UNIVERSITI PUTRA MALAYSIA

EFFECT OF MASKING TECHNIQUES ON COMPUTATIONAL COMPLEXITY REDUCTION OF SCALE INVARIANT FEATURE TRANSFORM

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By

YUNUSA ALI SAI'D

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATIONS

I dedicate this work of mine to my Mum and Dad. May the mercy of Allah be upon us all. Your support and courage is what made me what I am today. Thank you.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

EFFECT OF MASKING TECHNIQUES ON COMPUTATIONAL COMPLEXITY REDUCTION OF SCALE INVARIANT FEATURE TRANSFORM

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April 2015

Chair: Professor Madya Mohammad Hamiruce Marhaban, Ph.D.

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The Scale Invariant Feature Transform (SIFT) is algorithm use in feature detection and description, it is famous and has dominated the research community. The SIFT is a standard compared to others. Notwithstanding its sturdiness, SIFT has limitation of computational complexity, this has pose great limitation to real time and on-line implementations. Effort has been done by researchers to improve on SIFT performance because of it robustness, the computational cost was reduced to some extent but the distinctiveness cannot be compared with others(Descriptors). Thus, the aim of this research is to propose masking techniques to images, by eliminating areas with no or sparse keypoints in the feature extraction process, thereby reducing the computational cost of SIFT as the dominant descriptor in computer and robotic vision. Performance of the proposed approach was able to reduce the computational time to 47.27% at 0.7 Threshold with 17.94% in keypoint reduction. However, the masked SIFT was used in place categorization for performance evaluation. The evaluation was conducted using two classifiers in pattern recognition on the classification of Royal Institute of Technology-Image Data for Robot Localization (KTH-IDOL2) database. The classifiers are Nearest Neighbor (NN) and Multilayer Perceptron (MLP). Comparison of the categorization and classification accuracy produced 70% with the nearest neighbor(NN) and improved to 80% with Multilayer perceptron. In conclusion, the proposed approach was able to improved the computational time of SIFT higher than the recent published work in literature.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doctor Falsafah

KESAN TEKNIK PELITUPAN KEPADA PENGURANGAN KERUMITAN PENGIRAAN PENJALMAN SKALA CIRI TIDAK BERUBAH

Oleh

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Penggunaan algoritma Penjelmaan Skala Ciri Tidak Berubah (SIFT) yang terkenal dalam pengesanan dan pemerihalan sesuatu ciri telah mendominasi komuniti penyelidikan atas faktor kekukuhannya. Meskipun kukuh, penggunaan SIFT pada masa sebenar atau atas talian adalah terhad kerana kerumitan dalam pengiraannya. Pelbagai usaha dan teknik yang sedang dan telah dilakukan oleh penyelidik-penyelidik untuk memperbaiki prestasi SIFT dengan mengurangkan masa pengiraannya tanpa mengurangi kekukuhannya. Untuk itu, kajian ini mencadangkan teknik pelitupan imej digunakan, iaitu dengan menghapuskan kawasan tanpa titik penting atau kurang padat semasa proses pengekstrakan ciri supaya masa pengiraan SIFT sebagai penghurai yang dominan didalam komputer dan visi robotik dapat dikurangkan. Menerusi pendekatan yang di-cadangkan, masa pengiraan telah dikurangkan sebanyak 47.27% pada 0.7 ambang dengan 17.94% titik penting dikurangkan. Untuk menilai ketepatan pengkategorian kawasan menerusi kaedah pelitupan SIFT, eksperimen dijalankan ke atas pengkalan data Royal Institute of Technology-Image Data for Robot Localization (KTH-IDOL2) dengan menggunakan dua pengelas sebagai pengiktirafan corak; iaitu Jiran Terhampir (NN) dan Perseptron Berbilang Lapis (MLP). Ketepatan klasifikasi yang dihasilkan dengan Jiran Terhampir (NN) adalah 70% dan meningkat kepada 80% dengan Perseptron Berbilang Lapis (MLP). Kesimpulannya, pendekatan yang dicadangkan dapat mengurangkan masa pengiraan SIFT lebih rendah berbanding kerja baru-baru ini yang disiarkan dalam sorotan kajian.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy.

