PERFORMANCE EVALUATION OF GPU ACCELERATED REAL-TIME DISCRIMINATIVE CORRELATION FILTER BASED SHORT-TERM VISUAL OBJECT TRACKING

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DEDICATION

Special dedication to my parents,

Teng Kok Heng & Sui Ai Keow

To my supervisor,

Associate Professor Dr. Lim Kim Chuan

My friends and fellow lecturers,

Thank you all for the support, believe and trust in me.

ABSTRACT

Computer vision has brought a lot of benefits and performance in various applications thanks to the recent advancement of technology. Discriminative Correlation Filter based visual object tracking method has shown state-of-the art tracking performance and robustness. Since DCF based visual object tracker uses convolutional feature for model representation requires huge computing resources and has caused the real-time performance to drop significantly. Due to this reason, real-time application such as DCF-based drone visual object tracking cannot be realised. After the implementation of selected DCF-based tracker (Channel and Spatial Reliability DCF, CSR-DCF) using OpenCV library in embedded systems, the hardware performance of selected DCF-based tracker is profiled and analysed by using Intel VTune Amplifier. The computational heavy image processing operation is then offloaded from CPU host to GPU device in attempting to accelerate the CSR-DCF tracking performance in OpenCV using OpenCL framework. Although some of the image processing operation such as colour conversion from RGB color space to HSV color space is accelerated by a significant amount from 10.467ms to 3.03ms, the benefit of offloading cannot be enjoyed due to the data transfer overhead between the CPU host and GPU device. Thus, to accelerate the CSR-DCF tracker, OpenVX framework provided by Intel OpenVINO toolkit is used. OpenVX acceleration has shown significant speed up of 27.14% for image processing operation such as image resize which is used in the first part of the CSR-DCF tracker.

ABSTRAK

Penglihatan komputer telah membawa banyak manfaat dan prestasi dalam pelbagai aplikasi terima kasih kepada kemajuan teknologi terkini. Kaedah pengesanan objek visual yang berasaskan Penapis Corak Diskriminasi telah menunjukkan prestasi penjejakan dan prestasi yang terkini. Pengesan objek visual berasaskan DCF menggunakan ciri convolutional untuk perwakilan model memerlukan sumber pengkomputeran yang besar, telah menyebabkan prestasi masa nyata jatuh dengan ketara. Oleh sebab itu, aplikasi masa nyata seperti pengesanan objek visual dron berdasarkan DCF tidak dapat direalisasikan. Selepas pelaksanaan tracker berdasarkan DCF (Channel and Spatial Reliability DCF, CSR-DCF) menggunakan OpenCV dalam sistem tertanam, Intel VTune Amplifier telah digunakan untuk membuat analisis. Operasi pemprosesan imej yang berat kemudian dilepaskan dari hos CPU ke peranti GPU dalam usaha untuk mempercepat kinerja penjejakan CSR-DCF dalam OpenCV menggunakan kerangka OpenCL. Walaupun beberapa operasi pemprosesan imej seperti penukaran warna dari ruang warna RGB ke ruang warna HSV dipercepat oleh jumlah yang signifikan dari 10.467ms hingga 3.03ms, faedah offloading tidak dapat dinikmati kerana overhead pemindahan data antara hos CPU dan peranti GPU. Oleh itu, untuk mempercepat pelacak CSR-DCF, rangka kerja OpenVX yang disediakan oleh toolkit Intel OpenVINO digunakan. Percepatan OpenVX telah memperlihatkan kelajuan yang signifikan sebanyak 27.14% untuk operasi pemprosesan imej seperti mengubah saiz imej yang digunakan di bahagian pertama pelacak CSR-DCF.

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DCF	:	Discriminative Correlation Filter
CSR-DCF	:	Channel and Spatial Reliability Discriminative Correlation Filter

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The field of artificial intelligence (AI) has been booming thanks to the technology advancement in recent years. Applications of AI in the field of medicine, education, data analysis, engineering and more has enhanced the quality of living and enables people to be more productive. For example, machine learning is used in image recognition, speech recognition and various applications. In this project, we will focus on applying artificial intelligence technology to assist security guard in their duty.

Visual object tracking is used for user object verification and recording purpose in real-time with camera on drone will act as a security guard patrol assistant in strengthening the security in Universiti Teknikal Malaysia Melaka (UTeM). Every day from 7am – 9pm, public can make use of road within the compound of UTeM to save

their traveling time. This is because UTeM has a path that act as a shortcut that allows public to travel from Ayer Keroh to Jasin and east coast highway as shown in the map in Figure 1.1.

