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Master Thesis

影像式偵測器於路口交通參數之擷取研究

A Study on Traffic Parameter Extraction from Image Detector at Intersection

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誌謝

又到了畢業的季節，時間過的真的很快，彷彿才剛進入交通組沒多久時光，一眨眼又要離開交通組這個大家庭。從論文定稿後遲遲不肯寫誌謝，因為帶有一點離別的悲傷，觸發了許多回憶。回首研究所這兩年的時光，有歡笑有苦痛，一路走來遇到了很多貴人，雖不非常平順，卻也沒有很大的波折。研究所這兩年真的是影響我一生很大，如同曹壽民老師所說的，進來後有沒有學到東西，兩年後就會很明顯的感受得出。這兩年承蒙交通組老師跟學長的提攜，學到了不少的東西。除了專業上的東西，也有關於一些人生的體認。而我能順利的畢業，首先得先感謝我的母親，我能無憂無慮的唸書，得靠母親背後辛苦的支持。也感謝我的女友婷鳳，感謝他陪我熬過研究所兩年，也感謝他包容有時壓力大會耍一下脾氣的我，由於他的照顧，我的壓力減輕不少。感謝張堂賢老師，讓我進入 ITS 實驗室，學到了很多有關於實務的東西，不再是紙上談兵，其勇於創新的精神也著實令我深感佩服。感謝其政、阿樂、宏仁等學長們帶我入門影像處理的領域，特別感謝阿樂學長讓我學到非常多的影像處理相關技術,使我從完全不會到上手寫出影像處理偵測器，還記得我第一次寫出影像處理程式時，興奮的想大叫，心中想真的是我能寫出的嗎?也特別感謝宏仁學長，他讓我精益求精，使我不斷的自我突破，常常提供一些很實用的意見，是激發我靈感的來源。感謝上民學長，教了我很多東西，除了提供我意見之餘，也教了我一些簡報的技巧，讓我受用無窮。而且對不斷問問題的我也不會覺得厭煩，相當的有耐心的解說，套一句話，真是佛心來也。感謝礫凱學長，常常請教他一些 java 的問題，有 java 的問題問他就對了。感謝交通組最 man 的阿宏，跟他同組做報告，也學到了不少的東西。感謝 ITS 實驗室的成員們，元瑞、駿哥、阿維、鳥兒、洪城、阿芳、阿寧，有你們的陪伴帶給我不少的歡樂，一起歡樂，一起吐槽，一起出遊。留了好多好多美好的回憶。337 的成員們，你們是最棒的，阿芳是個巧思的人，元端則是當苦力的人，哈哈，常常負責執行阿芳的靈感，而我則是最閒的人，在 337 的日子真的很快樂，

常常會有些有趣的事發生，阿芳看電視笑到快抽搐，真擔心他喘不過氣。他也是個盡責的導遊，澎湖真的很好玩，有機會一定還要在去的啦。最後要用特別的篇幅來感謝我的好朋友張元瑞同學。記得第一次見到他是坐高鐵的時候，那時看起來老實憨厚的他，認識久了，其實卻不是那麼一回事，說話時常需要打折扣。不過他卻是非常熱心助人，當初做計劃案，鼎力相助，不但設計腳架還隨我大熱天四處奔波，實在是令我感動。常常有事要麻煩他，他也二話不說的答應，實在是非常難得的朋友。最後感謝交通組的各位，懷念大家一起歡樂的日子。

陳彥政

2008 夏于志鴻館 337 室

摘要

路口監控和資料蒐集在交通上是非常重要的課題。以往我們必須靠人工調查方式取得交通參數，在近年來，愈來愈多人研究如何發展影像偵測系統用來蒐集交通參數，如車流量、速度等。蒐集這些交通參數可以讓交通專業人員了解路況並進一步的進行交通控制。影像偵測器在快速道路的應用已經相當的成熟，用在擷取交通參數上有非常高的準確率。但是在路口上的研究則非常的少。因為路口的交通環境比快速道路還要複雜，車輛很難被良好的追蹤，但是路口的交通參數往往是很重要的，發展一套系統能適用於路口是必須的。

在台灣，機車佔有車輛非常大的比例。由於機車具有高機動性，動線複雜，使它非常難在路口中被偵測到。它成了影像偵測器擁有高信賴、高準確率的一個挑戰。

本研究中發展出一個擁有強健的演算且具有高準確率的影像式偵測器系統，經過不同情況下的測試，可達到八成以上。

關鍵詞：車輛擷取、動態門檻值、陰影移除、遮蔽處理、車輛追蹤。

Abstract

Intersection Monitoring and data collection are very important issue to traffic. In recent year, more and more people research how to develop an image detector system to collect traffic parameters such as traffic flow, speed etc. To obtain these traffic parameters can improve urban traffic by optimizing signal at intersection. The research of image detector on highway had been developed maturely that can extract traffic parameter with high accurate rate. However, the researches about data collection at intersection are few. Because intersection is more complex than highway, vehicle is difficult to be tracked well at intersection. A system that can be applied at intersection has to be developed.

In Taiwan, motorcycle occupies numerous percentages of vehicles. Because of some characteristics of it, motorcycles are difficult to detect at intersection. It becomes a challenge for image detector system to have reliable ability of vehicle detection.

In this thesis, a system which has reliable detection ability and robust algorithm on real time for data collection is necessary. After testing this system, average accurate rate of it can reach more than 80%.

Keywords: vehicle extraction, dynamic threshold, shadow removal, occlusion resolution, vehicle tracking.

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Chapter 1

Introduction

1.1 Motivation

Intersection monitoring and data collection are very important issue in traffic. The situation at intersection could be realized by these traffic data we collected, and we can use these data to improve urban traffic. On the side, the increase of private vehicle cause traffic in urban became bad and bad. Volume of vehicles is full of the roadway that cause traffic jam occurs frequently. Because of limited land, it is uneconomical to build more roadways and it is impossible to satisfy with the traffic requirement. In order to resolve this hard problem, ITS (Intelligent Transportation System) which use advanced communications technologies to improve transportation safety and mobility was developed. In recent twenty years, more and more people make efforts in ITS issue. One of important issue in ITS is how to collect data for the use in traffic. Traditionally, we use loop detector and manpower to collect traffic data. Both of them have drawbacks in date collection. At intersection, we often improve traffic efficiency and safety by collecting traffic parameters such as turn ratio, traffic flow, and time delay to optimize signal. Loop detector just can obtain traffic flow and it is difficult to maintain. In the past, we usually collected data at intersection by manpower that needs very many people to investigate, but the effect was low.

In recent year, the technique of detector had large advancement, and non-invasion detector such as micro wave based and Image based had become trend for extracting traffic parameters. Especially, Image detector was researched by more and more people because of the advancement of computer and image processing. It had been developed for long time and there are several products to present, Autoscope is one of the famous business software. Image detector has a lot of advantage, so many traffic parameters such as traffic flow, turn ratio, time delay, headway and occupancy can be extracted by it that is more than other types of detector. It is different to loop detector which needs to be set up by destroying pavement, so we could establish and maintain it easily. It also provides a vision-based system that can assist with user to realize the situation at intersection quickly and let traffic management become easier.

Traffic environment in Taiwan is very special and complex, motorcycle has a lot of percentages in all kinds of vehicle. There are more than thirteen million motorcycles on the roadway. Every two people have ones. This phenomenon causes that data collection become very difficult by using image detector. We have to care this problem, the motorcycle makes the traffic environment become more complex and more danger, however there is too less research to discuss it. That is why this important issue is necessary to be resolved and we want to develop a system that can detect different types of vehicle at intersection.

1.2 Objective

Image detector can supply rich information on roadway. It not only can collect traffic parameter but also detect incident. On the side, image detector had already possessed capability to work on real-time because of the advancement of computer hardware. Therefore, the objective of this thesis is to develop a system that deal with image sequence which is supplied from CCTV or shot by manpower at intersection to extract traffic parameters in real-time. Vehicle type is also important traffic data, so the system in this study had to recognize different vehicle type. We just classify three categories of vehicle which are motorcycle, small vehicle and large vehicle.

In this thesis, the system is programmed by java language for cross-platform. Because java is high-level language, its efficiency is slow than other low-level language. This problem we need to resolve. The accurate rate and efficiency of Image detector have the relation of trade-off. We hope this system can reach high accurate rate which is more than 80% and at the same time, it also can be implemented in real-time.

The flowchart of study procedures in this thesis in illustrated in Figure 1.1. This thesis consists of five chapters. Chapter 1 is to introduce the background of image detector. Chapter 2 represents the fundamental image processing method used in this thesis. Chapter 3 is about the development of system. Chapter 4 illustrates how to extract traffic parameters and shows the result of detection. Chapter 5 is conclusion and future work.

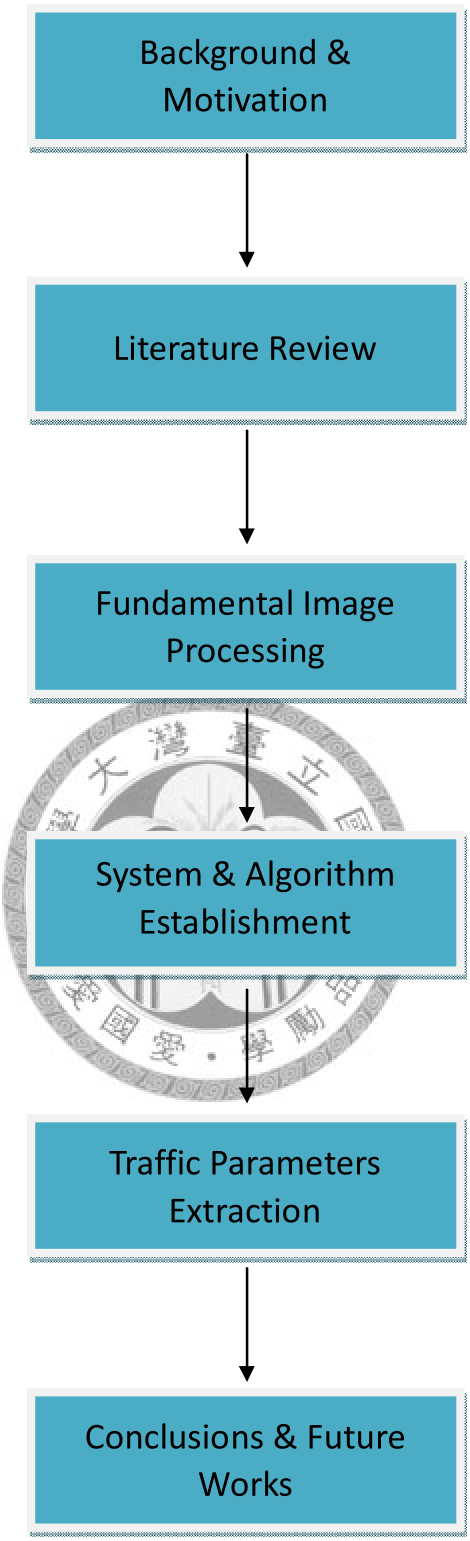


Figure 1.1 Flow chart of research procedures in this study.

1.3 Literature Review

In traditionally, we usually use inductive loop detector to collect traffic data because of its cheapness and stability. Although it is widely used in the world, it also has serial drawback. It is an invasion detector which had to destroy pavement to set it under roadway. While we destroy the pavement, the traffic is interrupted. If there are so many loop detectors have to be set, it will influence traffic flow very much. Because of this drawback, in the recent year, non-invasion detectors such as micro-wave and image detector had been researched actively to resolve this problem. Now they have pretty good results of data collection. The comparison of detectors is shown in table 1 and table 2.

Table 1.1 Functions of different vehicle detector.

Type / Parameter	Loop detector	Micro wave	RFID	Image detector	Image in bad weather
Volume	◎	◎	◎	◎	○
Speed	◎	◎	◎	◎	○
Occupancy	○	◎	◎	◎	○
Headway	○	◎	○	○	○
Queue length	X	X	X	◎	○
Turn ratio	X	X	◎	◎	○
Category	○	◎	◎	◎	○
Incident detection	○	○	○	◎	○
Reliability	high	medium	medium	medium	low
Accuracy	high	medium	high	high	low

◎ Good

○ Median

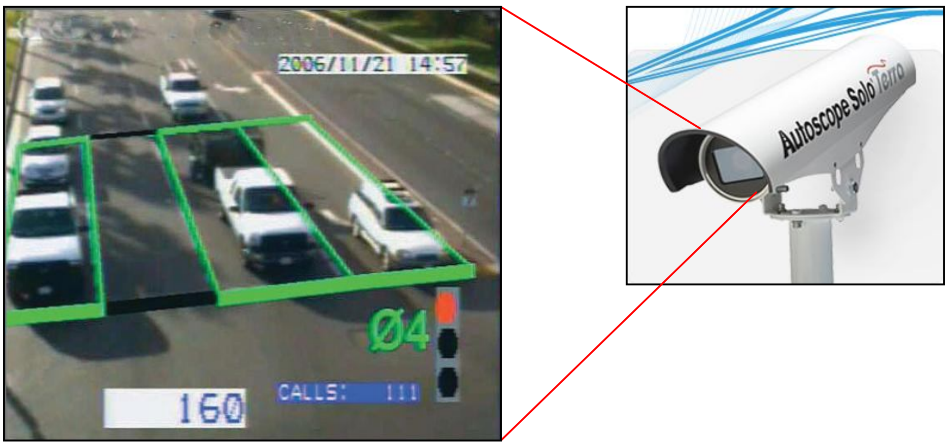
X Cannot

Table 1.2 The advantage and drawback of different vehicle detector.

	Advantage	Drawback
Loop detector	Cheapness. High accurate rate. It is not easy to be destroyed by people. It is suitable to most sites.	It is necessary to elect site carefully. It will influence traffic flow when we install. It is easy to be destroyed by heavy vehicles. It cannot to obtain turn ratio. It cannot detect vehicle which change lane.
Image detector	It can obtain numerous parameters such as turn ratio and incident detection. It can detect in multi-lane It supplies a visible interface to user.	It is easy to be influence by climate. It has to use different algorithm at day and night.
Micro wave	It did not to be influence by climate & weather. Its life cycle is long and almost did not need to be maintained. It can detect in multi-lands. Its volume is small. High accurate rate It can detect numerous parameters	Expensiveness. It will obtain error data when speed of vehicle is too slow. It cannot obtain turn ratio. Some vehicles will have false detection by its multi-path reflection.
RFID (semi-active)	Its life cycle is long. It did not to be influence by climate and weather. It can obtain turn ratio. The distance of communicat-ion is moderate.	Tag need to be glued to vehicle at specific angle. It needs to be legislated by government. Its battery have to be changed regularly

The development of image detector had a long time. In early period, there are so many researches such as America WADS (Wide Area Detection System), British UMIST, Australian VDD, French Titan, Swedish SRIT to develop image sensor system. So many advance countries focus on this issue. Due to the advance of computer hardware, the technologies of image detector have a lot of improvement. The methods which apply to image detector system are many, but each of them has the same target which is to make the accurate rate higher or increase the efficiency of system. Both of accurate rate and efficiency is trade-off. To balance them is important.

Autoscope developed by Minnesota University is one of the famous commercial system applied to extract traffic parameters. This system was developed by the result of researches which was accumulated step by step. The operation of Autoscope is shown in Figure 1.2.



Resource: http://autoscope.com/

Figure 1.2　Interface of Autoscope.

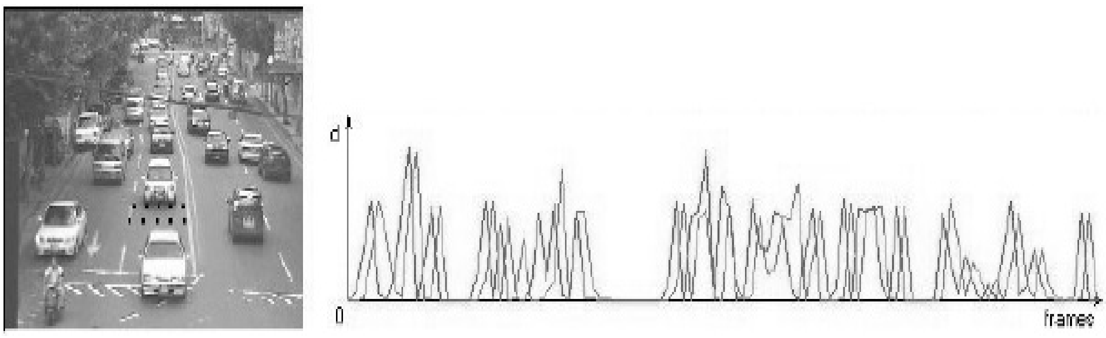
It havd to be set the detection zone on screen by staff. When the vehicles pass over the zone, the system will count traffic flows. This system used widely in the world have powerful functions to process in a lot of traffic environments such as highway, tunnel, intersection and not only can extract traffic data but also can detect incidents. However, it also have drawback which is too expensive, and can't obtain the turn ratio because of limited detection zone.

In Taiwan, the researches about image detector started later, but in recent year, more and more paper were related this topic. The drawbacks of image detector and characteristic of detection had been discussed widely. Chiao-Tung University had cooperated with IOT (institute of transportation) to develop a system that can suit traffic environment in Taiwan and resolve the congestion and climatic problems. It will have the product soon, after the transference of technique.

The processes of Image detector have two important stage, vehicle detection and vehicle tracking. Each of them has numerous methods to reach the same result. These two stage is introduced as following.

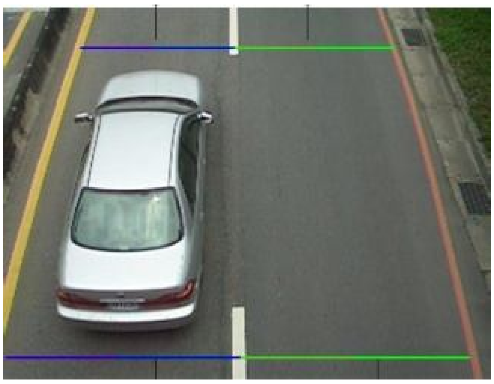
Vehicle detection

This stage is to detect vehicle which appear or not. Traditionally, it has three main types to segment vehicle from the image sequence. First method is to set some detection points on image sequence. [Park et al. 1998] set ten detection points on the image sequence. When vehicles pass through these points, pixel value of them will be changed. In the early time, due to speed of processing, the method was often used on real-time. However this method is influenced by noise easily because it just deals with few points, another method to improve it is set detection line to replace these points. [Gau 2005] draws detection lines on image sequence to obtain speed and traffic volume, each lane have two lines.



[Park et al. 1998]

Figure 1.3 Detecting vehicles by virtual detection points.



[Gau 2005]

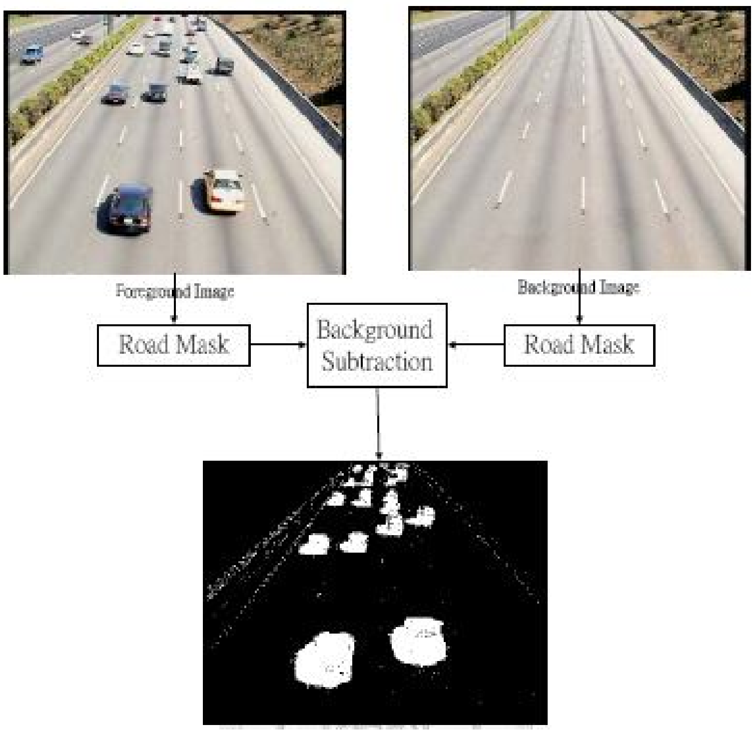
Figure 1.4 Detecting vehicles by virtual detection lines.

Second method is to arrange virtual detection zone on image sequence. Autoscope is to use this method. [Shiu 2004] arranges virtual detection zone and uses the concept of entropy. When vehicle pass over it, the parameters, traffic flows, speed, occupancy can be extracted. This is an efficient method, but like the first method, it just had ability to deal with specific area on image sequence and can't track vehicle.

[Shiu 2004]

Figure 1.5 Detecting vehicles by virtual detection zone.

In order to obtain more information, the third method, full window method was developed. Recently, more and more people use this method to extract more traffic parameters. Full window method is complex and used different technique to process image sequence. [Wu 2004] used background subtraction method which is widely used by many research because of its fast work. Before using this method, we have to generate a static background image from image sequence. However the method is easily influenced by light change in the environment. The way to avoid this problem is to update background image.

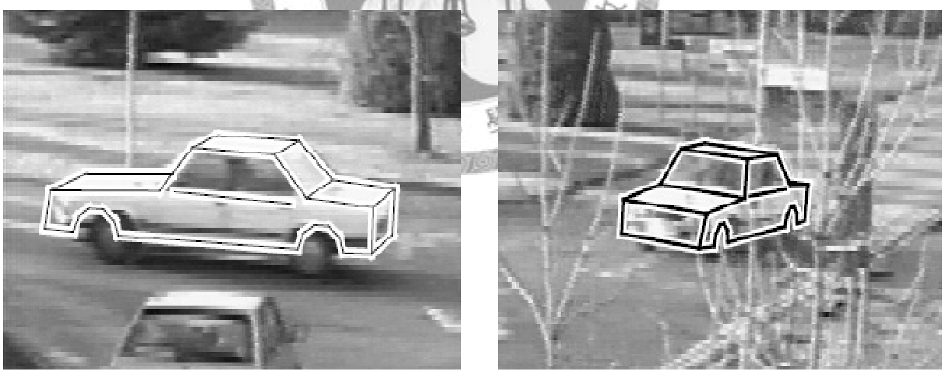


[Wu 2004]

Figure 1.6 Background subtraction method.

