DESIGN AND IMPLEMENTATION OF DEEP LEARNING ENABLED MOBILE ROAD SAFETY INSPECTION SYSTEM

CHONG WENG KONG

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DEDICATION

This study is wholeheartedly dedicated to my beloved parents, who have been my source of inspiration and continually providing their moral, spiritual, emotional and financial support.

ABSTRACT

An AI-enabled mobile road safety inspection system based on Deep Neural Network (DNN) is proposed in this work. A complete mobile road safety inspection system takes into account of many aspects such as road condition, traffic volume, road curvature for road safety inspection and this study focuses solely on the speed of vehicles surrounding the road safety survey vehicle travelling along the road. The developed system consists of Intel OpenVINO Inference Engine for deep neural network vehicle detection, Deep SORT tracker for vehicle tracking, and planar homography based vehicle distance and speed estimation. The vehicle speed detection system is then evaluated using three different cameras in order to determine best optimized field of view and speed measurement accuracy. Results of evaluation show that automatic speed estimation with DNN achieve accuracy with $-2.08 \pm 5.24 km/h$ to $15.55 \pm 19.24 km/h$ error on normal wide angle camera. Speed error analysis were carried out on center image part of lens distorted camera (PICAM 360) and corrected image of panoramic 360° camera (Vuze+) where single pixel error in DNN auto vehicle detection could introduce speed estimation error up to 0.18km/h.

ABSTRAK

Dalam kajian ini, sebuah sistem pengukuran kelajuan kenderaan berasaskan Rangkaian Neural Dalam (DNN) telah dibangunkan sebagai sebahagian daripada sistem pemeriksaan keselamatan jalan raya yang lengkap. Tiga kaedah utama telah digunakan sepanjang kajian ini, iaitu penggunaan Enjin Inferensi OpenVINO Intel untuk mengesan kenderaan, penggunaan Penjejak SORT Mendalam untuk menjejak kenderaan dan pengukuran jarak serta kelajuaan kenderaan berdasarkan matriks homografi. Penilaian kemudian telah dijalankan ke atas sistem pengukuran kelajuaan kenderaan tersebut dengan menggunakan tiga kamera yang berbeza untuk menentukan medan penglihatan yang terbaik dan ketepatan sistem tersebut. Keputusan eksperimen menggunakan sistem pengukuran kelajuan bersama DNN menunjukkan bahawa sistem tersebut mencapai ketepatan dengan ralat dari -2.08±5.2358km/j hingga 15.55±19.24km/j semasa menggunakan kamera biasa. Analisis kesilapan sistem pengukuran kelajuan yang dijalankan pada bahagian tengah imej PICAM 360 dan imej panorama berdarjah 360° yang telah dibetulkan menunjukkan bahawa kesilapan setiap piksel dalam pengesanan kenderaan melalui DNN akan memperkenalkan ralat sebanyak 0.18km/j.

ACKNOWLEDGEMENTS

Firstly, I would like to thank my supervisor, Assoc. Prof. Dr. Lim Kim Chuan for his guidance and support throughout this project. I also express my gratitude to my family who instills positive thoughts and gives me moral support. Last but not least, I would like to shout out to all my friends who have gone through hardships with me and gave me valuable suggestions.

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LIST OF SYMBOLS AND ABBREVIATIONS

DNN	:	Deep Neural Network
FOV	:	Field of vision
CNN	:	Convolutional Neural Network
EuroRAP	:	European Road Assessment Programme
mAP	:	Mean Average Precision
IoU	:	Intersection and area of union
SORT	:	Simple Online and Realtime Tracking
MOT	:	Multiple Object Tracking
VSM	:	Vector Object tracking
ICTA	:	Image Centroid Tracking Algorithm
DLT	:	Direct Linear Transformation
SVD	:	Singular Value Decomposition
OBD	:	On-board Diagnostic

CHAPTER 1:

INTRODUCTION

1.1 Project Background

1.3 million are killed in road crashes each year worldwide. Reliable detection of speed of moving vehicles is considered key to traffic law enforcement in most countries and is seen by many as an important tool to reduce the number of traffic accidents and fatalities [1]. In order to achieve this, international road assessment programmes have been developed to monitor the safety quality of the road network and to draw attention of the authority to the need for physical road improvements. The predictive safety rating protocols proposed by the road safety programme evaluates the safeness of a road and how well a road protects road-users if a crash occurs.