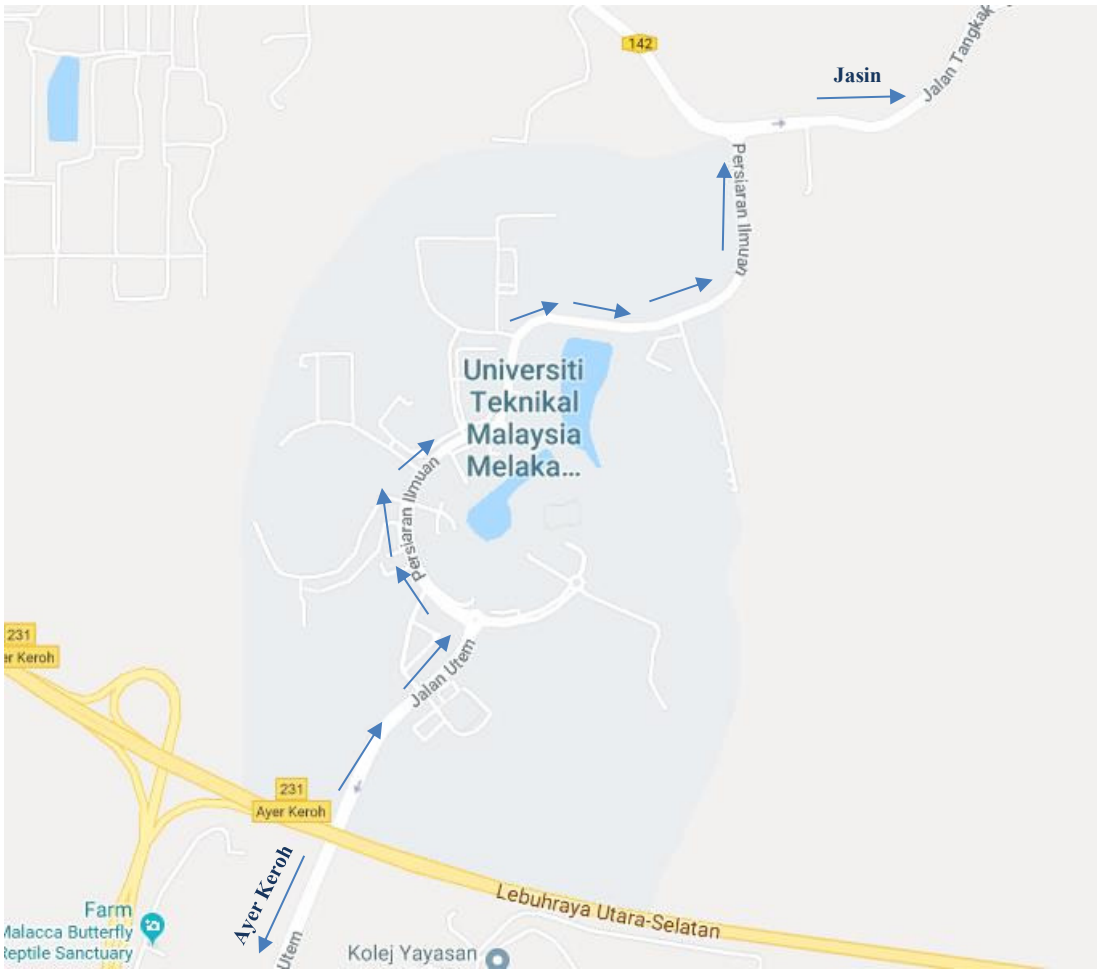

Figure 1.1: Map of route from Ayer Keroh to Jasin and east coast highway pass through UTeM

Instead of solely relying on security guards to guide and monitor both the UTeM students/staffs and publics/visitors, the drone will track and lead the publics/visitor according to their planned routes. If the visitor is suspicious, the security guard will deploy the drone to select and track the target vehicle and make sure the target does not deviate from the route and immediately alert the security control center if deviation is detected.

Figure 1.2: A drone tracking a vehicle

Figure 1.3: A drone tracking a cyclist

In this project, Intel GPU accelerated Discriminative Correlation Filter (DCF) based state-of-the-art visual tracking method, running right in the Intel embedded board of drone controller, will be used to track the target.