[Wu et al. 2007] used temporal different method to extract vehicle in traffic jam conditions. This method which uses the difference of two or three current image to segment vehicle from image sequence could resolve the problem of light change and didn't need to generate background image, but it is easy to obtain fractional objects on image.

[Ferryman et al. 1995] use beforehand 3D model to match the contour of vehicle, this method can resolve vehicle occlusion on image, and track vehicle at the same time. However, we have to build numerous categories and many different angles of models that are difficult to implement it.

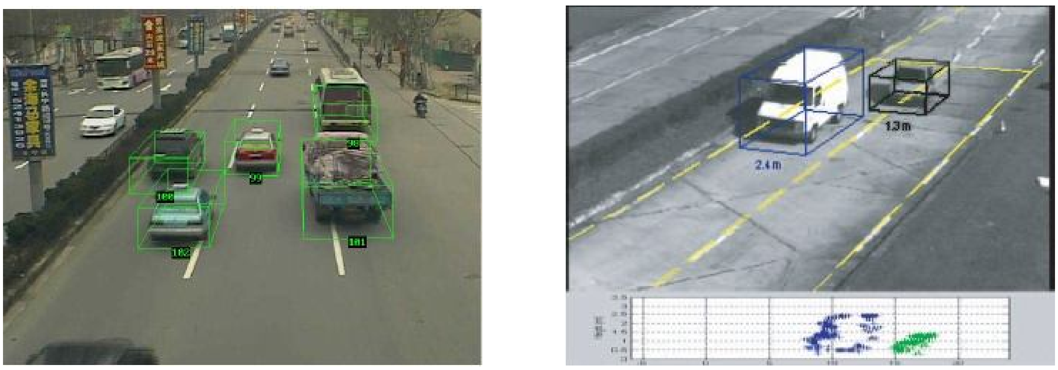


[Ferryman et al. 1995]

Figure 1.7 3D model based method.

Optical flow method used by is also a technique to segment vehicle from image. Because vehicle is rigid object, the same vehicle in successive frame had the same optical flow. [Yan 2004] used the coarse-to-fine structure to calculate optical flow that can reduce the calculation and selected feature points to obtain more reliable result for calculating 3D velocity correctly. This method also can resolve vehicle occlusion but it is difficult to be implemented on real time due to the heavy computation.

In traditionally, we often use single camera to get 2D image. In recent year, there are several researches which use multiple cameras to acquire 3D image for further processing. Using 3D image can obtain more accurate information about vehicle, and also could resolve vehicle occlusion easily. [Hu et al. 2007] and [Douret et al. 2004] obtain good effect form processing 3D image to extract vehicle. It supplies another way applied to image detector.



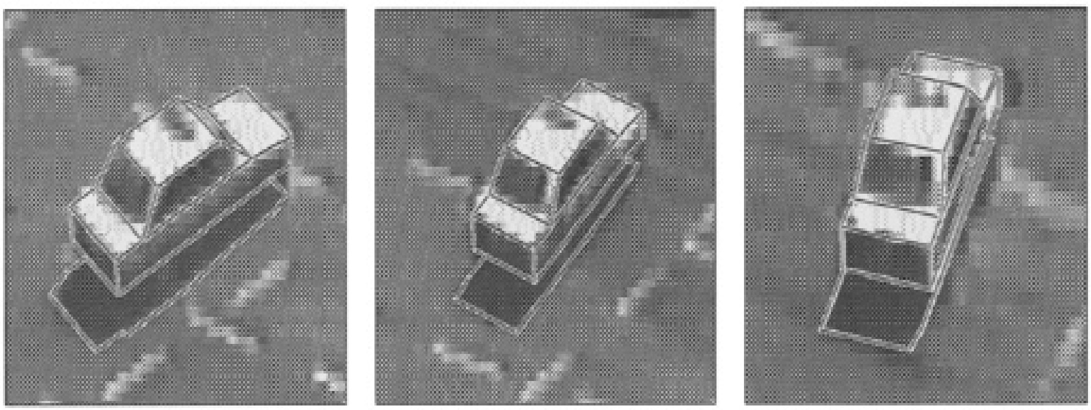
[Hu et al. 2007] [Douret, J et al. 2004]

Figure 1.8 multi-cameras 3D volumetric method.

Vehicle tracking

Vehicle tracking is an important process after segmenting vehicle from image. Through this step, we can extract traffic parameters. From the literatures, the different approaches for vehicle tracking could be classified as four categories which are model based tracking, region based tracking, active contour based tracking and feature based tracking.

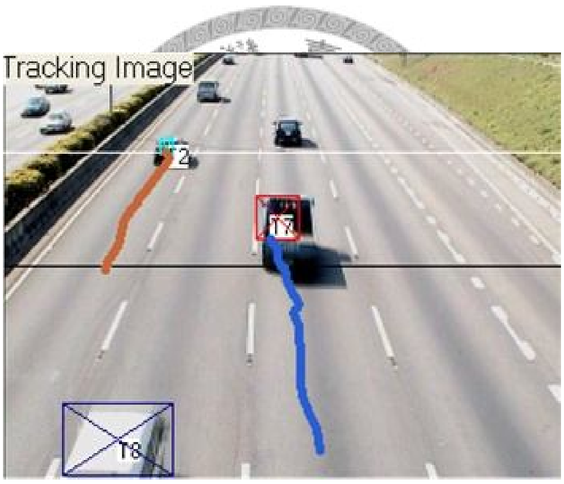
[Koller et al.] use 3D models to match vehicles and check vehicle on next frame. If vehicle on next frame is matched, the association of the same vehicle in successive frame could be found then vehicle can be tracked. However, it is unrealistic to expect to be able to have all detailed models of vehicle that could be found on the roadway.



[Koller et al. 1993]

Figure 1.9　3D model based tracking.

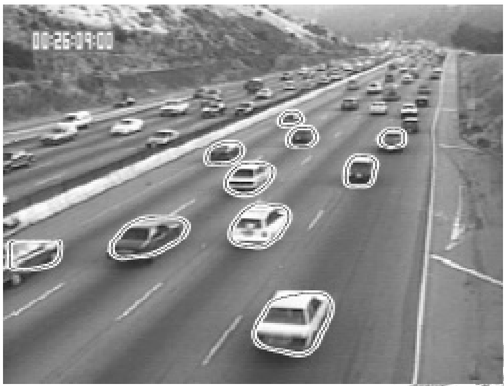
Region based tracking algorithm which is a common approach to be used tracks vehicles according to variations of the image regions corresponding to the vehicle object. [Jorge et al. 1998] use Kalman filter to predict the next time position of vehicle that can track vehicle accurately. [Wu et al. 2006] uses the centroid of vehicle which have the minimum distance between different frame and some region object information such as angle to track vehicle. Nevertheless, both of them can’t track vehicle when vehicles are occlusive.



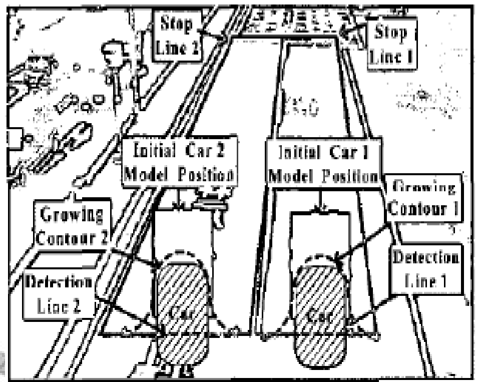
[Wu 2004]

Figure 1.10 Region based tracking.

Active contour based tracking algorithm tracks vehicles by representing their contours and updating them dynamically in successive frames. Using contour to track vehicles is very fast because of its less computation. [Li et al. 2003] presented a study on a stand-alone image tracking system for automatic traffic monitoring by active contour technique. The drawback of this approach is when the initialization of contour is failure, the tracking will make error. Initialization is the difficult part of this approach.



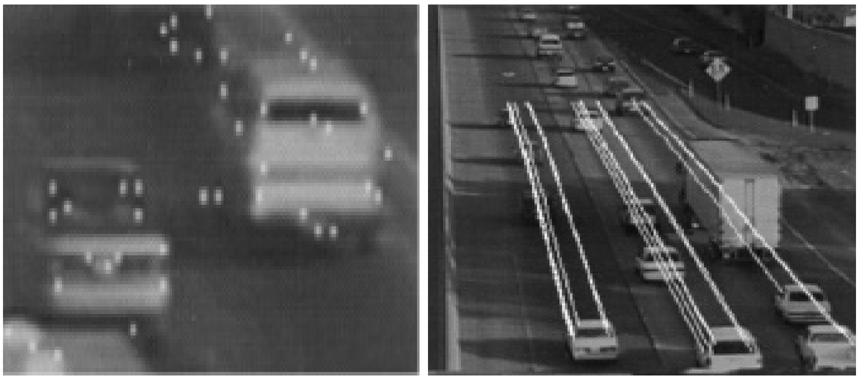
[Malik et al. 1994]



[Lin et al. 2003]

Figure 1.11 Active contour based tracking.

Feature based tracking algorithm tracks vehicle by sub-feature of vehicle such as distinguishable points or lines on the object instead of whole object. The advantage of this approach is that even vehicles have partial occlusion, some features of vehicle are still visible and can be used to track vehicle. [Beymer et al. 1997] used corner points of vehicle as feature is successful to track vehicle by using Kalman filter to predict the location and velocity of given corner points in next frame.



[Beymer et al. 1998]

Figure 1.12 Feature based tracking.

1.4 summary

In recent year, non-invasive detectors used in traffic data collection become the trend. Especially, image detector is a burgeoning one that is used widely in the world because of its high feasibility. It has several advantages: easy maintenance, numerous parameters obtainment, adjustable detection region, friendly user interface. Although there is many literatures to research this issue, they mostly focus on the road section. Date collection at intersection is more important than road section. Besides, image detector has some problems such as climate, night, shock, occlusion need to be resolved. Image detection system still needs to be improved.

Chapter 2

Fundamental image processing

2.1 Introduction

In this study, image processing is an important technique that we have to realize it for dealing with image sequence. In this chapter, image acquisition process and image processing techniques are introduced. These image processing techniques including image segmentation, noise reduction, edge detection, morphological algorithms and binary image labeling are the base of methodology discussed in this thesis.

2.2 Image Acquisition Process

An example of the digital image acquisition process is shown as figure 2.1. Energy from an illumination source being reflected from a scene element then image system collects the incoming energy and focuses it onto an image plane. The output of this image system is digitized image which shall be denoted two-dimensional functions of the form f(x, y). The function of image is illustrated as figure 2.2.

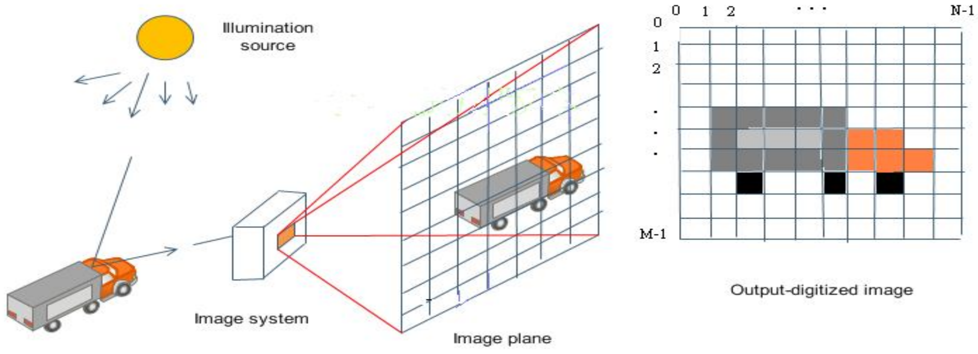


Figure 2.1 An example of digital image acquisition process.

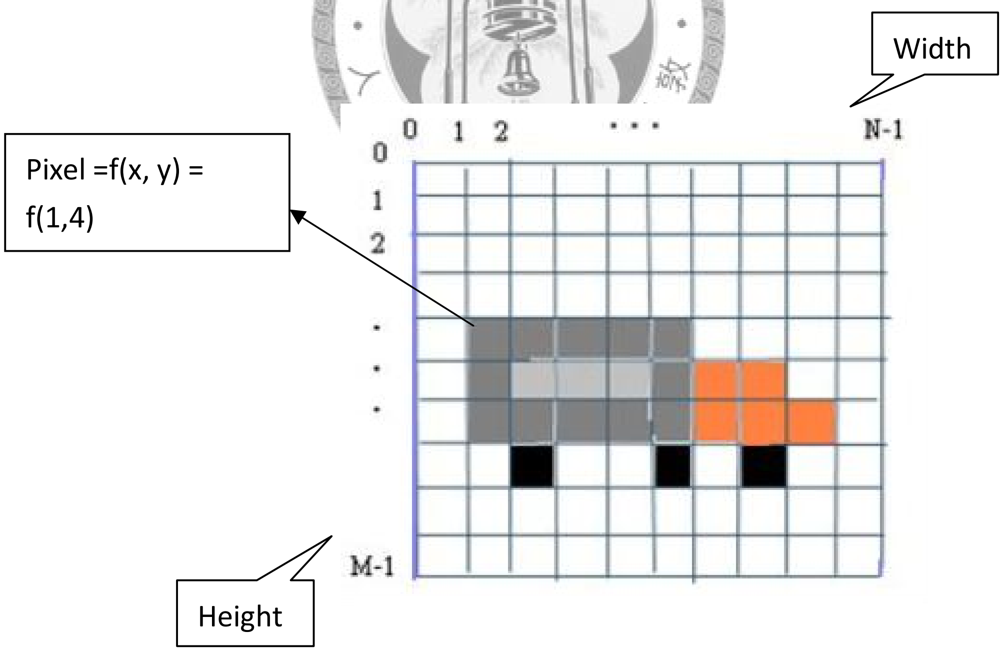


Figure 2.2 A diagram of image function.

2.3 Image Enhancement

In this section, image enhancement in the spatial domain is introduced. The principal objective of enhancement is to process the image which has noise or gets blur from sampling. Noise reduction is an important issue and has many approaches. Before using them, we have to realize box filter which is illustrated as figure 2.3. The mask of box filter have 3x3, 5x5, 7x7 etc. 3x3 mask is used in this study. f(x, y) is the point we want to process, others is its eight-neighborhoods.

f(x-1, y-1)	f(x, y-1)	f(x+1. y-1)
f(x-1, y)	f(x, y)	f(x+1, y)
f(x-1, y)	f(x, y+1)	f(x+1, y+1)

Figure 2.3 Pixel of image under 3x3 mask.

Smoothing Linear Filters

This filter sometimes is called averaging filter. It is simply the average of the pixels contained in the neighborhood of the filter mask. The mask coefficients are shown as figure 2.4. The processing is moving the filter mask from point to point in an image. At each point(x, y), the pixel value is calculated by Eq. 2.3-1

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

Figure 2.4 Smooth linear filters mask.

$$pixel(x,y)=\sum_{s=-1}^{1}\sum_{t=-1}^{1}1/9\,f(x+s,y+t) \qquad (2.3\text{-}1)$$

Median filter

Median filter is one of approaches for reducing noise. It is an order-statistics filter. The processing is to sort the pixel value of mask then pick the median as the pixel value of this point. For instance, that 3X3 mask has values (80, 15, 100, 25, 30, 50, 65, 10, 20). These values are sorted as (10, 15, 20, 25, 30, 50, 65, 80, 100), the given value to this point is the median of 30.

2.4 Edge Detection

Edge detection is the operation of detecting significant local changes in an image. This approach is also useful to image segmentation. Gradient used for detecting local change in the image is the 2D equivalent of the first derivative. The gradient $\nabla \mathrm{f}$ of an image at location(x, y) is defined as the vector:

$$\nabla \mathrm{f} = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \tag{2.4-1}$$

The magnitude ∇f of this gradient is given by

$$\nabla f = \mathrm{mag}(\nabla \mathrm{f}) = \left[G_x^2 + G_y^2 \right]^{1/2} \tag{2.4-2}$$

In order to reduce computational burden because of squares and square roots, ∇f is approximated by absolute values

$$\nabla f \approx |G_x| + |G_y| \tag{2.4-3}$$

The direction of gradient vector also is an important quantity, it is defined as

$$d(x, y) = \tan^{-1}\left(\frac{G_y}{G_x}\right) \tag{2.4-4}$$

These derivatives can be implemented for an image by using masks shown in figure 2.5. These masks called Roberts cross-gradient operator.

0	-1
1	0

-1	0
0	1

Figure 2.5 Roberts cross-gradient operators.

2X2 mask is awkward to be implemented because it does not have a clear center. A better approach named Sobel operator is developed. It use 3X3 masks shown in figure 2.6.

-1	0	1
-2	0	2
-1	0	1

(a)

-1	-2	-1
0	0	0
1	2	1

(b)

Figure 2.6 Sobel operators. (a) Sobel vertical mask. (b) Sobel horizontal mask.

2.5 Image segmentation

Image segmentation is an important issue to image processing. In dynamic sequence, how to segment moving object is we interest in. some useful approaches is discussed as following.

Change detection

The most obvious method of detecting change between two frames is to compare the corresponding pixel of two frames to check whether they are the same or the difference is very small. A binary difference image between frames F (t) and F (t+1) can be obtained by eq. 2.5-1.

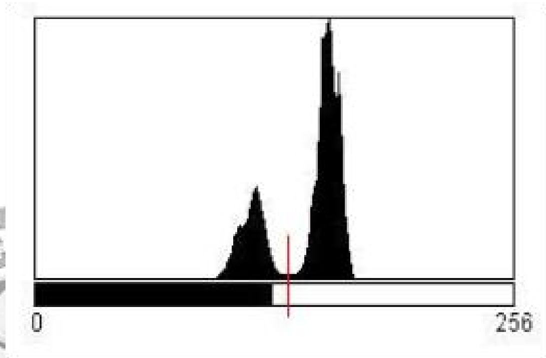
$$D(x,y)=\begin{cases}1 & if\ |F(x,y,t)|-|F(x,y,t+1)|>T \\ 0 & otherewise\end{cases} \quad (2.5\text{-}1)$$

where T is threshold.

Thresholding

This approach is to observe the distribution of pixel value, and find the best threshold to segment the object. Histogram of pixel values can help us to observe distribution easily. In figure 2.7, it can be clear separated two parts from histogram.

(a)



(b)

Figure 2.7 Gray histogram of starfruit.

a. Basic Adaptive Thresholding

This algorithm is focus on the property of pixel value on whole image to automatically generate threshold value for segmenting object. The logic of this algorithm is as follows:

Step 1: Choose initial threshold values t to operate.

Step 2: Using t to separate two sets of pixel on whole image, one set is the group greater than t we call it G_1, another set is group smaller than t we call it G_2.

Step 3: Compute the pixel value mean μ1, μ2 of G_1 and G_2.

Step 4: Compute new threshold value T* which is given by

$$T^* = \frac{1}{2}(\mu 1 + \mu 2) \qquad (2.5\text{-}2)$$

to compute step 2-4 iteratively until the difference of t and T* is smaller than constant D, then T* is chosen to segment image for obtain binary image. This algorithm is useful for the obvious distribution of pixel value.

b. OTSU method

This approach is similar to above algorithm. The difference is the basis of segmentation is variation of groups. To suppose pixel value of an image is within 0~K. its histogram is shown in figure 2.9. The distribution of pixel value can be separated into two parts G1 and G2 to obtain the minimum variation by optimal threshold. The number of pixel value i is represented to n_i and $N=n_0+n_1+......n_k$ is the total number of pixel value. $P(i)$ is the probability of pixel value *i*.

$$P(i) = \frac{n_i}{N} \;\;,\;\; P(i) \geq 0 \;\;,\;\; \sum_{i=0}^{K} P(i) = 1 \tag{2.5-3}$$

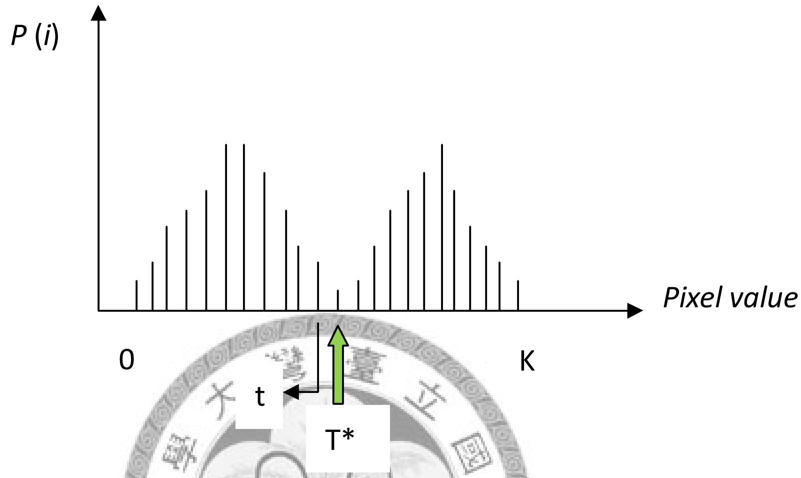


Figure 2.8 gray-level probability density functions of two regions in an image.