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LIST OF ABBREVIATIONS

SIFT	Scale Invariant Feature Transform
NN	Nearest Neighbour
PCA	Principal Component Analysis
GDOH	Gradient Distance and Orientation Histogram
DOG	Difference of Gaussian
DOM	Difference of mean
SOM	Sum of Mean
SLAM	Simultaneous Localization and Mapping
SVM	Support Vector Machine
MLP	Multilayer Perceptron

CHAPTER 1

INTRODUCTION

1.1 Background

The computer vision and robotic research community used algorithms such as (Speed Up-Robust Feature) SURF, (Scale Invariant Feature Transform) SIFT, (Feature From Accelerated Segment Test) FAST an so on, for extracting features, describing an object in an image, object detection and recognition.

These algorithms tend to extract distinctive features which are invariant to scale, orientation, and illumination changes, that can detect the same features in different images with changes in view point and background. SURF,SIFT and FAST have different limitation and benefit.

However, performance evaluation conducted shows that the (SIFT) is the best compared to other methods (Mikolajczyk and Schmid, 2005). SIFT was invented (Lowe, 1999) and First presented to the research community in 1999 and later some enhancement were made to the algorithm in 2004 (Lowe, 2004). The features detected during extraction process are used for matching query image in database of various object captured at different positions. A match is established when most of the keypoints are consisted on an object features. With the scale space theory (Witkin, ????), SIFT can analyze image using the scale space by forming an image pyramid with Gaussian blur filters to estimate the Difference of Gaussian (DoG) that occur between two stages of image scale space pyramid. potential keypoints location are calculated by determining maxima and minima through adjacent difference of Gaussian stages. The keypoints are examined for stability and for each stable location descriptors are formed. The representation of the local image data are formed by the descriptor around the keypoints in a manner robust to scale, orientation, rotation and illumination changes (Rihan, 2005).

SIFT was first design for object detection and recognition (Morel and G., 2011). However, because it is invariant to scale, orientation, translation, rotation and zoom, it has wide application in robotic research, map building and manageable in hybridization (integrating different map). The principle of hybridization is to overcome limitations of different maps, thereby benefits are derived. Various ways to carry out hybridization exist in the literature, for example, Buschka and Saffiotti (2004),and Thrun (1998) have planned hybrid metric-topological maps to combine precision of metric maps alongside with the justifiably of topological maps. In addition, Topological map are being built on the high of a metric one, whereas others do the opposite. Feature map are applied together with each topological and metric data, whereas others use clearly separated representations. Despite this, there is no systematic approach on how various maps are to be combined and produce to work. This problem makes any hybrid map somehow challenging(Buschka and Saffiotti, 2004) but, feature map can overcome this limitation. Feature based map record the position of important features like corner and intersection. However, it is quite straight forward to draw a second illustration of those maps as a result of precise spatial information they offered (Se et al., 2002).

1.2 Feature Based Approach Using SIFT

Application of feature based approach using SIFT have produced favorable outcome in numerous areas such as object recognition (Lowe, 2004), localization for mobile robot (Kosecka and Yang, 2005) and panoramas frame work (Brown and Lowe, 2003). SIFT produced the best result based on comparative analysis conducted on different descriptors (Mikolajczk and Schmid (2005)). The following two unique distinguishing points make SIFT famous in computer vision and robotics(Xiaosong, 2006) :

(i) Highly distinctive extracted keypoints by SIFT are invariant to illumination, scale, image transformation and changes to camera view point.

(ii) computational speed of the algorithm is enhanced with Difference of Gaussian (DoG) and Laplacian of Gaussian (LoG) approximation within the average time to produce good features.