Besides, short-term visual object tracking method is used. Short-term visual object tracking is the problem of continuously localizing a target in a video-sequence given a single example of its appearance. There are many challenges or short-term tracking. Factors such as illumination change, occlusion, fast object or camera motion will make object tracking with drone very challenging. In recent short-term tracking evaluations, it has consistently confirmed the advantages of semi-supervised discriminative tracking approaches. Among all the methods, Discriminative Correlation Filter (DCF) have shown state-of-the-art tracking accuracy and robustness in all the standard benchmarks.

Discriminative Correlation Filter (DCF) utilizes multi-dimensional features that produced by convoluting the input image frame with the learned kernels to formulate a set of filters to represent the target object. Thus, it will require huge computational resources to accelerate the DCF operations. Discriminative Correlation Filter with Channel and Spatial Reliability (CSR-DCF) [1] tracking method is chosen to implement in this project.

With this, the safety of the people and property are protected from day-to-day operations. The drone will follow its target and make sure people or vehicle is going with the planned path.

Since drone and object tracker is used, the cost of man power can be reduced drastically in the open campus. Besides that, the safety of the compound can be ensured by preventing people wandering around the compound freely.

1.2 Problem Statement

Visual tracking is evolving very fast which has increasingly attracting the attention of the vision community. Due to this, many new tracking algorithms has appeared presented in journals and conferences.

Recent tracking method such as Discriminative Correlation Filter (DCF) based tracker [1], [2], [3], [4] and [5] requires huge computational resources and hence the real-time frame per second (FPS) performance has dropped significantly despite of high accuracy and robustness.

Therefore, server grade graphics processing unit (GPU) is used to perform the complex calculation but it consumes a lot of power. Because of this problem, many battery-powered applications that requires huge computational resources cannot be done. Thus, low powered embedded system GPU is more suitable to be run on battery-powered applications such as object tracking using drone. Besides that, there are no report on the performance study of implementing and optimization of DCF tracker running on embedded system GPU.

1.3 Research Objectives

This section presents the objectives for this project. The research objectives are as follows:

- To implement Discriminative Correlation Filter (DCF) based visual tracker in embedded board.

- To accelerate and analyze Discriminative Correlation Filter (DCF) based visual tracker with embedded GPU.
- To optimize the performance of the DCF object tracker with the insight provided by Intel VTune Amplifier.

1.4 Scope of Work

The scope of work of this project is divided into two parts.

Firstly, the tracking method. The tracking method used in this project is short-term tracking method. Short-term tracking means redetection of the target object will not be reinitialized after the tracking target is lost. In contrast, long-term object tracking means there will be a redetection of the target object where the object tracker will be reinitialized to continue the tracking process.

Next, discriminative Correlation Filter (DCF) based tracker is used. Discriminative Correlation Filter (DCF) is one of the state-of-the-art object tracking methods which gives robust performance and high accuracy.

Tools and software used in this project are list in Table 1.1 which is the summary for the scope of work for this project.

Table 1.1: Summary for scope of work

Subject	Content
Tracking method	• Short-term • Discriminative Correlation Filter (DCF)

Tools / Software	• GNU Compiler Collection 5.2 • CMake 3.11 • Intel OpenCL SDK • OpenCV • Intel VTune Amplifier • Linux Ubuntu 16.04 and Centos 7.4 • UP Squared board • Intel Aero RTF drone

1.5 Chapter Summary

Chapter 1 describes the general overview of this project. The background of this project, problem statement, objectives and scope of work will be discussed in the beginning of the chapter. Chapter 2 discusses the previous work of established visual object trackers and the video dataset challenge used to benchmark the performance of the tracker. The method of discriminative correlation filter visual object tracking, computing hardware, parallel computing, OpenCL framework and OpenVX are also discussed in this chapter.

Chapter 3 discusses about the implementation of discriminative correlation filter based visual object tracker (CSR-DCF) in Intel Aero RTF drone embedded board, the hardware performance of CSR-DCF tracker running only in CPU. Besides, the hardware performance of CSR-DCF tracker with some image processing tasks offload from CPU host to GPU device is also presented. The possibility of using OpenVX to accelerate the CSR-DCF tracker is discussed in the last part of Chapter 3.

Chapter 4 presents the performance result of speed, hardware performance of CSR-DCF tracker running only in CPU and hardware performance of CSR-DCF tracker