The probability of group G1 and G2 are presented in eq. 2.5-4 & 2.5-5.

$$P(G_1) = \sum_{i=0}^{t} i * P(i) \tag{2.5-4}$$

$$P(G_2) = \sum_{i=t+1}^{K} i * P(i) = 1 - P(G_1) \tag{2.5-5}$$

The mean of group G1 and G2 are given by

$$\mu_1 = \sum_{i=0}^{t} i * P(i \mid G_1) = \sum_{i=0}^{t} i * \frac{P(i)}{P(G_1)} \quad (2.5\text{-}6)$$

$$\mu_2 = \sum_{i=t+1}^{K} i * P(i \mid G_2) = \sum_{i=t+1}^{K} i * \frac{P(i)}{P(G_2)} \quad (2.5\text{-}7)$$

The variation of Group G1 and G2 are given by

$$\sigma_1 = \sum_{i=0}^{t} (i - \mu_1)^2 * P(i \mid G_1) \quad (2.5\text{-}8)$$

$$\sigma_2 = \sum_{i=t+1}^{K} (i - \mu_2)^2 * P(i \mid G_2) \quad (2.5\text{-}9)$$

The variation and mean of whole groups is given by

$$\sigma_T^2 = \sum_{i=0}^{K} (i - \mu_T)^2 * P(i) \quad (2.5\text{-}10)$$

$$\mu_T = \sum_{i=0}^{K} i * P(i) \quad (2.5\text{-}11)$$

The variation sum within each group is given by

$$\sigma_G^2 = P(G_1) * \sigma_1^2 + P(G_2) * \sigma_2^2 \quad (2.5\text{-}12)$$

The variation between each group is given by

$$\sigma_B^2 = P(G_1) * (\mu_1 - \mu_T)^2 + P(G_2) * (\mu_2 - \mu_T)^2 \qquad (2.5\text{-}13)$$

The Subject of OTSU method to decide the optimal threshold is to minimize the variation sum within each group and to maximize the variation between each group. In generally, to maximize the variation between each group is used for obtaining optimal threshold (Eq.2.5-14).

$$Max \quad \sigma_B^2, \quad 0 \le t \le K \qquad (2.5\text{-}14)$$

2.6 Morphological Operation

The basic of morphological operation including dilation, erosion, closing and opening are used in this study. These operations aim at shapes on image region to process or to describe them. The definitions of these operations are defined as follows:

Dilation

This operation is to enlarge the regions of binary image. The dilation of binary image B by structuring element S is denoted by $B \oplus S$ and is defined by

$$B \oplus S = \bigcup_{b_{i \in B}} S_b \quad (2.6\text{-}1)$$

Erosion

This operation makes the regions of binary image smaller. The erosion of binary image B by structuring element S is denoted by $B \Theta S$ and is defined by

$$B \Theta S = \{b \mid b + s \in B \forall s \in S\} \quad (2.6\text{-}2)$$

Closing

This operation is to combine dilation and erosion. It can close up internal hole in the region of binary image. the closing of binary image B by structuring element S is denoted by $B \cdot S$ and is defined by

$$B \bullet S = (B \oplus S) \Theta S \quad (2.6\text{-}3)$$

This operation does dilation first and then does erosion.

Opening

This operation is also to combine dilation and erosion. It is different to closing by doing erosion first and then doing closing. Opening can remove the small portion of region that stick out from the boundary into the background region, smoothes the contour of an object and eliminates thin protrusions. The opening of binary image *B* by structuring element *S* is denoted by $B \circ S$ and is defined by

$$B \circ S = (B \Theta S) \oplus S \tag{2.6-4}$$

In this study the 3x3 rectangular mask is employed as the structuring element S as shown in Figure 2.10

1	1	1
1	1	1
1	1	1

Figure 2.9 Structuring elements S.

2.7 Connected Component Labeling

The purpose of connected component labeling algorithm is to find connected components in an image and assign a unique label to all the points in the same component. After operating this algorithm in binary image, the geometric relation of each component can be obtained from image. Clustering these points in the same components can extract object from binary image. Obtaining this information can be used for further process in this study.

Recursive Connected Components Algorithm

This algorithm is a recursive method. It scans the image point by point and iteratively assign label until no more unlabeled pixel which pixel value is 1 form binary image. The procedure of this algorithm is as follows:

Step 1: Scan the image to find unlabeled "1" pixel and assign it a new label L.

Step 2: Recursively assign a label L to all its "1" neighbors.

Step 3: Stop if there are no more unlabeled "1" pixels.

Step 3: Go to step 1.

Sequential Connected Components Algorithm using 4-connectivity

This algorithm is different to recursive method. It did not need to recursively assign label to neighbors. It just has to scan image few time to accomplish the labeling. The procedure is shown as follows:

Step1: Scan the image left to right, top to bottom

Step2: If the pixel is "1", then

- *(a) If only one of its upper and left neighbors has a label, then copy the label.*
- *(b) If both have the same label, then copy the label.*
- *(c) If both have different labels, then copy the upper's label and enter the labels in the equivalence table as equivalent labels.*
- *(d) Otherwise assign a new label to this pixel and enter this label in the equivalence table.*

Step3: if there are more pixels to consider, then go to step2.

Step4: Find the lowest label for each equivalent set in the equivalence table

Step5: Scan the picture. Replace each label by the lowest label in its equivalent set.

2.8 Summary

In this section, realizing fundamental image processing is important and helps us to do some useful work. These approaches are the basis in further processing. Through them, we can segment interesting object from image and analyze them. Some approaches of image processing employed in this study will be introduced at next chapter.

Chapter 3

Vehicle Detection System

3.1 Introduction

In this system, the main propose is to extract traffic parameters, traffic flows, turn ratio and vehicle categories, at the same time can be applied in exist CCTV. Through segmenting vehicle from video captured by DV, we can analyze it to obtain information. In this chapter, system configuration, and pre-process are introduced.

3.2 System Overview

In this study, CCD camera is used for capturing image sequence of traffic flow at the cross intersection. The image sequence is stored in image which size is 320X240 pixels and format is JPEG to be processed later. The speed of Image processing is decided by Hardware and software. In our system, general equipment is used, and the programming language is Java which efficiency is slower than c++, however it has numerous advantages.

Hardware

A. Laptop:

CPU: Intel Pentium M processor 735A (1.7GHz, 400MHz FSB, 2MB L2 Cache)

Display Card: Intel Graphics Media Accelerator

Memory: DDR2 667 1G*2

HDD 60G 5400rpm

B. CCD:

JVC GZ-MG505U

This CCD has AES (Auto Electric Shutter) which will influence the result of image processing in this study. The problem will be discussed later.

Figure 3.1 JVC CCD

Software

A. OS:

Windows XP Professional

B. Programming Language:

Java

JDK 1.5

IDE: Borland JBuilder 2006

Java is an object-oriented, platform-independent, multithreaded programming environment. The advantages of it are it can be used in different platform without the problem of integration and it is robust and steady, so it is more suitable to be used in Traffic Control Center (TCC).

Environment analysis

In this study, how to extract traffic parameters at intersection is discussed. In the past, the researches discuss how to obtain traffic parameters are always on highway or urban roadway. In these three sites, the algorithms for obtaining data are very different. In direct perception, the order of complex degree is intersection, urban roadway then highway.

A. Highway

Highway shown in figure 3.2 is the simplest traffic environment. The characteristic of traffic flow here are the velocity of vehicle is very fast, vehicle change lane easily, no motorcycle and the phenomenon of vehicle occlusion occur less.

Figure 3.2 Highway.

B. Urban Roadway

The characteristic of traffic flow on urban roadway shown in figure 3.3 are that the velocity of vehicle is moderate, sometimes here has congestion, vehicle change lane hardly, the direction of traffic flows is fixed, vehicle occlusion often occur even traffic flow is low and motorcycle has to be considered that increases the complex degree on roadway. Fortunately, the direction of traffic flow is fixed and there are some approaches can deal with the problem on road section.

Figure 3.3 Urban roadway.

C. Intersection

Intersection shown in figure 3.4 is the most complex traffic environment. It has to be considered numerous factors. Here we had to consider more than two directions of traffic flows. The motorcycle behaviors is more complex at intersection, we also have to consider the two-step left turn. There are many vehicle groups to pass through intersection after the starting of green light that make image processing become more difficult.

Figure 3.4 Intersection.

The issue of Motorcycle

In Taiwan, the work to detect and track motorcycle is very difficult. The characteristic of motorcycle flow is very different to car. It can be generalize three points as follows:

A. High Velocity

In generally, motorcycles usually pass through intersection by high velocity unless the traffic flows is heavy. Because of this characteristic, centroid of motorcycle object on image has higher displacement.

B. High Maneuverability

Motorcycle has high maneuverability because of small volume. They can easily through into the space between two vehicles, and overtake front vehicle, so if we employ virtual zone to detect, it will occur false alarm.

C. Complex Trajectory

Because of high maneuverability, Motorcycle trajectory is very complex and its location is difficult to be predicted next time that increases the difficult of tracking.

Because of these three characteristics, tracking motorcycle becomes more difficult. Two-step left turn also cause tracking become complex. Another problem is that motorcycles often pass through intersection in groups. This phenomenon make vehicle occur occlusion easily. It is impossible to segment each motorcycle clustered at intersection.

System Procedure

The procedure in this study consists of six stages: pre-processing, foreground segmentation, shadow removal, occlusion resolution, tracking and traffic parameters extraction. The flow chart of procedure in this study is illustrated in Figure 3.5. Each stage is introduced as follows:

A. Pre-Processing stage:

Pre-processing is implemented when this system is installed at new site. Before detecting vehicle, we have to do some works including background image construction, environmental geometry information acquired by camera calibration. Background image construction is for the purpose of foreground segmentation. Camera calibration is for the purpose of vehicle identification.

B. Foreground Segmentation stage

After pre-processing is completed successfully, the next stage is to detect moving object on the image. These moving objects are almost vehicles or pedestrian. In this study, pedestrian did not be considered.

C. Shadow Removal stage

At day time, if sunlight is strong, it is possible that the shadow of moving vehicle will be considered as foreground moving objects and this result will influence the accurate rate of system. As a result, it is necessary to remove shadow of moving vehicles.

D. Occlusion Resolution stage

This phenomenon of occlusion occurs easily at intersection even traffic flows is low. When occlusion is occurred, more than two moving vehicles are considered as one moving object extracted from image.

E. Vehicle Tracking stage

This stage is most important in this system. In this stage, corresponding relationship for each segmented object over time will be linked to obtain the trajectory, vehicle direct, and velocity information of each tracked vehicle.

F. Traffic Parameters Extraction stage

After operating these stages above, the final stage is to extract traffic parameters from analyze the information obtained by foreground objects.

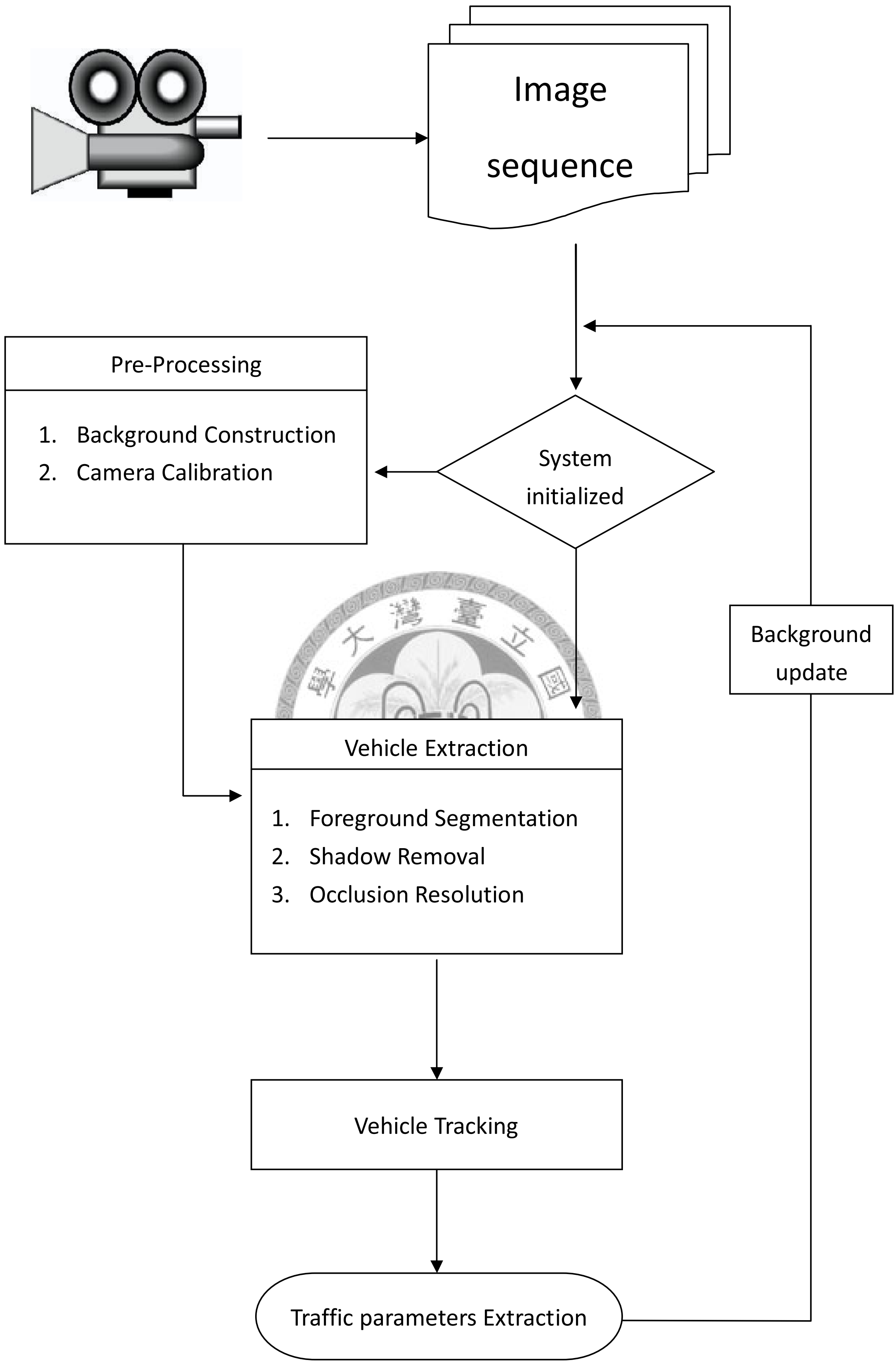


Figure 3.5 Flow Chart of System Procedure.

3.3 Pro-processing

This stage includes background construction and camera calibration. The detail and result is shown as follows.

Background Construction

Background subtraction method is used for segmenting moving object in this system, so the first thing is background construction. In traditionally, statistic methods such as mean, median, majority are mostly used. In the recent year, single Gaussian model method [Kumer et al.2002] which is to save each pixel value as Gaussian model used to segment foreground is proposed. The characteristic of statistic methods is that they need long time to train the background image. Averaging image which use mean is common method but it also consider the pixel value which is non-background. The result of this method is influenced easily by noise and the quality of background image is bad without enough samples. Median method is influenced easily by extreme pixel value. At the same time this method need to order the pixel value that is inefficient. In generally, the pixel value which often appears is the background pixel value probably, so we can use majority to obtain background pixel value but this method also have the same problem as median. The advantage of these three statistic parameters had discussed in [Lin 2007].

In this thesis, progressive background construction [Wang 2002] is used. This approach which can fast construct background is correctional method of majority. It eliminates non-background pixel value, and calculates the majority of background pixel value.

$D_{x,y}$ presented in eq. 3.3-1 is the difference of two successive frames at location (x, y). If $D_{x,y}$ is lower than threshold T_D, pixel value at location (x, y) is background pixel value, the other is non-background pixel value. Partial-background Image is the image without non-background pixel value presented as eq. 3.3-2.

$$D_{x,y,t} = | I_{x,y,t} - I_{x,y,t-1} | \tag{3.3-1}$$

$$\text{Partial-background Image(x,y,t)} = \begin{cases} I_{x,y,t} & if\ D_{x,y,t} < T_d \quad (background) \\ 0 & D_{x,y,t} > T_d \quad (non-background) \end{cases}$$

(3.3-2)

Where T_d is a small constant.

After obtain the partial-background Image in different time, to calculate the appearance number of each pixel value and noted them on confidence table. To refresh confidence table over time, we can generate background image quickly from confidence table.

Confidence value *v (t)* is calculated by eq. 3.3-3. If the pixel value on confidence table appears again, the confidence value of it will be raised. If the pixel value on confidence table did not appear, the confidence value will be decreased and eliminated until the value is lower than zero. *a* is pixel value on confidence table. *A, D* and *K* are small constant.

$$v(t) = v(t-1) + A\delta(\text{Difference-Image}(t), a) - D \qquad (3.3\text{-}3)$$

$$0 \le v(t) \le K$$

$$D < A < K$$

$$\delta(l,r) = \begin{cases} 1 & |l-r| < \lambda \\ 0 & otherwise \end{cases} \qquad (3.3\text{-}4)$$

According [Wang 2002], A=3, D=1, K=10 are used in this system. ：δ (*l , r*) is the function of difference-Image and confidence table. If the difference of confidence table pixel values and Difference-Image pixel value is lower than small constant λ, we give it “1” used in eq. 3.3-3, others is given zero. Once the difference of confidence table values and Difference-Image are all greater then λ, we have to generate new confidence pixel value into confidence table and set its confidence value 1.

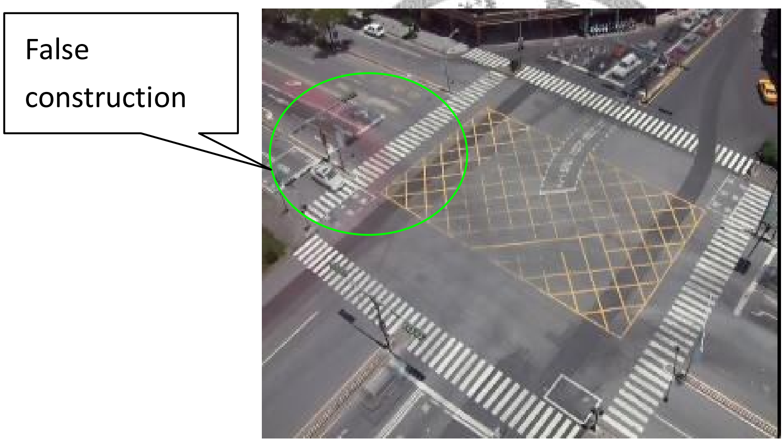
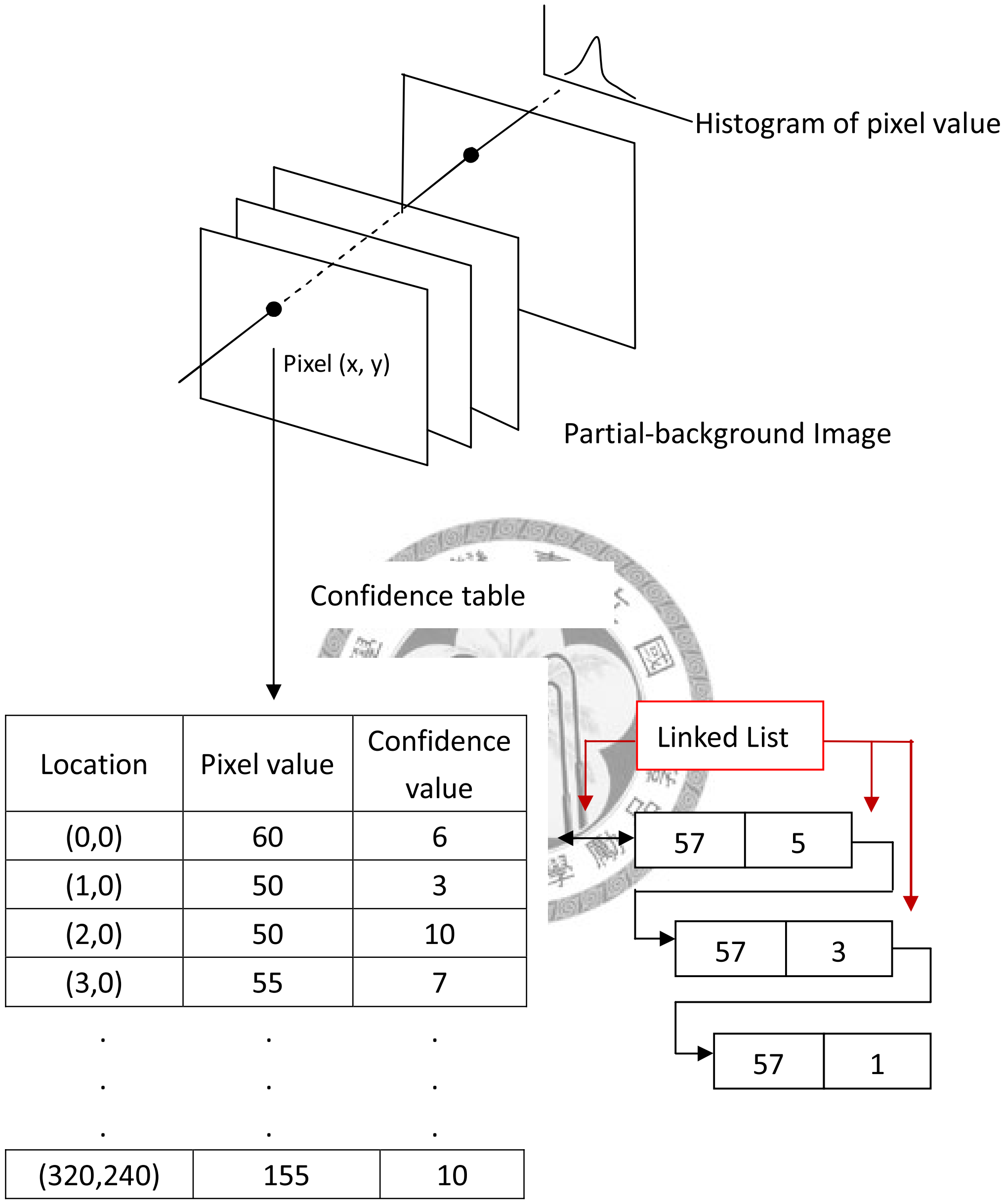


Figure 3.6　The result of averaging 1000 Frames.