Road safety inspections are undertaken in 2 stages:

i. A specially equipped survey vehicle records images of the road as it travels along it,

ii. Road features are recorded from image data by coders, according to protocol [2].

Parameters which are considered during the rating of a road safety are the type of road divider the road has, traffic volume of the road, etc. This study explicitly concentrates on the speed of vehicles, which is one of the important parameters to make roads safe. Automated speed estimation system can be developed with the use of deep neural network (DNN) for accurate object detection and planar homography to express the projection of object on road surface plane to camera image plane. Target vehicle will be detected automatically in the first image and tracked through the subsequent recorded camera image sequences. The speed of the target vehicle will then be determined by firstly resolve the position of the vehicle on the road surface plane in each image with planar homography and the changes of position with respect to timestamp of the image sequences.

A 360° image provides the surrounding view of which the camera image is taken. Compared to normal camera image view, a 360° image enabling full field of view or field of vision (FOV). A 360° image or video is usually taken by using multiple cameras or by using a dedicated imaging device which contains multiple camera modules and lenses embedded into a device. The videos or images are taken in different angles and perspectives in such a way that their FOVs overlap each other. The separate footages are then merged into a single spherical image or video through a process called video stitching. Equirectangular and cubic map are the 2 main spherical formats for 360° image, in which equirectangular image consists of a single image with an aspect ratio of 2:1 (the width is twice the height) while cubic map consists of 6 cube faces to fill the sphere surrounding the point in which the image is taken. Examples of equirectangular image and cube map are as shown in Figure 1.1 and Figure 1.2.