1.3 Problem Statement

Surrounding areas of image can be described in different ways. SIFT features seem to be appropriate framework for deriving useful representations of the image. It tries to search out a brand new reduced topological space that provides the simplest separation between the various categories within the image. Moreover, the representation are more condensed than the original raw image.

The detectors and descriptors are widely used for object detection, recognition and map building with application to domestic robot, autonomous vehicle and unmanned aerial vehicle. It is mostly thought over carefully that improvement in the past ten years on the application has been one of the famous goal reached in the research community of computer vision and robotics.

Despite the sturdiness of SIFT, it has limitation of computational complexity because of the time needed to calculate the 128 Dimensional features Lowe, 2004. This has pose great limitation to real time and on-line implementations, especially, that now system are run using hand held devices Acharya et al. (2014). However, various effort were made by researchers to improve on SIFT computational complexity because of its robustness. The computational time was reduced to some extent using SURF and PCA-SIFT, but, the distinctiveness was not able to achieve good performance as SIFT (Mikolajczyk and Schmid, 2005).

Data association of image features using classification of label instances in real time with the known traditional approaches (SVM, NN, etc.) produce low accuracy results. Wrong data association produce incompatible map that lead to deviation in path planning and navigation in golem position. Thus, computational complexity and data association in the mapping algorithm are some of the key difficulty that need to be addressed (Thrun and Leonard (2008),Durrant-Whyte and Bailey (2008),Thrun (2002)).

1.3.1 Research Question

(i) Can isolating region with low or sparse keypoints in an image, reduce the processing time so that only areas with concentrated keypoints having high entropy will be extracted?

(ii) What is suitable values for the entropy threshold and window size so that the processing time can be reduced without sacrificing the performance?

(iii) How can we improve the classification accuracy place categorization?

(iv) What is the relationship between entropy and keypoints?

1.4 Research Objectives

The aim of the study is to investigate feature based techniques to reduce the processing time of SIFT. The specific objectives are to :

(i) Develop an algorithm based on SIFT with masking to reduced keypoint descriptors in order to reduce processing time.

(ii) Compare the performance of the proposed algorithm with the original SIFT algorithm.

1.5 Thesis Contributions

The contributions of this work are as follows:

(i) Proposed introduction of masking approach on SIFT to reduce the computational complexity, in order to make it suitable for real time application.

(ii) Implementation of masking SIFT features by matching to establish a threshold value.

(iii) Established relationship between entropy and keypoints.

(iv) Use masked features to improve classification accuracy.

1.6 Scope and Limitations

The Scope and Limitations for this research work are as follows:

(i) The research work focus on the reduction of computational cost of the algorithm SIFT in feature extraction.

(ii) The research work conducted experiment on information loss based on entropy threshold as a very important factor in place categorization and classification.

(iii) The research work experiment on computational complexity based on entropy threshold for place categorization and classification.

(iv) The research work conducted experiment on various window size based on entropy threshold.

(v) The research work undertook to proposed a mathematical model using least square approach to predict processing time for any number of keypoints and at selected threshold.

(vi) The experiment conducted in this research work were based on 2D data only

(vii) The Research work is limited to indoor environment.

(viii) The experimental result are limited only to masking on KTH-IDOL database.

1.7 Thesis Structure

SIFT as a algorithm that have dominated the robotic research community has the limitation of computational complexity, which is an issue of concern. Therefore, chapter Two present review of the most common efforts to solve SIFT problem.

SIFT algorithm in feature extraction to reduce the computational complexity were presented in chapter Three. The procedures and implementation of masking area with low entropy were discussed.

In chapter four, result of the proposed approach was presented. The comparison between the original SIFT and Masked SIFT was discussed. Furthermore, evaluations to test the proposed approach were experimented.

Chapter five presents the conclusion and recommendation for future work.

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