Location	Pixel value	Confidence value
(0,0)	60	6
(1,0)	50	3
(2,0)	50	10
(3,0)	55	7
.	.	.
.	.	.
.	.	.
(320,240)	155	10

Figure 3.7 A diagram of confidence table and partial-background histogram.

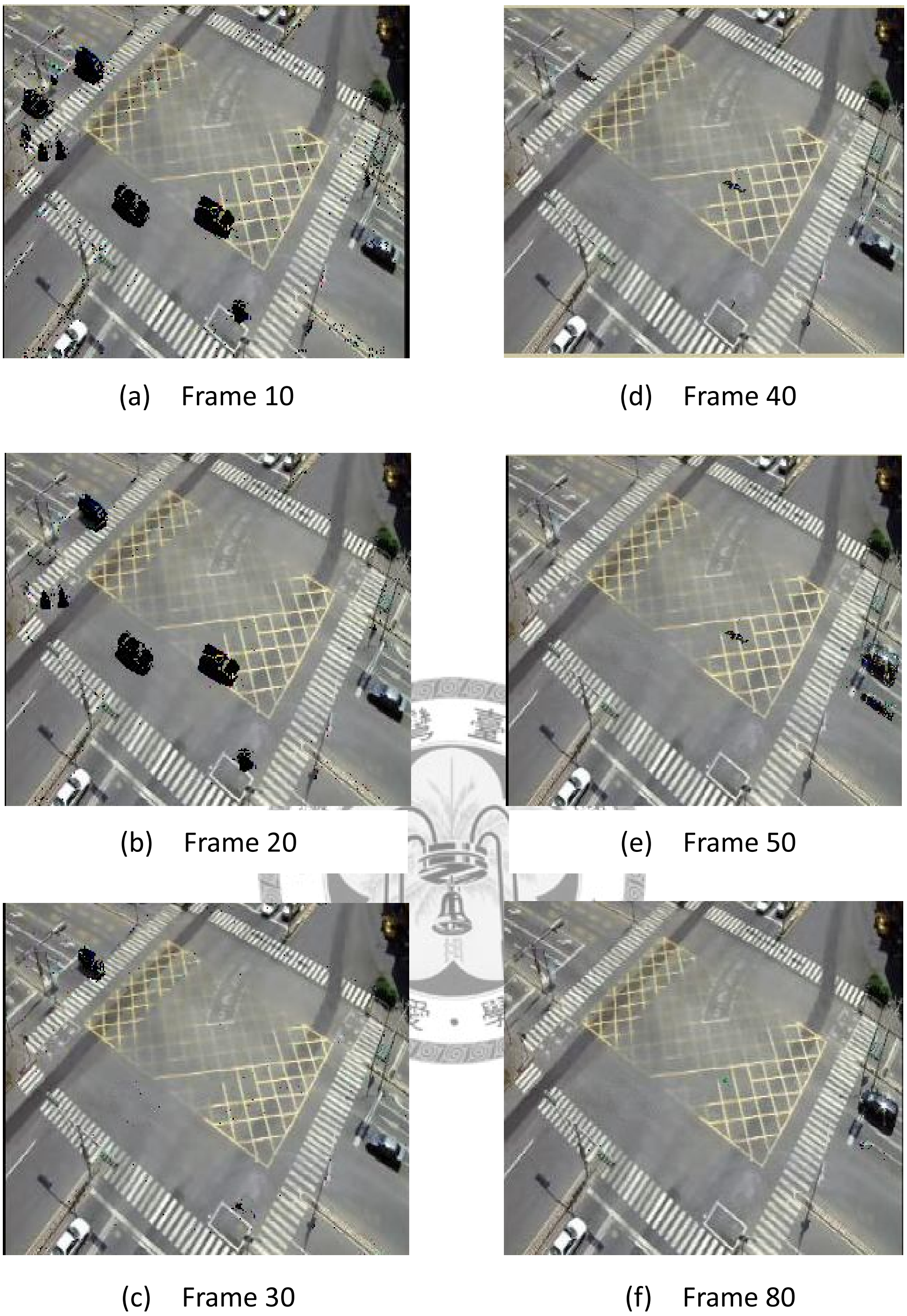


Figure 3.8 Procedure of background construction. (a) - (e) Background image in different time. (f) The final result of background image.

Adaptive Background Update

The illumination in outdoor will be changed with time passing, so just a static background image cannot cope with all situation at intersection. In order to resolve this problem, adaptive background update approach shown as eq. 3.3-5 is used in this system.

$$Background(x,y) = \frac{m-1}{m} Background(x,y) + \frac{1}{m} current(x,y,t) \quad (3.3\text{-}5)$$

Background is updated in every time, where *m* is an integer. If the value of *m* is chosen too large, the result of background update will be unobvious that lose the purpose of background update. On the other hand, if the value is too small, some noise is considered that will make errors in our processing. The appropriate value is necessary in this system. According to [Huang 2004], *m* is 8.

In order to avoid the error, background update just considers the pixel value at location (x, y) without moving objects.

Camera Calibration

3D object via camera to project on the image pane, the image pane is 2D coordinate but true world is 3D coordinate. Because of the projection, the relation of scale on the image is different from true world. In order to obtain the relation of scale in true world for identifying category of vehicle and measuring velocity, camera calibration is necessary. [Bas and Chrisman, 1998] proposed an easy approach that can use camera calibration for traffic monitoring. This approach does not need staff to measure on site. Massachusetts Institute of Technology had used this calibration to measure the velocity of vehicle and verified this approach can work well for measuring velocity within 1%~2% error rate, so it is adopted to transfer the perspective image to top-view image in this system. Figure 3.8 is shown the transfer from world coordinate and image world coordinate. The relation of scale can be expressed as following equation [Bas and Chrisman, 1998].

$$X_i = f\frac{X_w \cos\theta - Y_w \sin\theta}{X_w \cos\tau \sin\theta + Y_w \cos\tau \cos\theta + (h/\sin\tau)} \tag{3.3-5}$$

$$Y_i = f\frac{-X_w \sin\tau \sin\theta - Y_w \sin\tau \cos\theta}{X_w \cos\tau \sin\theta + Y_w \cos\tau \cos\theta + (h/\sin\tau)} \tag{3.3-6}$$

X_i, Y_i is the coordinates of image obtained by equation 3.3-5 and 3.3-6. This transfer is used for the world image coordinates after obtaining the world coordinates X_w, Y_w. The relation of world image coordinates and camera coordinates is shown as eq. 3.3-7 and eq.3.3-8.

$$X_W = f\frac{-(Y_i \sin\theta - X_i \cos\theta \sin\tau)h}{\sin\tau(Y_i \cos\tau + f\sin\tau)} \tag{3.3-7}$$

$$Y_W = f\frac{-(Y_i \cos\theta - X_i \sin\theta \sin\tau)h}{\sin\tau(Y_i \cos\tau + f\sin\tau)} \tag{3.3-8}$$

According to [Bas and Chrisman, 1998], the orientation angle, the tilt τ and the pan θ can be automatically by following equation without investigation in advance. This approach is very useful for fixed camera which angle can be adjusted by staff.

$$f = -\frac{Y_{vanish}}{\tan\tau} \tag{3.3-9}$$

$$\theta = -\tan\left(\frac{\cos\tau X_{vanish}}{f}\right) \tag{3.3-10}$$

Where f is focal length of camera, Y_{vanish}, X_{vansh} is the vanishing points on 2D image coordinates shown as Figure 3.11. Vanishing points is decided by two parallel lines in the world. In this study, the two parallel lines is crosswalk line at intersection.

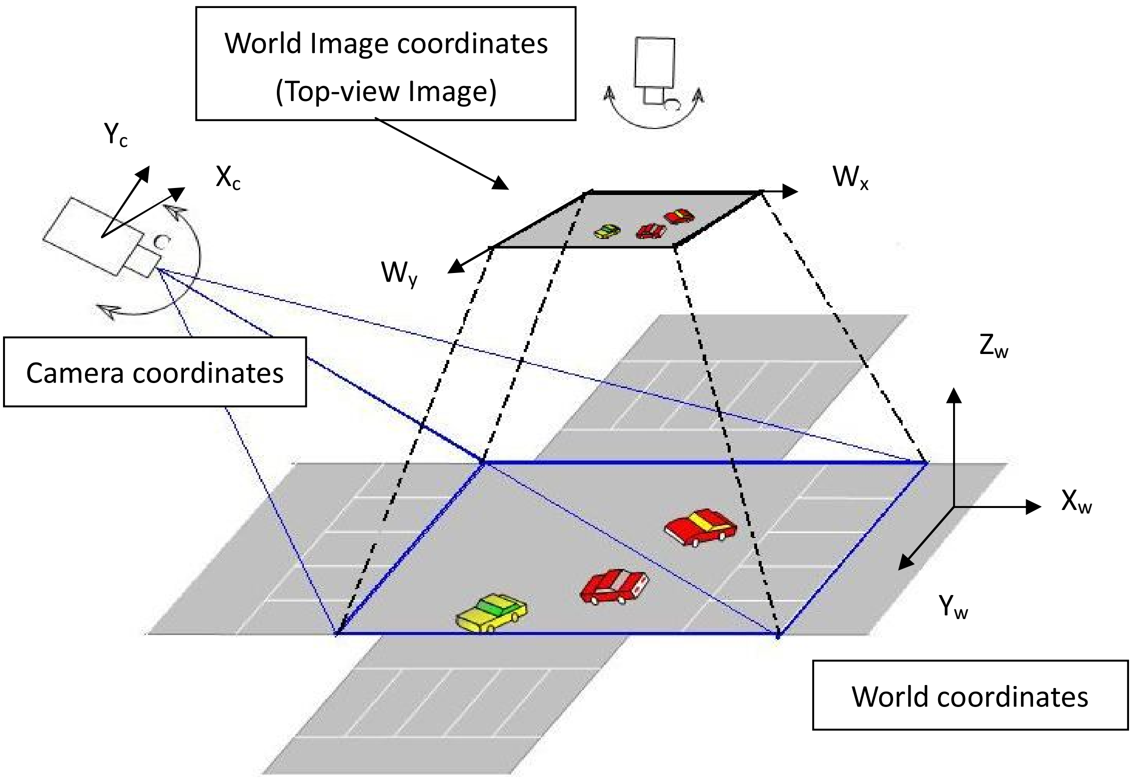


Figure 3.9 Relation of camera coordinates, world coordinates and world image coordinates.

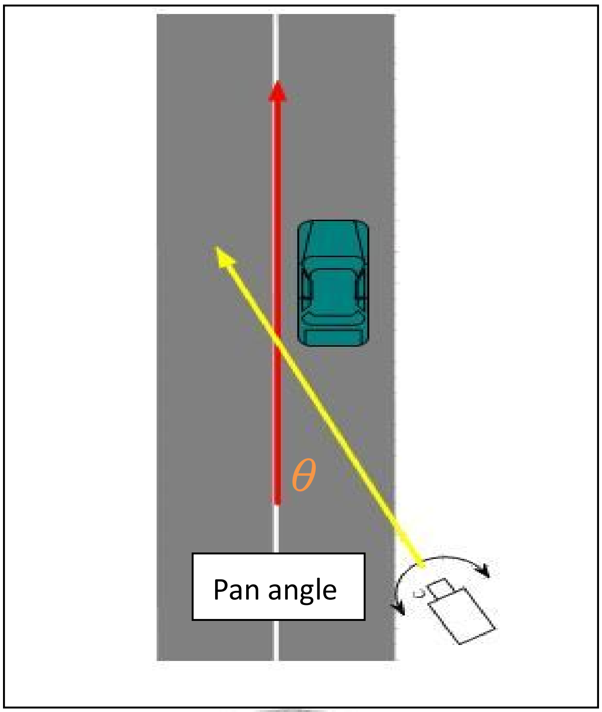


Figure 3.10 Top view of camera setup.

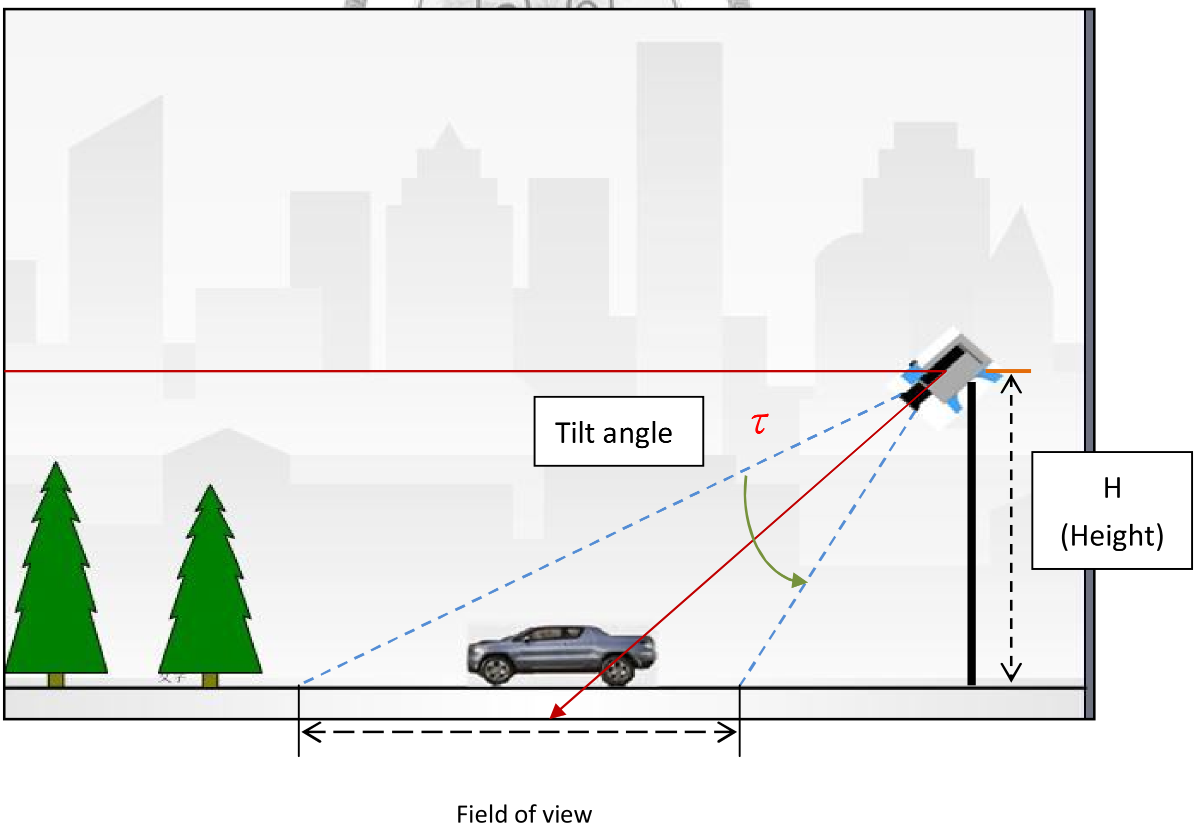


Figure 3.11 Side view of camera setup.

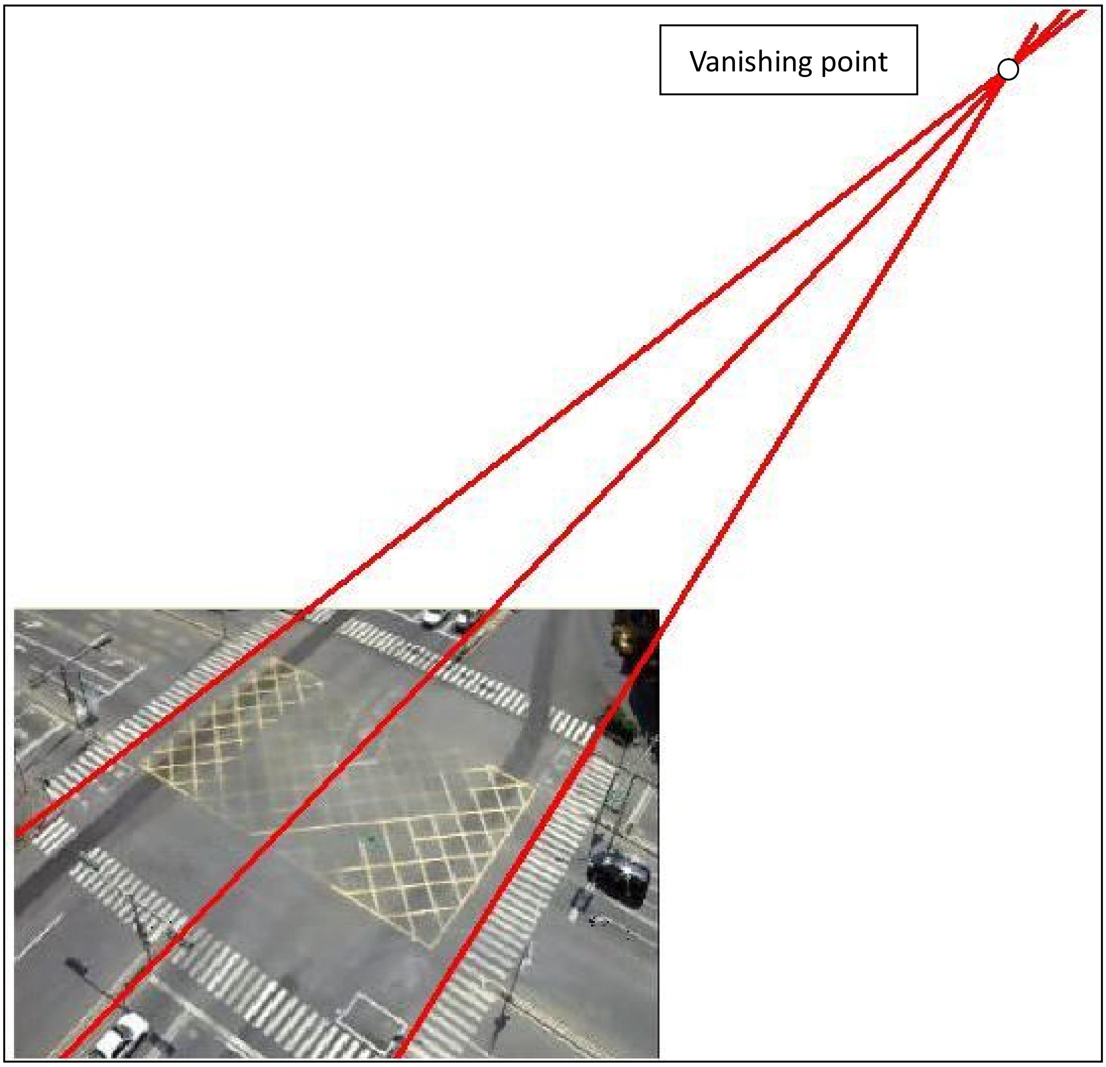


Figure 3.12　Vanishing point displayed on intersection image.

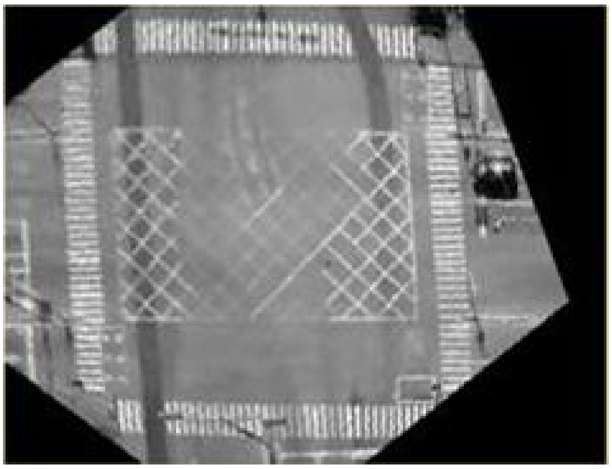


Figure 3.13 Top-view image.

Vanishing points is obtained by eq. 3.3-11 and 3.3-12 while the two parallel lines is drawn on the user interface shown as figure 3.13 and the pull bar is used to adjust the parameters about top-view image.

$$X_{vanish} = \frac{D_X^1 \cdot D_Y^2 \cdot X_S^2 + D_X^1 \cdot D_X^2 \cdot Y_S^1 - D_Y^1 \cdot D_X^2 \cdot X_S^1 - D_X^1 \cdot D_X^2 \cdot Y_S^2}{D_X^1 \cdot D_Y^2 - D_Y^1 \cdot D_X^2} \quad (3.3\text{-}11)$$

$$Y_{vanish} = \frac{D_Y^1}{D_X^1}(X_{vanish} - X_S^1) + Y_S^1 \quad (3.3\text{-}12)$$

Each line has two points, starting point and ending point. (X_S^i , Y_S^i) is the coordinate of starting point of *i*th line. (X_E^i , Y_E^i) is the coordinate of sending point of *i*th line. D_X^i , D_Y^i is the difference of X, Y coordinate of *i*th line.

Figure 3.14 User interface of top-view image transfer.

3.4 Vehicle Extraction

In this section, foreground segmentation, shadow removal and occlusion resolve is introduced. Vehicle will be extracted completely after these procedures.

