more than 90 percents with a condition that the targets are less than 50 percents occluded.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN SEBUAH ROBOT BERGERAK BERASASKAN PENGLIHATAN UNTUK MENGESAN DAN MENENTUAN KEDUDUKAN BOLA GOLF

Oleh

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Satu cabaran getir dalam pembinaan robot bergerak sendiri adalah mengesan sasaran, mengelak hadangan dan menjejak sasaran. Banyak jenis pengesan yang digunakan untuk tujuan tersebut seperti inframerah, sonar, pengesan penglihatan dan cahaya laser. Penglihatan tunggal adalah salah satu cara yang digunakan untuk tujuan itu. Ini kerana ia mudah dan kos pengkomputeran rendah berbanding penglihatan stereo. Berdasarkan situasi semasa pembangunan robot bergerak sendiri, penglihatan digunakan untuk kegunaan pelbagai seperti pengenalan sasaran, mengelak halangan dan penjelajahan.

Demi memenuhi tujuan – tujuan tersebut sebagai satu contoh robot bergerak harus dapat menentukan jarak sasaran yang dikesan dan juga sudut sasaran dari kedudukannya sendiri. Daripada maklumat yang dikumpulkan pergerakan robot dapat dilakukan dengan cekap untuk menghampiri sasaran.

Tesis ini menyentuh isu penentuan kedudukan bola golf. Pengesan yang digunakan untuk penentuan kedudukan ialah sebuah kamera warna. Ujikaji penentuan kedudukan dilakukan didalam dan diluar bangunan. Objektif adalah untuk menentukan kedudukan bola golf pada kedudukan yang berselerak untuk dikutip oleh sebuah robot bergerak. Jarak sasaran dianggar berdasarkan diameter bola golf. Ini adalah berdasarkan pandangan perspektif dimana saiz bola adalah berkadar songsang dengan jaraknya daripada kamera. Pengesanan bola golf adalah menggunakan teknik ambang warna yang ketara dalam format imej warna merah, hijau dan biru. Satu vector, **a**, dikira yang mewakili nilai purata untuk sampel sasaran. Kemudian dikira pula nilai purata dan sisihan piawai bagi setiap komponen warna merah, hijau dan biru. Nilai ambang akan terletak pada julat $\boldsymbol{\mu} \pm \boldsymbol{\sigma}$. Sebuah kotak berisipadu terbentuk dalam ruang format tiga warna yang berpusat pada **a**. Satu anggapan dibuat bahawa pencahayaan adalah tidak banyak berubah dan tidak mempengaruhi nilai ambang. Teknik ini dapat mengelak beban pengkomputan yang besar ke atas gambar warna. Bola golf dikenali menerusi teknik *k-NN* (*k*-jiran terdekat). Sifat fizikal bola golf seperti diameter, nisbah x-y dan luas digunakan sebagai masukan untuk pengasingan.

Perisian dibangunkan menggunakan Visual Basic 6 dengan sebuah komputer riba bertindak sebagai pengawal untuk pengambilan dan pemprosesan gambar. Cara penentuan kedudukan mengambil masa kurang dari satu saat. Teknik ini telah diuji di dalam bangunan and di padang. Ketepatan anggaran adalah melebihi 90 peratus apabila satu syarat dipatuhi iaitu sasaran mesti tidak terlindung lebih dari 50 peratus.

ACKNOWLEDGEMENTS

In the name of Allah, the Beneficent and the Merciful. It is with the deepest sense of gratitude to Allah who has given the strength and ability to complete this thesis as it is today.

I would like to express my deepest gratitude to my supervisor, Dr. Mohammad Hamiruce Marhaban and also to my co-supervisors, Assoc. Prof. Dr. Ishak Aris and Dr. Samsul Bahari Mohd. Noor who deserve the most credit for their moral support and abundance of guidance and assistance for the success of this thesis.

I certify that an Examination Committee has met on 7th February 2007 to conduct the final examination of Rizal Mat Jusoh on his Masters of Science thesis entitled "Development of a Mobile Robot Navigation Using Vision Based Golf Balls Detection and Location" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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