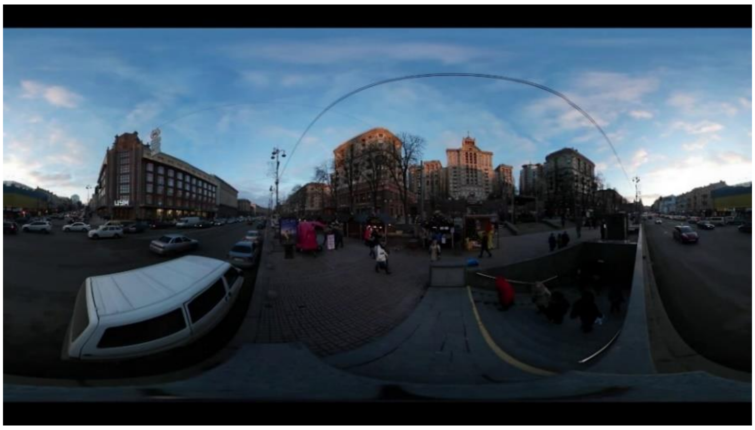

Image downloaded from: https://www.videoblocks.com/video/

Figure 1.1: 360° traffic image in equirectangular projection

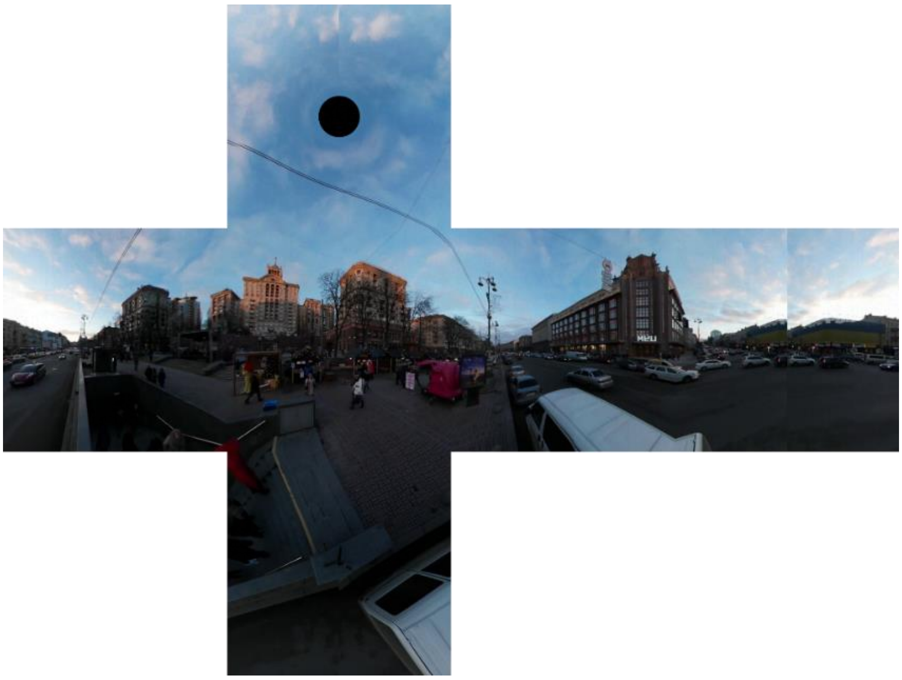

Figure 1.2: 360° traffic image in cubemap

The existing state-of-art convolutional neural network (CNN) detector provides only 2 types of implementation method for 360° image:

i. implements the conventional CNN to the 360° equirectangular inputs directly,
ii. obtains multiple perspective views from a single 360° image through multiple tangent planar projections as shown in Figure 1.2, where the 360° image is viewed as rectilinear from multiple perspective.

In this research, automated vehicle speed estimation will be carried out on 360° equirectangular projection which will be corrected into rectilinear or perspective view to get rid of geometric distortion. The result of the implementation will be analyzed.

1.2 Problem Statement

Speed of vehicle travelling on a road plays a major role in the safeness of the road. An increase in average speed of 1km/h will typically result in a 3% higher risk of a crash involving injuries, with a 4% to 5% increase for crashes that result in fatalities [3]. A car travelling at 50km/h will typically need 13 meters in which to stop, while a car travelling at 40km/h will stop in less than 8.5 meters [4]. Even when travelling in what considered low speed a car still need quite a distance to stop completely. Pedestrians are shown to have 90% chance of survival when struck by a car travelling at 30km/h or below, less than 50% chance surviving at 45 km/h and almost no chance of surviving an impact of 80 km/h [5].

360° imagery is used to optimize the angle of survey vehicle recording for subsequent detection. However, conventional convolutional neural network (CNN) system is designed to deal with image with regular planar structure. In contrary, vehicle appears distorted in spherical image and causes existing CNN architecture to have very poor detection accuracy as the CNN is trained on regular planar image. The conversion of spherical image to the most commonly used equirectangular projection will result in severe geometric distortion especially near the projection poles, influencing the performance of feature extractor of CNN.

1.3 Objective

i. To develop a real-time Deep Neural Network based vehicle speed measurement system.

ii. To evaluate and analyze the implemented surrounding vehicle speed measurement system for 360° surveillance camera.

1.4 Scope of Project

This project involves only speed detection on the road and does not cover other type of vehicle. Vehicle tracking is limited to those appearing within the field of view of the camera.

CHAPTER 2:

BACKGROUND STUDY

The overview of a mobile road safety inspection system will be firstly discussed in Chapter 2.1. Panoramic equirectangular image and the challenges it poses in this study will be discussed in Chapter 2.2. Next, Chapter 2.3 will present the cubemap representation of a 360° panoramic image. How mAP (mean average precision) which is a popular metric in measuring the accuracy for object detectors will be discussed in Chapter 2.4. Lastly, Chapter 2.5 will list and elaborate on previous works related to this study.

2.1 Mobile Road Safety Inspection System

Road safety inspection system is the evaluation of the safeness of the road for drivers, cyclist, pedestrian, etc. based on the conditions of the road. This system is