Foreground Segmentation

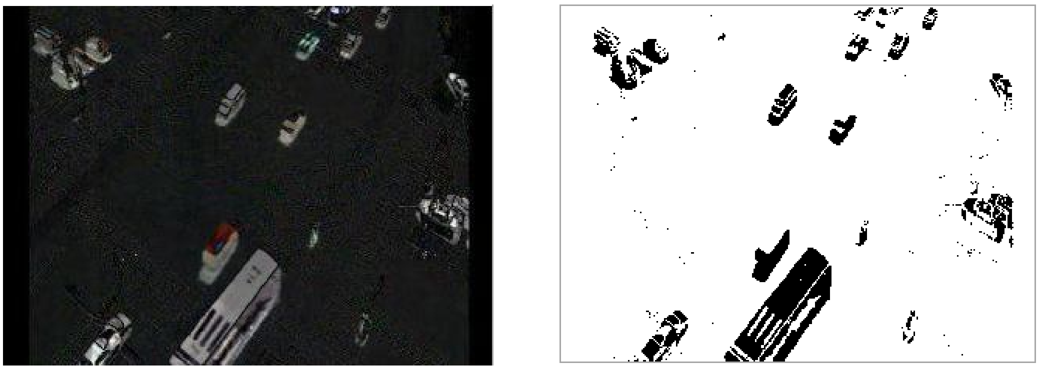
Static background subtraction was used in this thesis for subtracting foreground because of fast computational efficiency, so first to build a static background Image is necessary. We can start to do image processing after getting background image. The equation of subtracting object at location (x, y) is defined as follow:

$$D_{x,y}(t) = | I_{x,y}(t) - B_{x,y} | \qquad (3.4\text{-}1)$$

$$Object(x, y) = \begin{cases} 1 & if\ D_{x,y}(t) > T \\ 0 & otherwise \end{cases} \qquad (3.4\text{-}2)$$

$I_{x,y,}(t)$ is the pixel value at location (x,y) on t time. $B_{x,y,}$ is the background pixel at location (x,y) . The difference $D_{x,y,}(t)$ for each pixel of current image and background image at t time had to be calculated. If the difference is over than Threshold T, there is change on the background and it maybe exist moving object. By binary image Fig

3.14 (b), the object is segmented from image successfully.



(a) (b)

Figure 3.15 Foreground segmentation. (a) Difference image. (b) Binary Image of difference image.

A. Dynamic Threshold.

How to decide Threshold for separating background and foreground became binary image is important. If the chosen threshold is too small, the noise will be considered as object. Oppositely, the decided value too large, the object will lose or lead it become fragmental. If system only uses a fixed constant, the error will become more and more and hard to detect vehicle exactly, using adaptive threshold to resolve this problem is necessary. An approach proposed in this thesis can do a well work to solve this problem. This approach is to analyze the histogram of difference image. The indexes of our analysis are mean and standard deviation. The large regions on the image sequence are background, foreground object is few. The most of difference is near to zero and the values have concentrated trend. Because of this phenomenon, equations which present as following for obtaining adaptive threshold value is designed in this thesis.

$$T_{color} = Mean_{color} + SD_{color} \qquad ,color = r, g, b \tag{3.3-3}$$

$$T = \min \left\{ T_r , T_g , T_b \right\} \tag{3.3-4}$$

SD is standard deviation. The threshold value is decided by the minimization of the T_{color} *which* calculate the mean and standard deviation of three colors, red, green and blue.

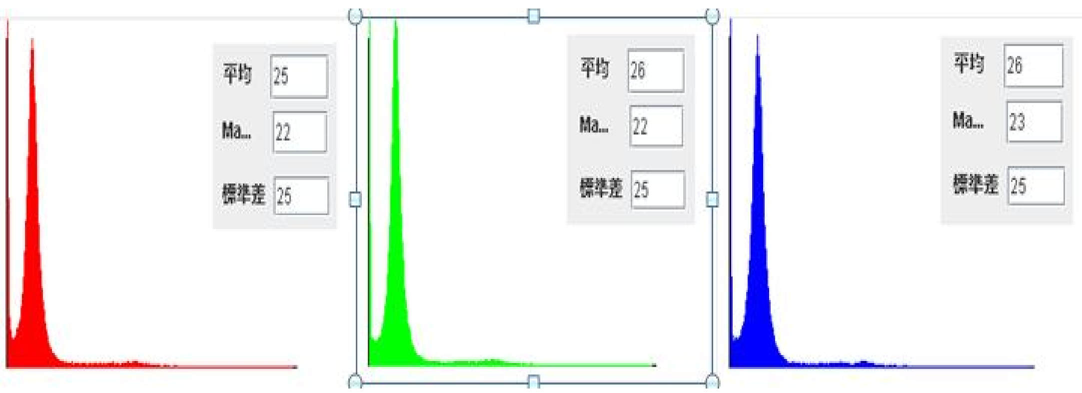


Figure 3.16 RGB Histogram of difference image.

This approach can also resolve AES problem and floating cloud. AES is a function of CCD. When pixels values have higher or lower illumination in larger region CCD will automatically adjust the illumination to reduce the contrast. However this function will influence the result of background subtraction. In order to avoid this situation appearing, it is necessary to do some processing.

Floating cloud also make the problem like AES. When a large area of cloud floats through the intersection in the sky, it will make the illumination of scene quickly lower. This problem still has to resolve by above approach.

In figure 3.16, to compare to these two frames, it can be easily observed that the illumination has changed between two frames. On frame 6037, the threshold value is 30 to make it become binary image which result is figure 3.17(b). The threshold value can does a well work, but on frame 6067, the illumination has been changed. If the threshold value still uses 30, the result is figure 3.17(d). The noise of this result image appears a large number. If this problem do not process, the result after finishing all image processing is figure 3.18. It is hard to extract object from image.

The analysis of frame 6067 difference image is shown as figure 3.18. After analyzing RGB color domain, we can obtain the threshold value 52. Using threshold value 52 to segment object from background can obtain good result as figure 3.18(d).

(a) 6037th Frame. (b) 6067th Frame.

Figure 3.17 The image with illumination change.

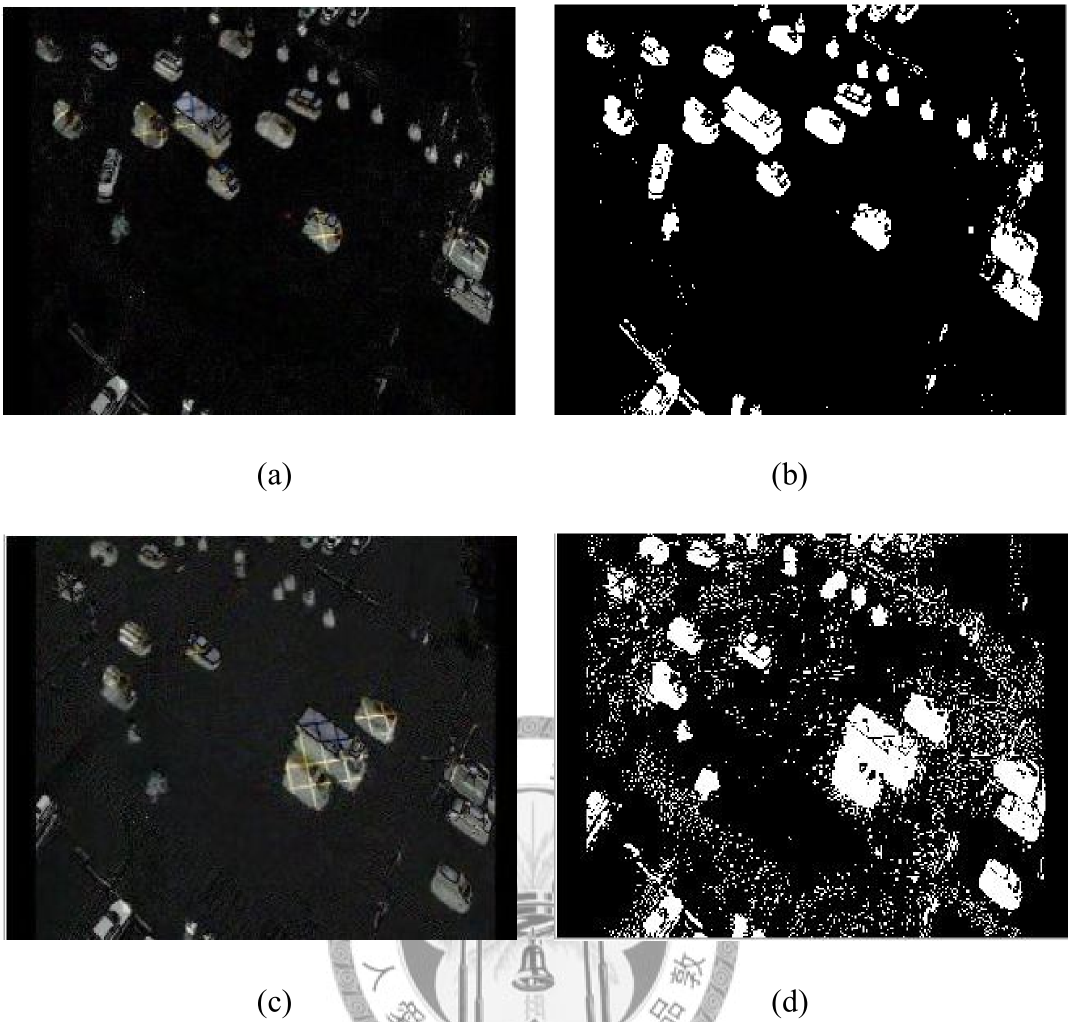


Figure 3.18 The result of fixed threshold value

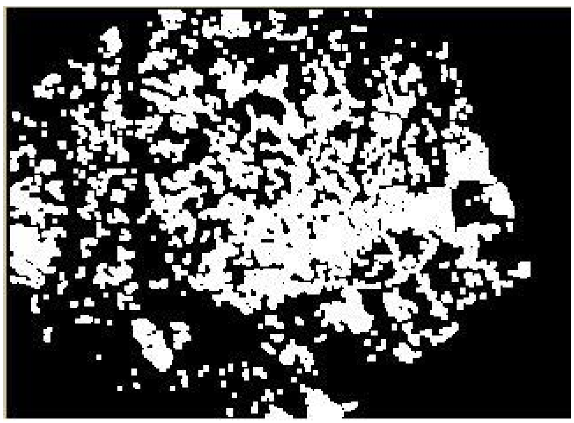
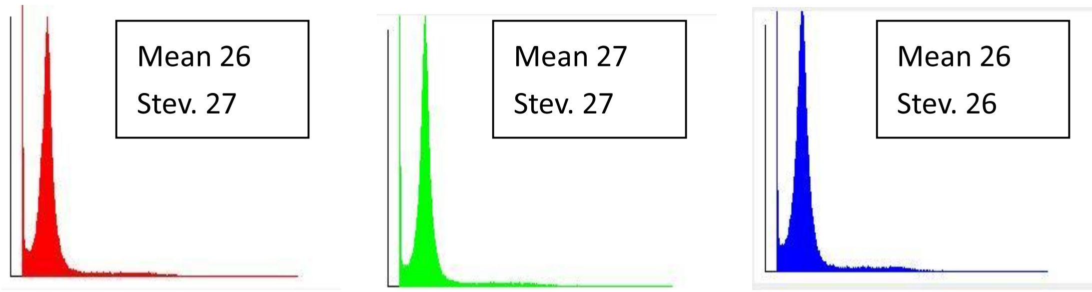
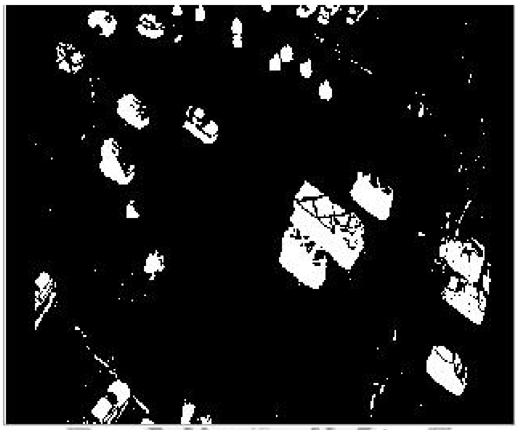


Figure 3.19 The result of frame 6067 after all image processing without dynamic threshold.



(a) (b) (c)

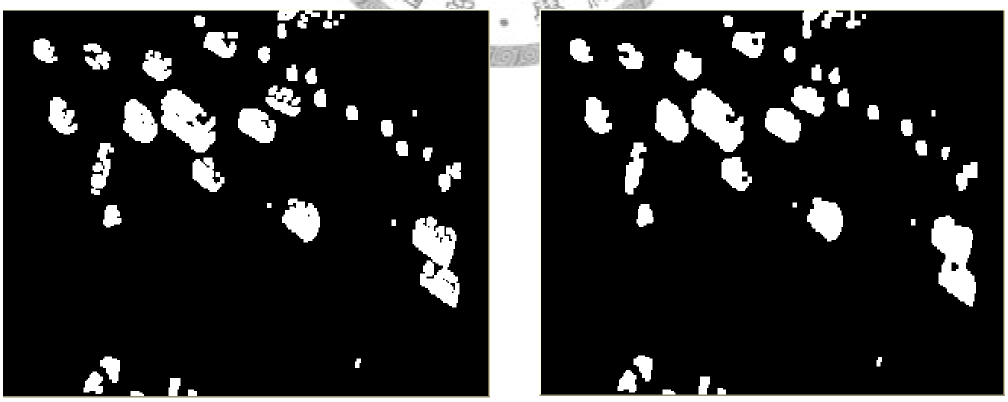


(d)

Figure 3.20 Result of frame 6067 by dynamic threshold. (a)-(c) the analysis of RGB on frame 6067 difference image(d) binary image by threshold value 52 .

B. Morphological Processing

After preliminary foreground segmentation, most region of object can be obtained. Next step is to do morphological processing. Although dynamic threshold approach can work well for object segmentation, it may still have some noise existing on binary image. The noise maybe are caused by the illumination change, weather change, the motion of background object (e.g. tree leaves) and small vibration of camera. These noises have to be eliminated from the binary image. Morphological processing includes opening and closing which are introduced in section 2.6. Opening smoothes the contour of an object, breaks narrow isthmuses and eliminates thin protrusions. Closing smooth section of contours, fuses narrow breaks and long thin gulfs, eliminates small holes and fills gaps in the contour. The result of morphological processing is shown in figure 3.19. Through this approach, we can see the object extract from background become smoother and noise is reduced.



(a) **(b)**

Figure 3.21 Morphological processing of frame 6037. (a) opening (b) closing

C. Blob Analysis

This stage is to cluster the same component of object and to analysis information of object. After morphological processing, the foreground object is almost segmented. For human eye, we can see where the moving object is easily. However, for computer, any information of the object region is unknown, so blob analysis is help computer to obtain the information of each region about moving object. The objective of bob analysis is to obtain the geometric information of each region which is the geometry of rectangular bounding box enclosing each object region. The area and size of each object region should be measured. Therefore, in the beginning of blob analysis, the first work is using connect component labeling to assign unique label to all points in the same component or region (see section 2.7). After blob analysis, the center point of rectangular bounding box and region area can be obtained for further processing. The result is shown as figure 3.22.

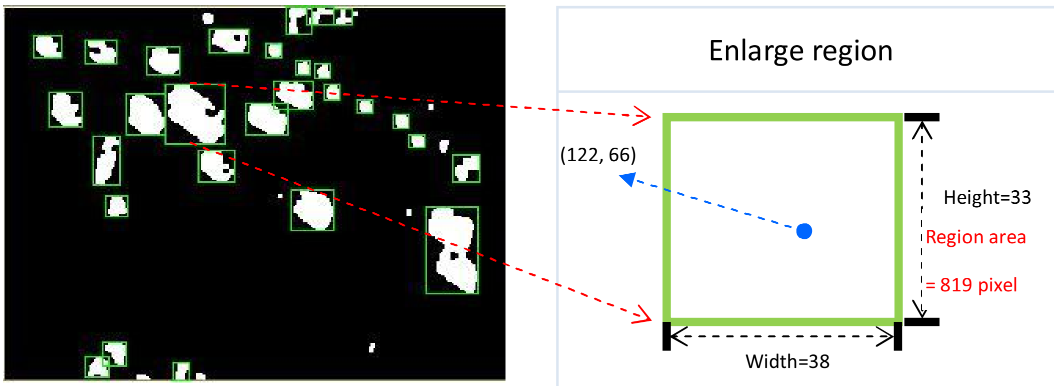


Figure 3.22 Result of blob analysis.

D. Hole-Filling

Although closing can eliminate small hole and fill gap in the contour, it may still have small holes in the binary region after morphological processing because of the big hole in original contour and broken object. In order to extract a complete object form image for obtaining accurate information to further analysis, hole filling is proposed in this study. This approach which scans upward to downward and rightward to leftward in a enclosed region of object to find gulfs and holes can fill the inside hole and smooth section in the binary region. The result of hole-filling is shown as figure 3.20, we can observe the region of red circle. It is obvious to find the change of vehicle, the hole is filled.

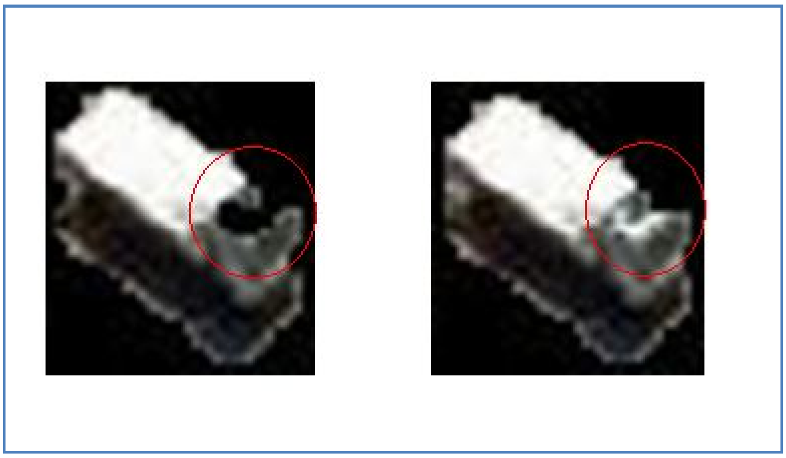


Figure 3.22 The result of hole filling.

3.5 Shadow removal

Moving shadow is always a problem that will cause the false detection of object and vehicle tracking error. This problem often occurs on the morning, nightfall and sunny day. In figure 3.23, we can see the shadow is thought as object region and to connect two vehicles on the image. There are many researches to discuss about it. In the pass, the process of shadow removal is complex and wastes a lot of time. So we want to develop an algorithm that can be easy and quickly work on real time.

Shadow

Shadow occurs when the object totally or partially occludes the light coming from the light source. Shadows are composed of two parts, self shadow and cast shadow. Self shadow which is not illuminated by the light source is part of object, so it would not be processed. In this study, we just care about cast shadow because its influence is more than self shadow. Cast shadow has two parts, umbra and penumbra. Umbra is dark black region of shadows where direct light is occluded completely by objects. Penumbra is the light black region of shadows where direct light is occluded partially by objects. The type of shadow is shown as figure 3.23. In this study only penumbra is processing because it often occupies large region in cast shadow and has large influence. Umbra losing color information completely is hard to remove well. At the same time the influence of umbra is small.

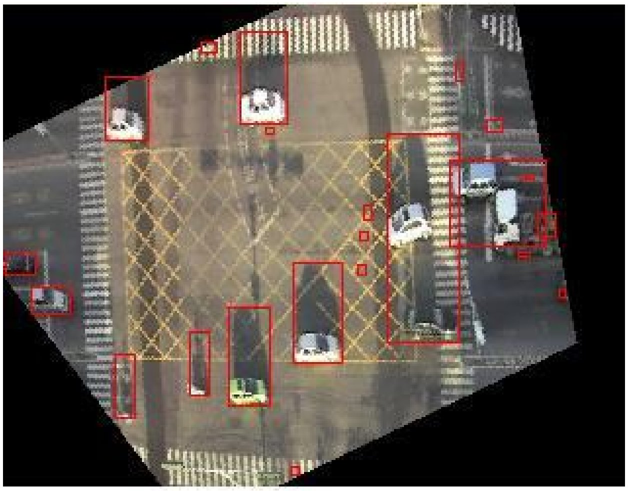
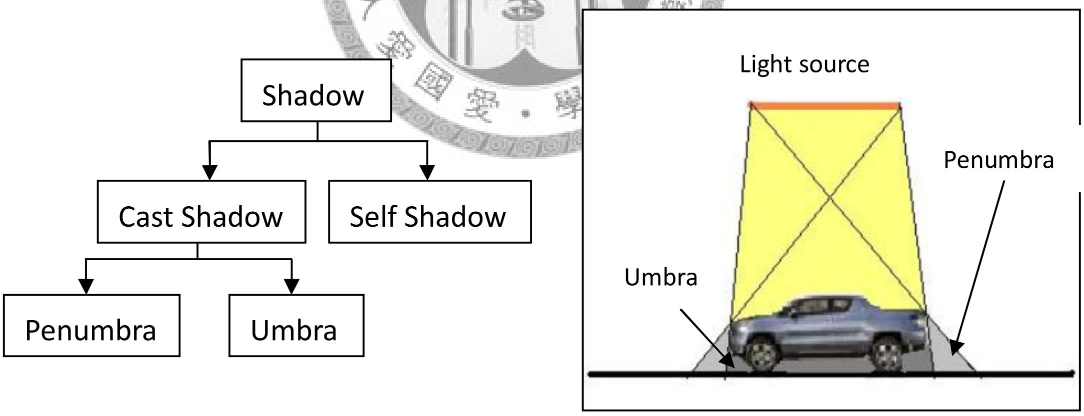


Figure 3.23 Foreground segmentation without shadow removal.



(a) (b)

Figure 3.24 Types of shadow.

In order to remove shadow points, to know the property of shadow in digital image is necessary. The properties of shadow as following have three parts:

1. The sequence pixel value of shadow is lower than background pixel value.
2. Shadow almost has no color information, and the hue is similar to background.
3. The gradient of shadow is similar to background.

According these characteristic, an approach is proposed in this study which procedure is shown as Fig 3.34. Only object region is processing for increasing computational efficient. The ratio of current image and background image got from gray pixel value to be stored a statistic model is used in this processing. After analyzing the model, the mean and standard variation can be extracted from this statistic model.

Because the value of pixel is decided by the product of illumination and reflectance, at fixed coefficient of reflectance, the pixel value of shadow will be proportional to background pixel value. Eq. 3.5-1 is presented the relation of shadow and background. C is a constant. If the ratio relation could be found, shadow points can be removed from background. Therefore, the next stage, statistic analysis of pixel value ratio is implemented for finding the ratio relation.

$$Shadow(x, y) = C \bullet B(x, y) \tag{3.5-1}$$

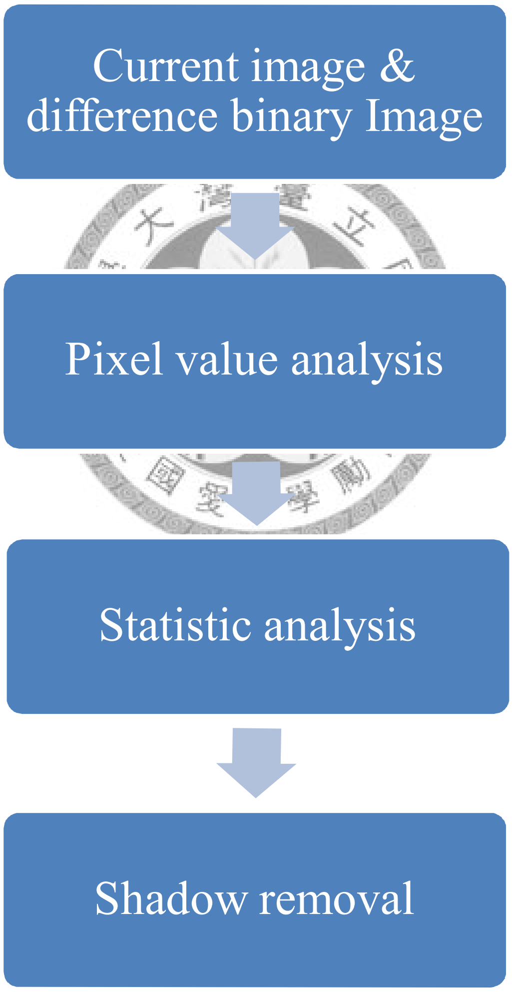


Figure 3.25 Procedure of shadow removal.

Statistic Analysis

Shadow on the image occupy lager region of object, and most of shadow ratio to background are nearly. According to this characteristic and eq. 3.5-1, storing the pixel ratio to statistic model, we could discover the most part of distribution are shadow, the other are objects. It is shown as figrue 3.25.

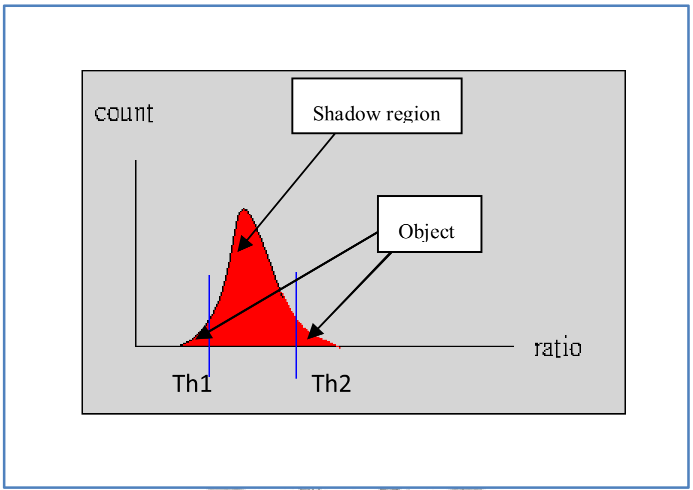


Figure 3.26　Pixel value ratio distribution.

According to pixel value of shadow points is lower than background pixel value at the same location and the statistic model of ratio, Equation 3.5-2 & 3.5-3 proposed in this study which can remove the shadow well and quickly. Parameter a in equation 3.5-3 is a constant, the value is designed to 0.75 by experiments. The finally result with shadow removal is shown as figure 3.27 and the ratio distrution of figure 3.27 is shown in figure 3.28.

$$Shadow(x,y)=\begin{cases}1 & if \quad current(x,y)<background(x,y) \\ & \quad \& \quad Th1<ratio(x,y)<Th2 \\ 0 & \quad otherwise\end{cases}$$

(3.5-2)

$$Th1 = Mean_{ratio} - a \bullet SD_{ratio}$$

$$Th2 = \mathrm{Mean}_{\mathrm{ratio}} + \mathrm{a} \bullet \mathrm{SD}_{\mathrm{ratio}}$$

(3.5-3)

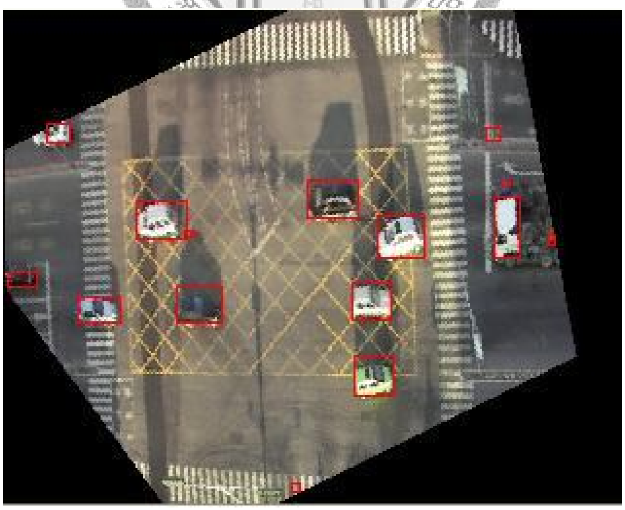


Figure 3.29 The result of shadow removal.

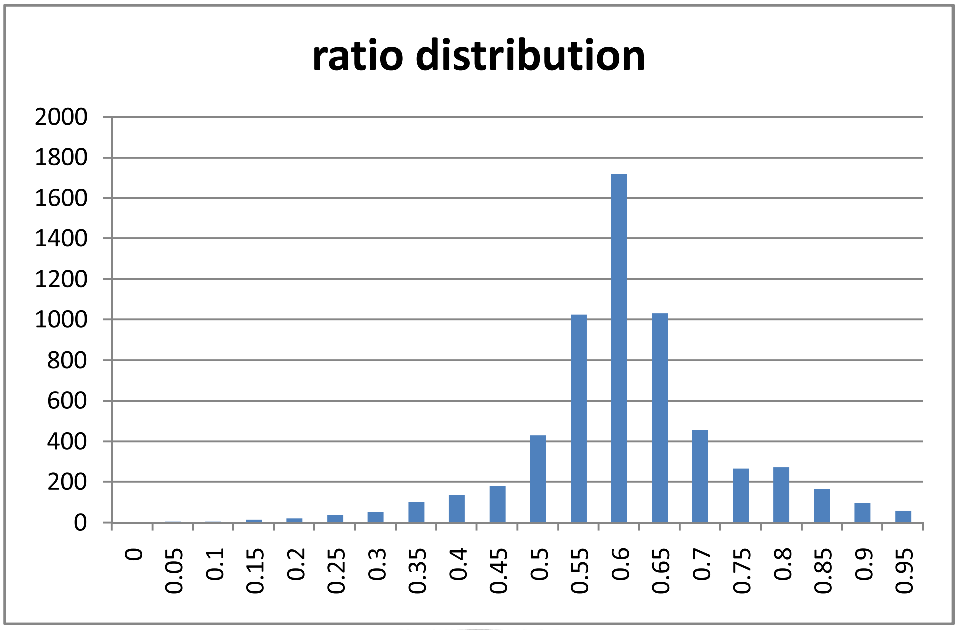


Figure 3.28 Histogram of pixel value ratio.

3.6 Occlusion Resolution

Because of camera slanted angle, vehicle occlusion would occur in digital image that is shown in figure 3.29. This phenomenon is happened when vehicle occlude partial or total another vehicle, vehicles are connected each other on the frame. In human eye, vehicle can be separated easily on the frame when vehicle occlusion is happened. However, for computer, when vehicle occlusion is happened, occluded vehicle would be thought as the same component of another vehicle covering it. That phenomenon would cause error of measuring information from object. According to observant, even though traffic flow is low, vehicle occlusion would be happened probably. In order to resolve this problem for robustness of system, an approach used spatial analysis of region is proposed in this study.

Spatial analysis

In the past, vehicle occlusion can be resolved by feature tracking such as using corner points for tracking. Another way is using optical flow to group the same vector of object. However, using above methods is needed to do complex calculation and spend a lot of time. In order to increase efficiency, using spatial analysis is a way to reach the same function and has a good efficiency at the same time.

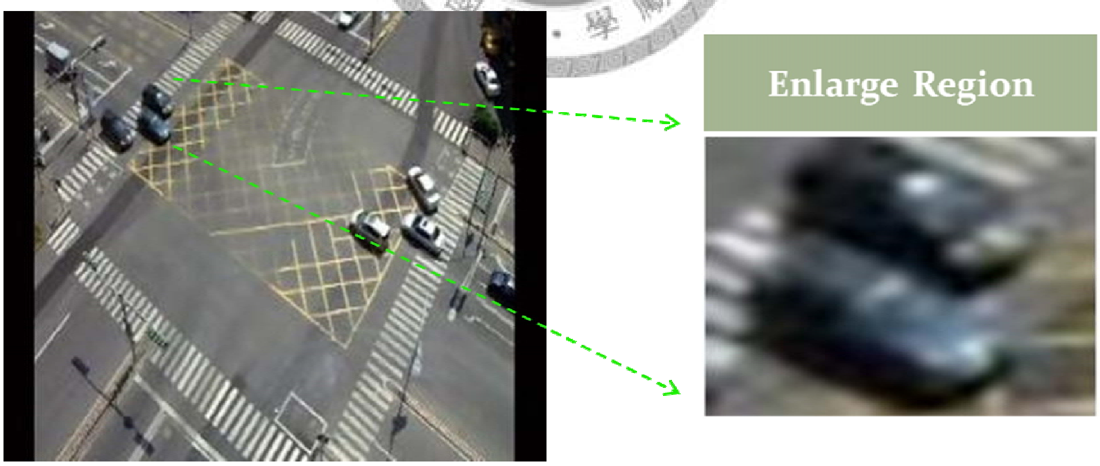


Figure 3.29 Vehicle occlusion.

The first step, to check object is necessary to split or not is important. We have to analyze the width of object in the rectangular boxing after component labeling. If the width is larger than average width of vehicle (shown in table 3.1) and pixel ratio is small than threshold value then the next step is preceded.

Next step, the four extreme points composing of object rectangular boxing is connected to find the short line. If the ratio of short line and longest line is lower than threshold value, the processing of spilt is necessary to be operated. The ratio is defined as following where D_s, D_l are the distance of the shortest and the longest line.

$$\text{line ratio} = \frac{D_s}{D_l} \tag{3.5-1}$$

Table 3.1 Average length and width of different vehicle.

Category	Average Length	Average Width
Sedan	4.31	1.62
Van	4.78	1.66
SUV	4.46	1.71
truck	6.87	1.92
City Bus	10.86	2.46
Motorcycle (50cc~125cc)	1.75	0.65

Split procedure

In this study, vehicle occlusion is classified four kinds, vertical occlusion, horizontal occlusion, left slanting, and right slanting which is shown in figure 3.31. If the object is thought to have occlusion then the non-object region in the rectangular boxing is projected in four different directions, top, underside, left, and right for finding breach to split object. The four directions projection is shown in figure 3.32. Through the projection of non-object region we can find the characteristics of breach which is presented as following.

1. At the breach point, the projection has larger change.
2. Breach points have peak value.

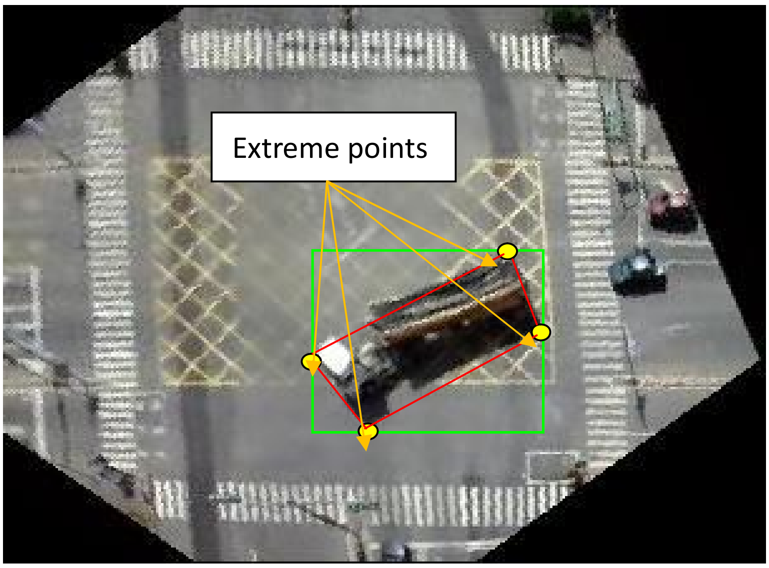


Figure 3.30 Extreme points of rectangle boxing.

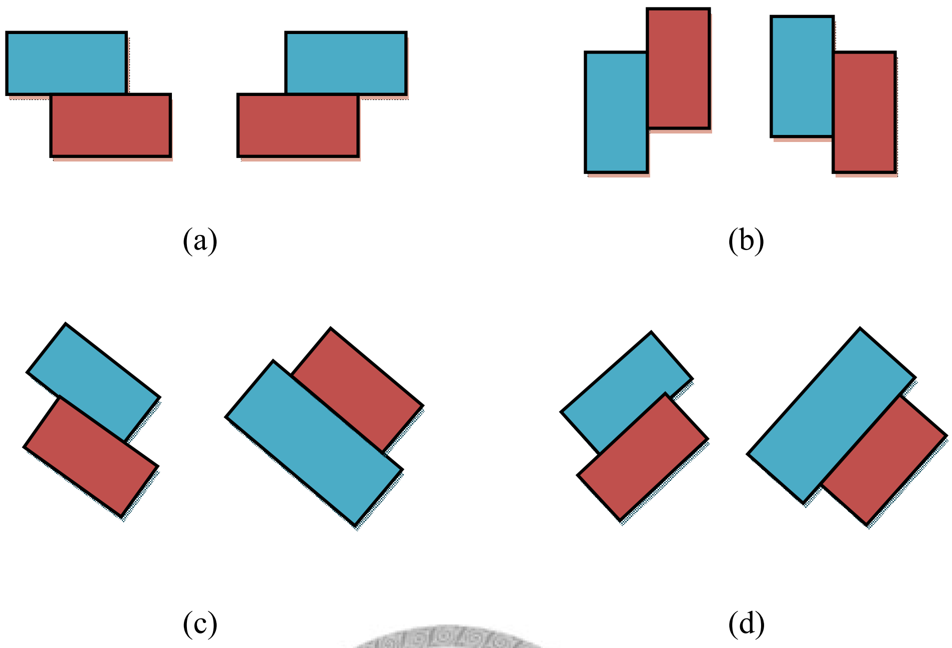


Figure 3.31 Four kinds vehicle occlusion. (a) Horizontal. (b) Vertical. (c) Left slanting. (d) Right slanting.

According these two characteristics, if absolute difference of each two adjacent points in the projection has the largest value, the point is the breach point. If the point has the largest peak value except for extreme points, it would be thought as breach point. After finding breach points, connecting them for splitting occluded object which is shown as figure 3.33, then the object is re-labeled for obtaining the region information. The flow chart of occluded vehicle split is shown as figure 3.34.

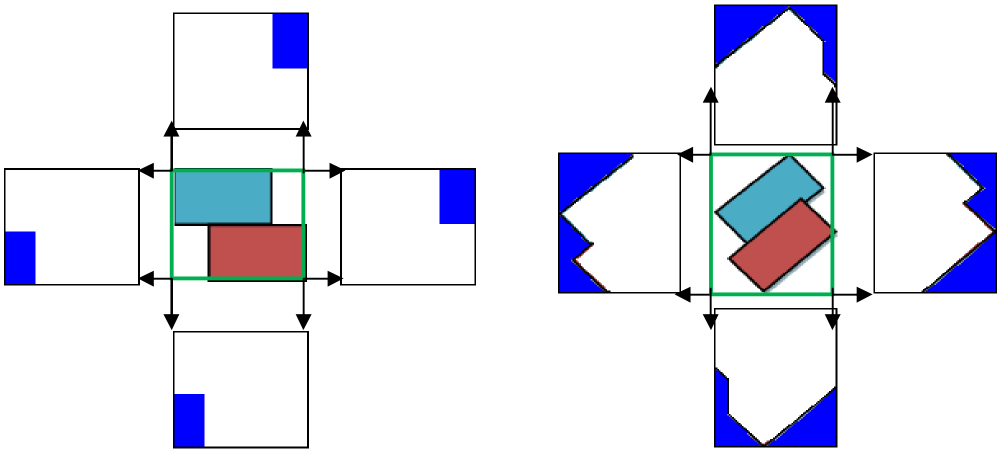
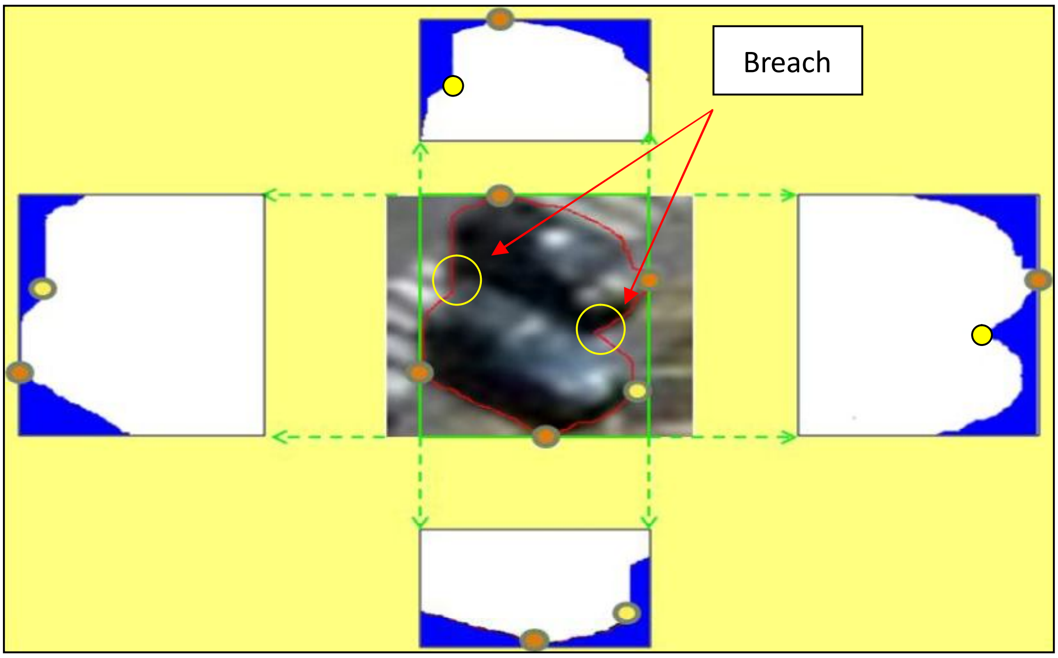
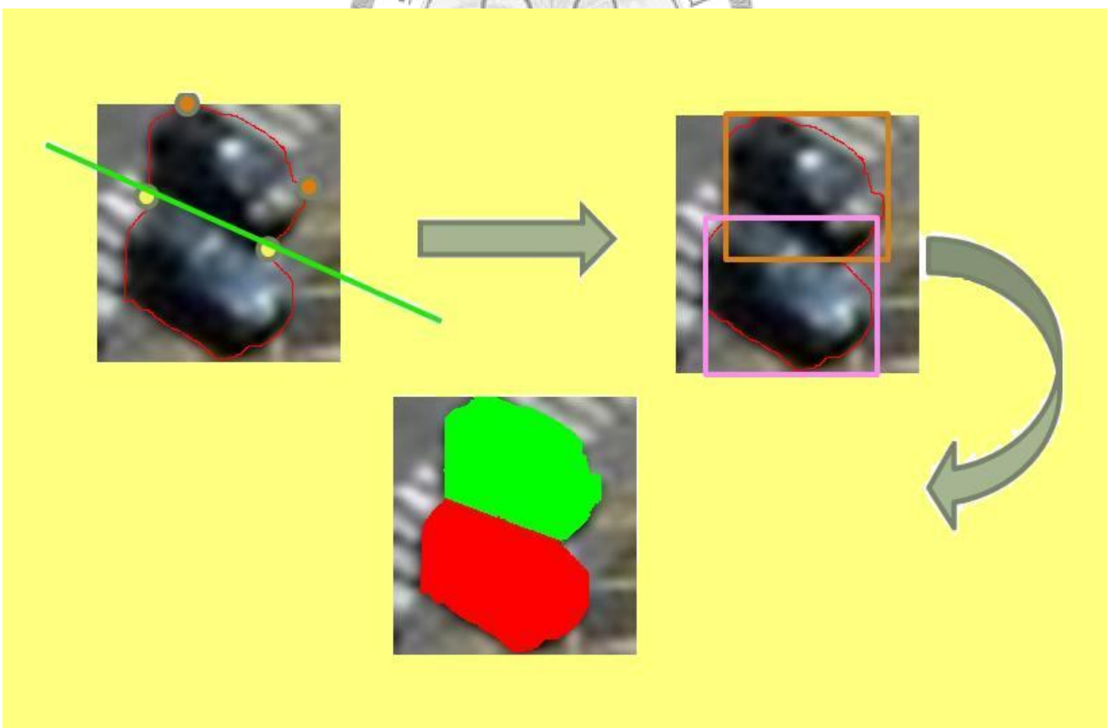


Figure 3.32 Projection of non-object region in four directions.



(a)



(b)

Figure 3.33 Splitting vehicle by breach points.

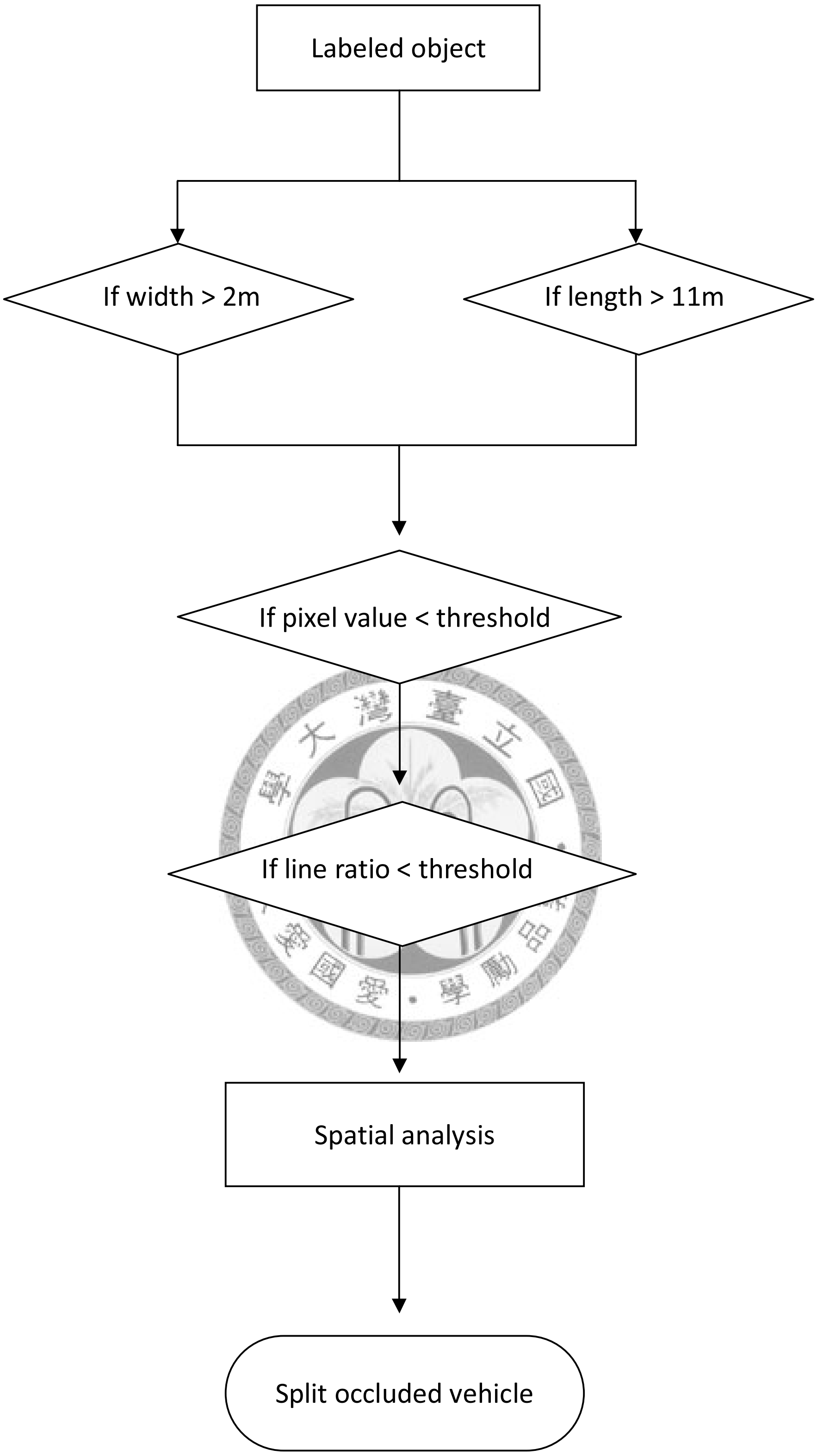


Figure 3.34 Flow chart of occluded vehicle split.

3.8 Vehicle Tracking

In order to obtain the traffic parameters, vehicle tracking is an important procedure in vehicle detection system. When objects were extracted from background, computer did not know the relation of the same object in different time frames. In order to associate the same object in different time frames, to compare the relation of previous time object to match the same object in different time frames is important. If the relation of each object in different time can be realized then we can obtain the trajectory of each vehicle and extract traffic parameters such as turn ratio, traffic flow and velocity. Vehicle tracking is a procedure to associate the same object in different time frames.

In this study, the approach which searches a fixed range to find the minimum distance of two objects in this boxing region is used. Figure 3.35 is illustrated a t time object to search a fixed distance in boxing region. Eq. 3.8-1 is presented the minimum distance of two object region which center locations are (x_1, y_1), (x_2, y_2).

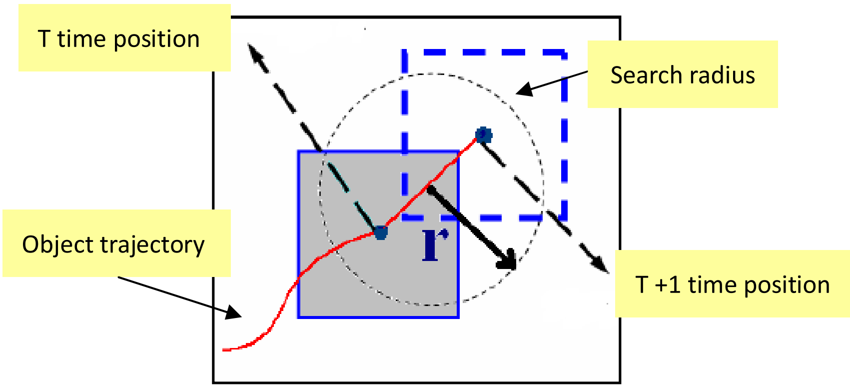


Figure 3.35 Region tracking.

$$\min \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{3.8-1}$$

Because this system have to track motorcycle, just using minimize cannot satisfy with the demand. According to the characteristics of motorcycle, high mobility and high velocity would make the initial tracking error by using minimum distance. So we have to add some estimation rules. In this study, extra estimation is to use the region area, and the pixel value for tracking accurately. The flow chart of matching object is illustrated as following figure 3.36.

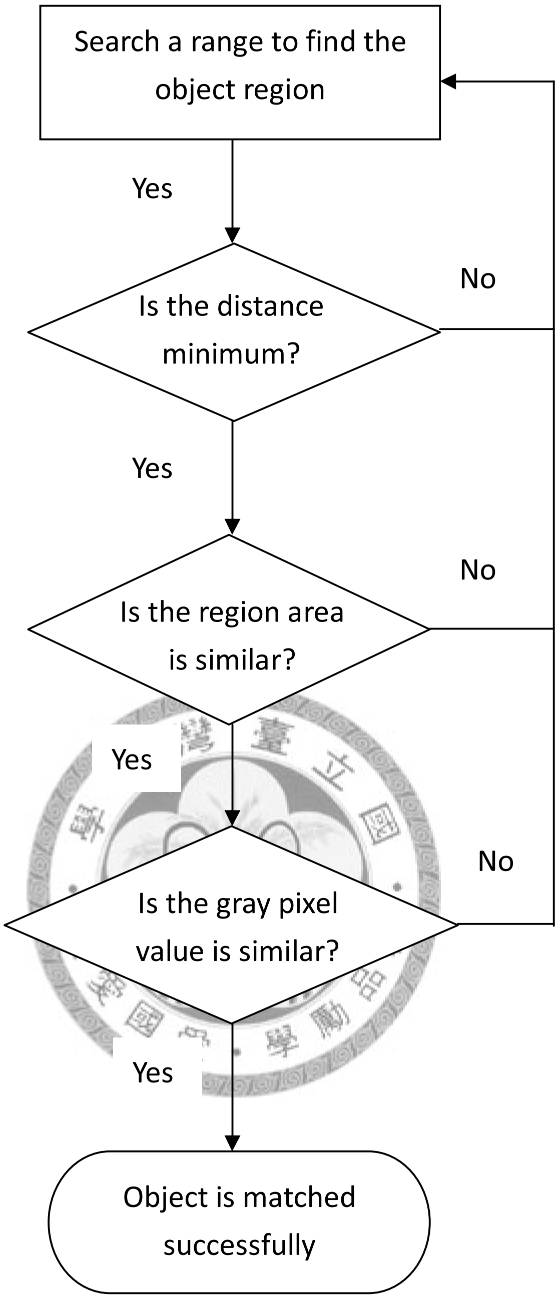


Figure 3.36 The rule of matching object.

Before operating vehicle tracking, we have to initiate the tracking data on frame 1. So vehicle tracking is begun on frame2. The procedure of vehicle tracking is shown in figure 3.37.

After matching all vehicles for associating each vehicle in different time frames, we have to establish the information of each vehicle. In this procedure, there are two important steps which are to add new vehicles information and remove the data of vanished vehicles. If existing object on current frame did not match any object in previous time, this object would be thought a new coming vehicle on the frame. So we have to establish new data about it for further tracking. If a object existed in previous time frame did not match any object in current frame, this object is thought disappeared. So we had to remove its' tracking data to avoid causing tracking error. The result of vehicle tracking is shown in figure 3.38.

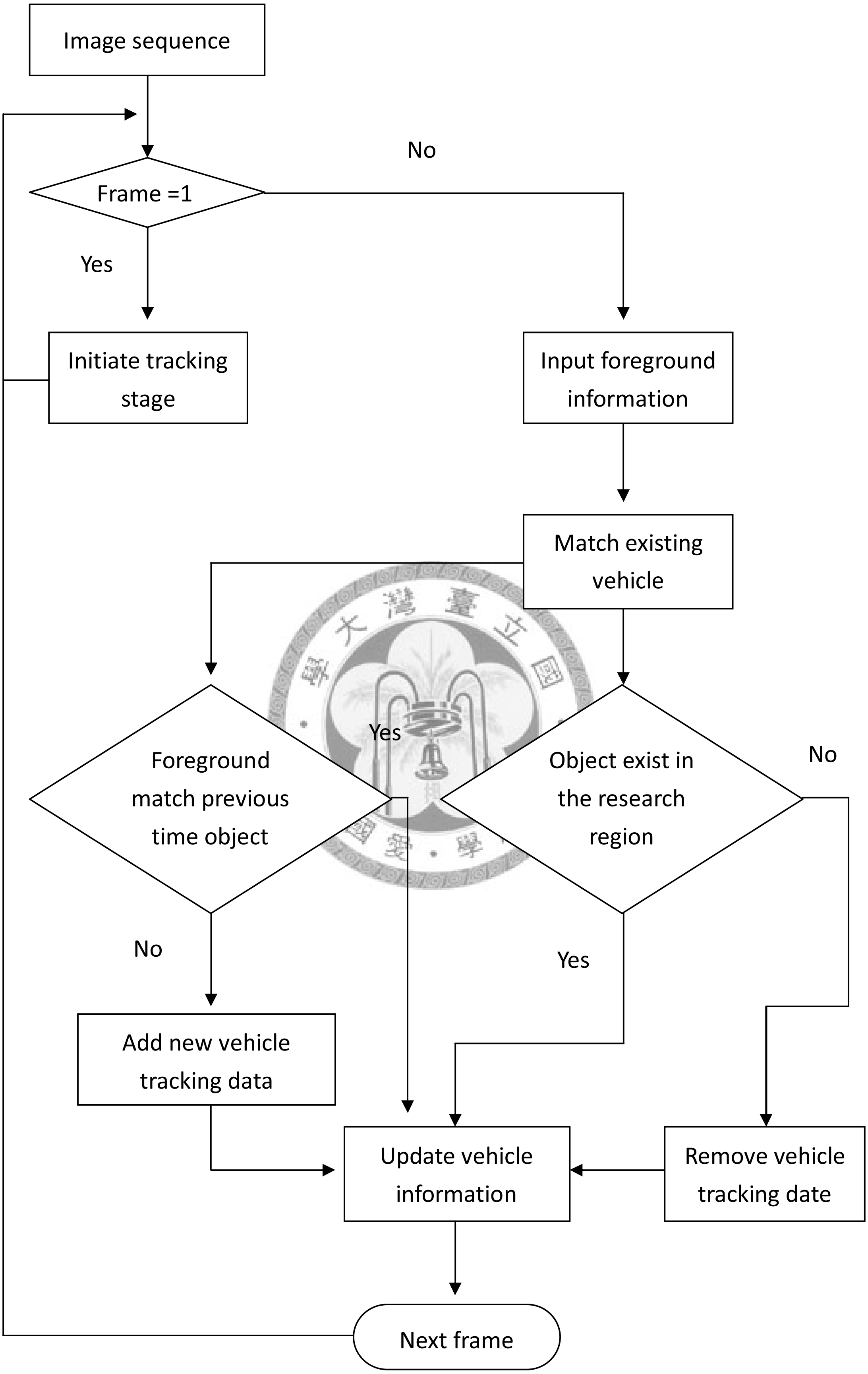


Figure 3.37 The procedure of vehicle tracking.

Chapter 4

Experimental Result

4.1 Introduction

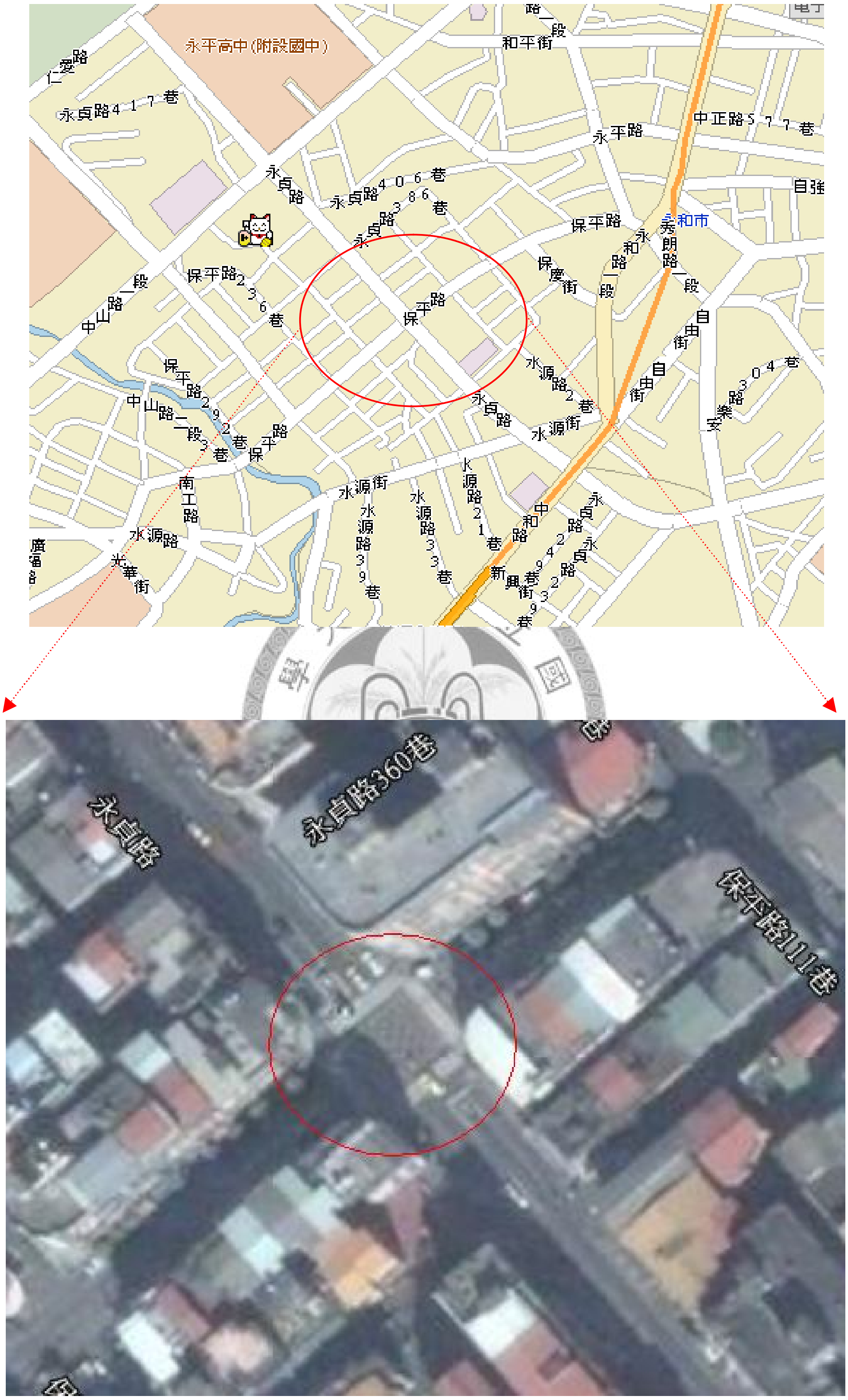
In this chapter, the experimental results of vehicle detection system are shown. This image detection system can obtain traffic flows, turn ratio and the drawing of vehicle trajectory at cross intersection. The image sequence is captured in the daytime which have morning, afternoon and nightfall tested by this system.

The experimental site in the daytime is at the cross intersection of Chunjing road and Gongjheng road in the Luodong, Yilan shown in figure 4.1. At night, the experimental site is at the cross intersection of Baoping and Yongzhen in Yonghe city.

In section 4.2, the main user interface and coordinates transfer are introduced. In sections 4.3, the results of proposed approaches will be displayed. In section 4.4, the experimental data and accurate rate table in different tested video will be displayed. Finally, the results of this system will be analyzed.


四維路
豐年路
文林路
學府路
羅東高中
樹人路
純精路三段
羅東國中
復興路一段
中華路
公正路284巷
愛國路
公正路
林森路
興東路
四育路
尚仁街
民治街
民享街
光華街
國華國中
公正國小
民生路
天津路
培英路
杏林街
翰林街
國華街
進德街
台汽羅東站
民權路

(a)



(b)

Figure 4.1　Experimental sites.

4.2 User Interface

User interface in this system have two types, Main UI and coordinates transfer UI which are introduced as following.

Main UI

Main User Interface of proposed image detection system has three main parts. First part is to show the tested image sequence and let us know the results of image processing. Second part is to display the tracking trace that can let us know the weaving at intersection. Third part is to count the traffic flow in four directions. Each direction has three different flows, left, straight and right. M, S, B denotes motorcycle, compact vehicle and full-size vehicle. This interface is displayed in figure 4.2

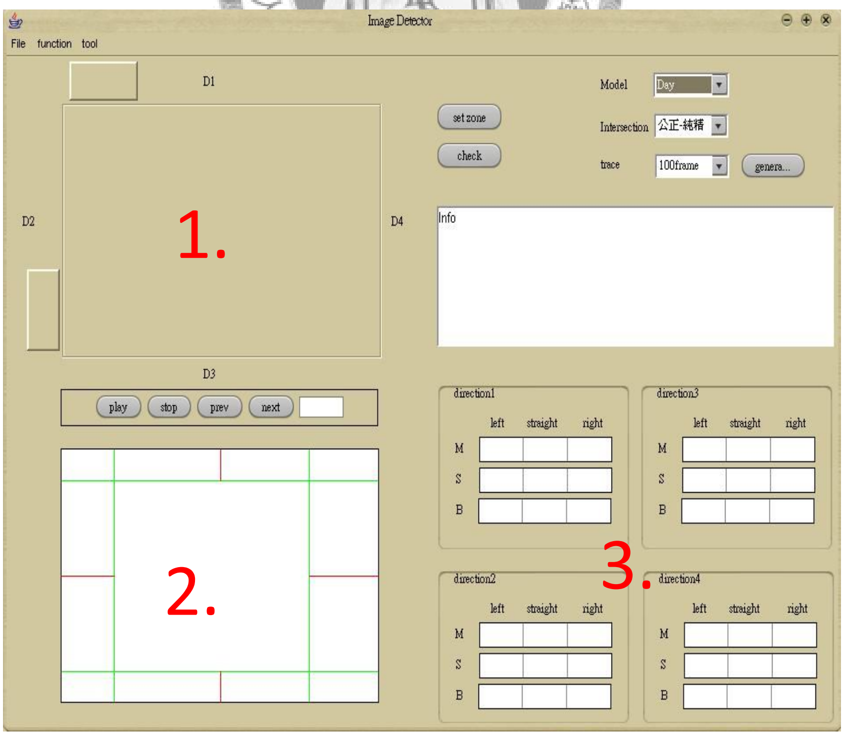


Figure 4.2 Main User Interface.

Coordinates transfer UI

Before implement the Main User Interface, we have to obtain basic parameters by Coordinates transfer User Interface presented in figure 4.3. In Coordinates transfer UI, there are four main parts. First part is to show the image to be had coordinates transfer. We have to draw two parallel lines in true world on this image. Second part is to display the result of top-view image. Third part will show the information of vanishing points coordinates. Forth part are the bar we can adjust to change the parameters value. While parameters are adjusted, the result display in real-time.

Figure 4.3 Coordinates transfer User Interface.

4.3 Approach Result

Background Image

Background construction at intersection is difficult than general road section. We are hard to obtain the complete whole background because of the waiting car. Forbye, we are just interesting in intersection region not road section. Even if the background image exist car on the road section, it would not influence the processing result. We only need to obtain the complete background of intersection region. Three background images in different time, morning, afternoon and nightfall are shown in figure 4.5.

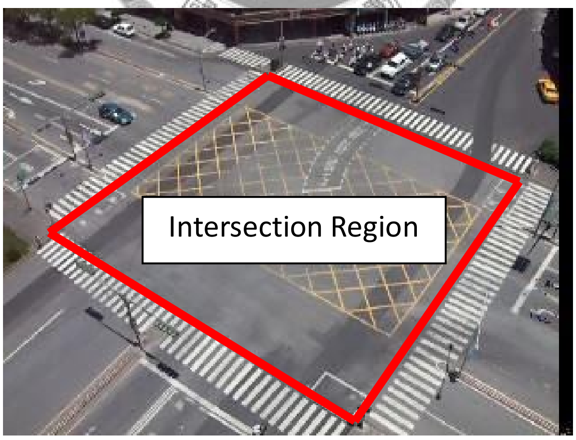
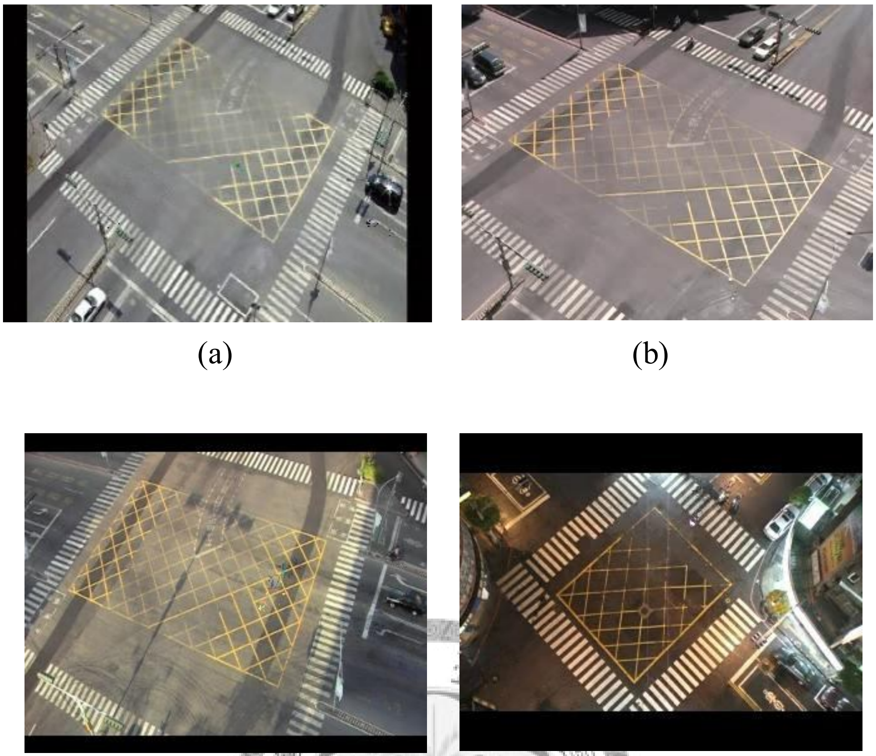


Figure 4.4 Intersection region.



(a) (b) (c) (d)

Figure 4.5 Background image.

Top-view Image

We need to have the information including the height of installed camera, vanishing point coordinates and tilt angle beforehand. After acquiring these parameters, we can obtain pan angle and focal length for coordinates transfer. The finally result of coordinates transfer for becoming Top-view image and its information is displayed in figure 4.6.

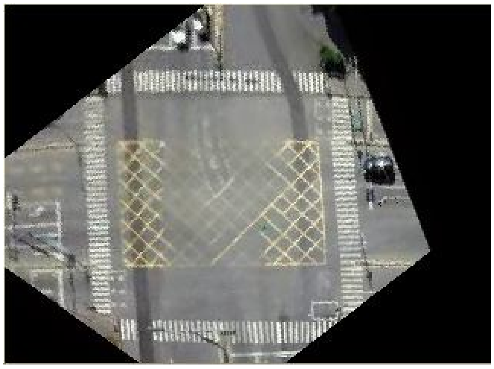
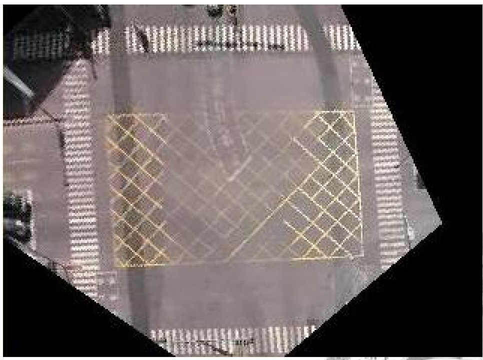
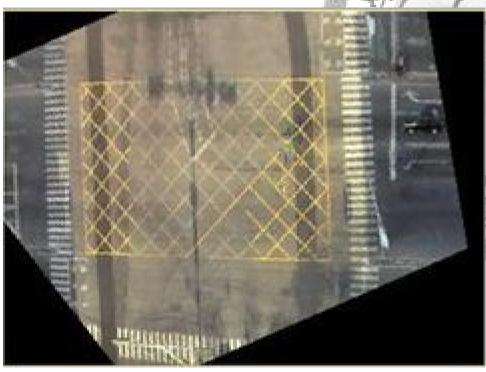
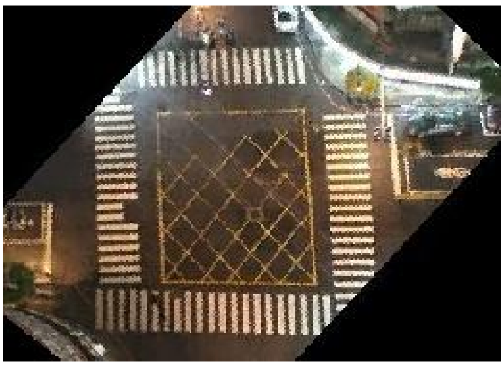
	Time: morning Vanishing point: (365,-448) Height: 40m Tilt angle: 71 degree Pan angle:38 degree Top-view H: 53 m Top-view Y: 12 m
	Time: afternoon Vanishing point: (496,-401) Height: 40m Tilt angle: 43 degree Pan angle:40 degree Top-view H: 80 m Top-view Y: 2 m
	Time: nightfall Vanishing point: (285,-547) Height: 40m Tilt angle: 57 degree Pan angle:22.5 degree Top-view H: 53 m Top-view Y: 0 m
	Time: night Vanishing point: (3664,-3011) Height: 37m Tilt angle:66 degree Pan angle:60 degree Top-view H:39 m Top-view Y:0 m

Figure 4.6 Top-view image and their information.

Dynamic threshold

Dynamic threshold has a benefit for increasing the robust of vehicle segmentation that can eliminate much noise on binary image to acquire good effect especially when it combined background update. In figure 4.7, we can see the obvious result at T+3 times.

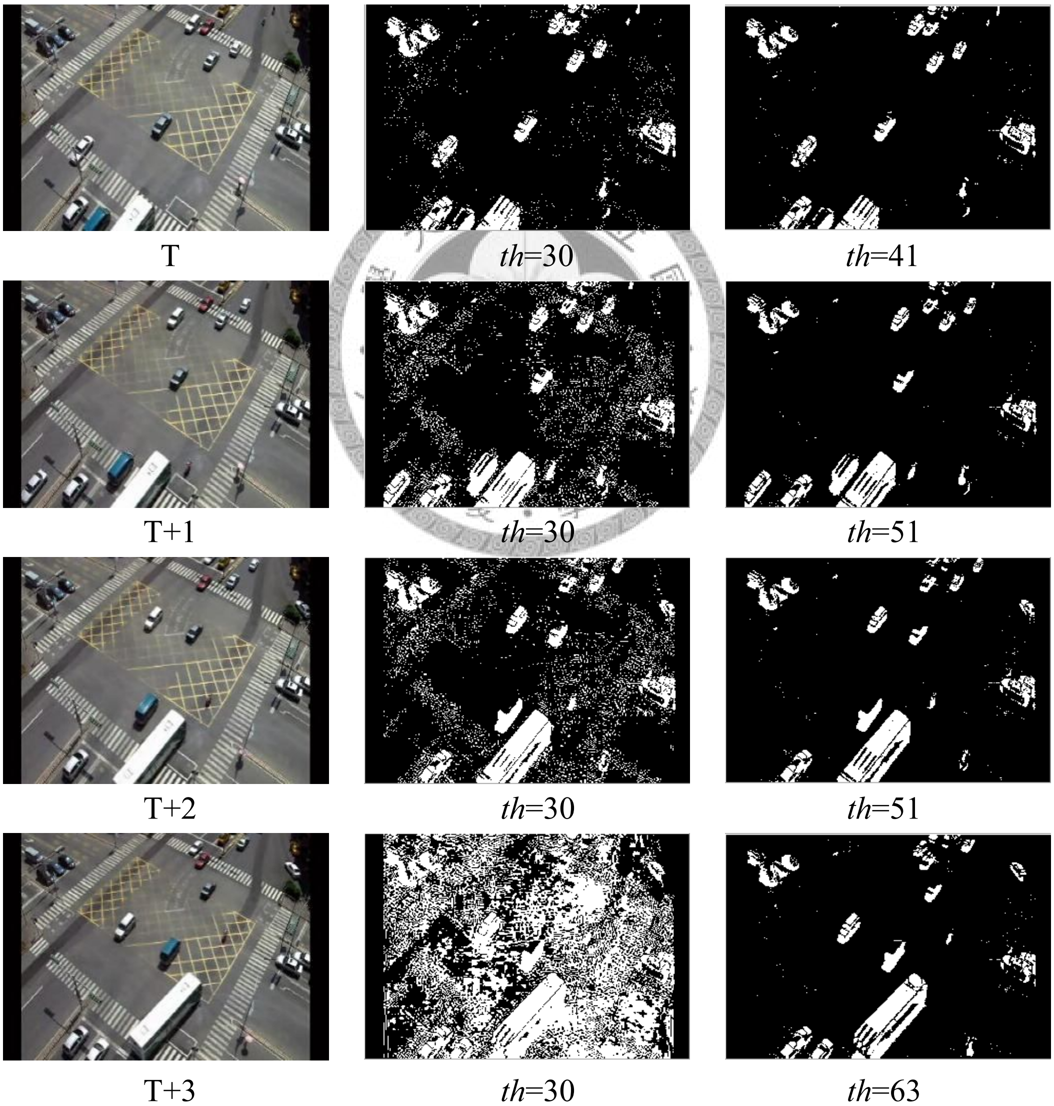
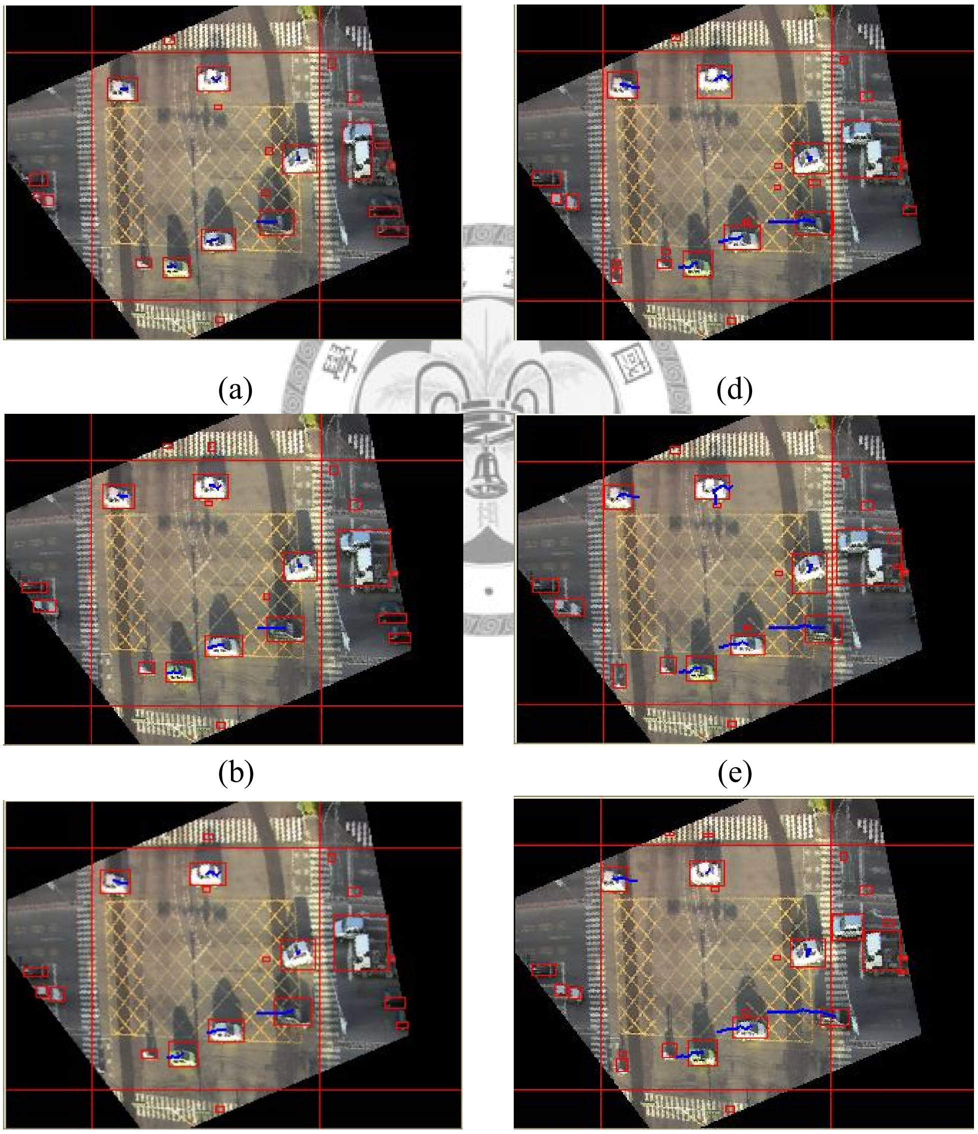


Figure 4.7 The results of vehicle segmentation with dynamic threshold.

Shadow removal

After using the approach of shadow removal proposed in this thesis, the most region of shadow had removed. The good result is shown as following figure. In figure 4.8, even motorcycle can be extracted after using shadow removal proposed in this thesis.



(a) (d) (b) (e) (c) (f)

Figure 4.8 Result of shadow removal.

Occlusion resolution

In our experiment, the occlusion of vehicle usually happened in horizontal flow. We can see the upper write car was occluded by under black car in figure 4.9 then these two vehicles are thought as the same object in image detection system. The result of occlusion resolution is shown in figure 4.10. After processing, these two joint vehicles are thought two vehicles.

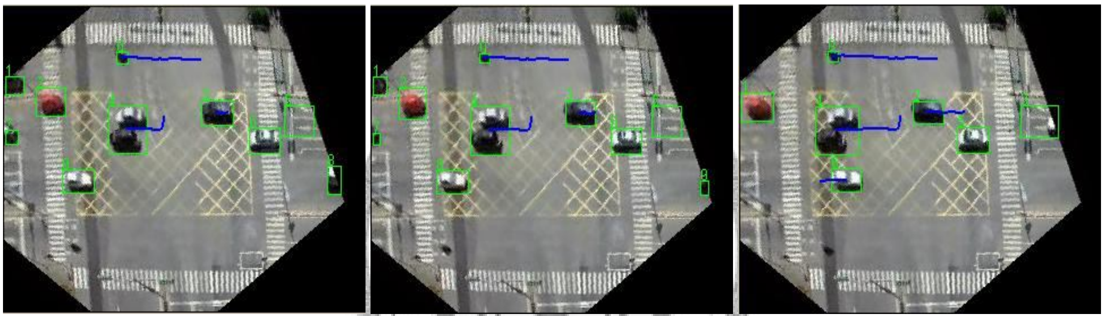


Figure 4.9 Occluded vehicle.

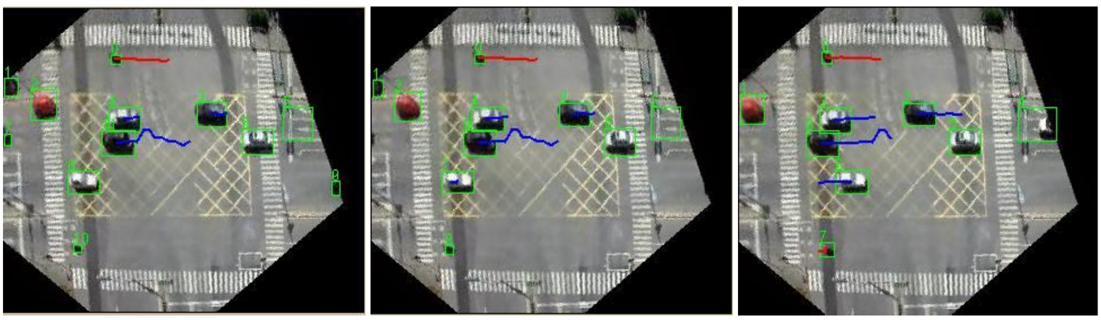
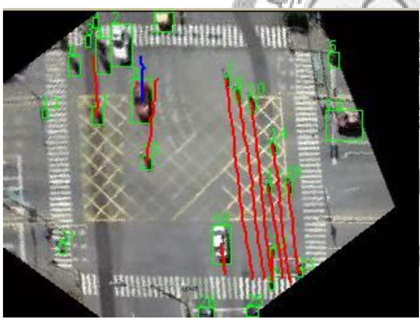


Figure 4.10 The result of occlusion resolution.

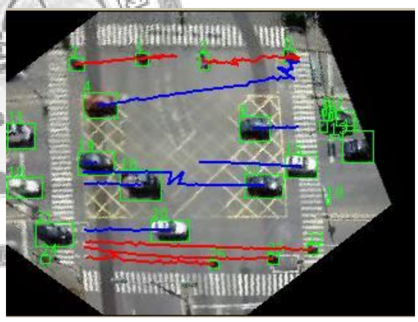
Vehicle tracking

Vehicle tracking is very complex at intersection because traffic flows have different directions. In this thesis, there are three tracking types at intersection, horizontal tracking, vertical tracking and slanted tracking. When vehicle had been tracked we could obtain the trajectory of vehicle shown in figure 4.11.

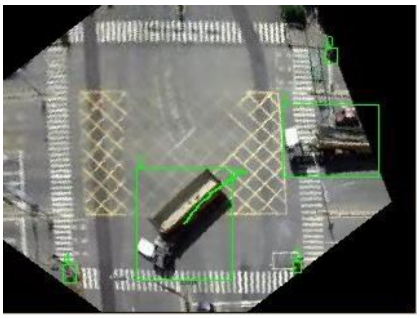
In this thesis, vehicles were classified tree types, motorcycle, compact vehicle and full-size vehicle. The definition of Full-size in this system is the length vehicle more than 9 m. Red trajectory denotes motorcycle. Blue trajectory denotes compact vehicle. Green trajectory denotes full-size vehicle.



(a)



(b)



(c)

Figure 4.11 Vehicle tracking. (a) Vertical tracking. (b) Horizontal tracking. (c) Slanted tracking.

Drawing of vehicle trajectory

By the drawing of vehicle trajectory, we can see the weaving at intersection. The drawings are shown as following figures.

Figure 4.12　The drawing of vehicle trajectory during 100 frame.

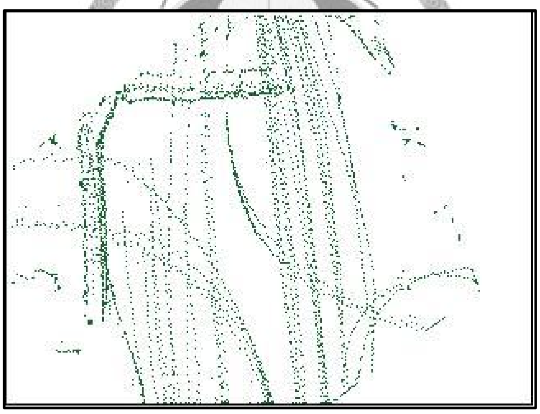


Figure 4.13　The drawing of vehicle trajectory during 500 frame.

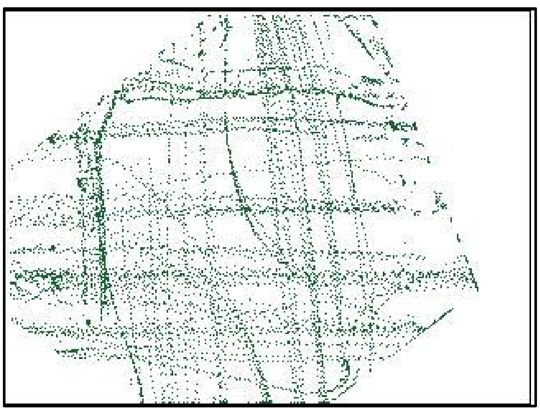


Figure 4.14　The drawing of vehicle trajectory during 1000 frame.

4.4 Experimental Estimation

In this section, the experimental estimation of traffic flow and turn ratio in three tested time are displayed. Motorcycle flow in this system just considers straight direction and right turn direction.

Accurate rate (AR) is defined as following equation 4.4-1. Estimation is the calculation of proposed system.

$$AR(\%) = 1 - \left(\frac{|estimation - actual\ data|}{actual\ data}\right) \qquad (4.4\text{-}1)$$

$$Left\ turn\ ratio = \frac{V_{left}}{V_{total}} \qquad (4.4\text{-}2)$$

$$Right\ turn\ ratio = \frac{V_{right}}{V_{total}} \qquad (4.4\text{-}3)$$

V_{total}, V_{left} *and* V_{right} are traffic volume of total, left and right in each direction.

Because motorcycle need two-step turn left, the left turn flow was thought another straight direction in this system.

1. Morning

The time of Tested video in the morning has 15 minutes. Table 4.1 display the total traffic flow of motorcycle, compact and full-size vehicle at intersection The accurate rates of three type vehicles are more than 95%.

Table 4.1 Total traffic flow of three types vehicles in the morning.

	Motorcycle	Small car	Full-size vehicle
Detection data	215	409	12
Actual data	224	416	12
Accurate rate	95.98%	98.32%	100%

A. motorcycle

The motorcycle estimation of traffic flow and turn ratio in the morning are displayed in table 4.2 and table 4.3. Accurate rates of motorcycle volume are all more then 80%.

Table 4.2 Traffic flow of motorcycle in the morning.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	X			64	60	93.33	0	0	100
Approach 2	X			36	34	94.12	1	1	100
Approach 3	X			77	93	82.81	0	0	100
Approach 4	X			38	37	97.30	0	0	100

Table 4.3 Turn ratio of motorcycle in the morning.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	X	X	X	0	0	100
Approach 2	X	X	X	0.0270	0.0286	94.41
Approach 3	X	X	X	0	0	100
Approach 4	X	X	X	0	0	100

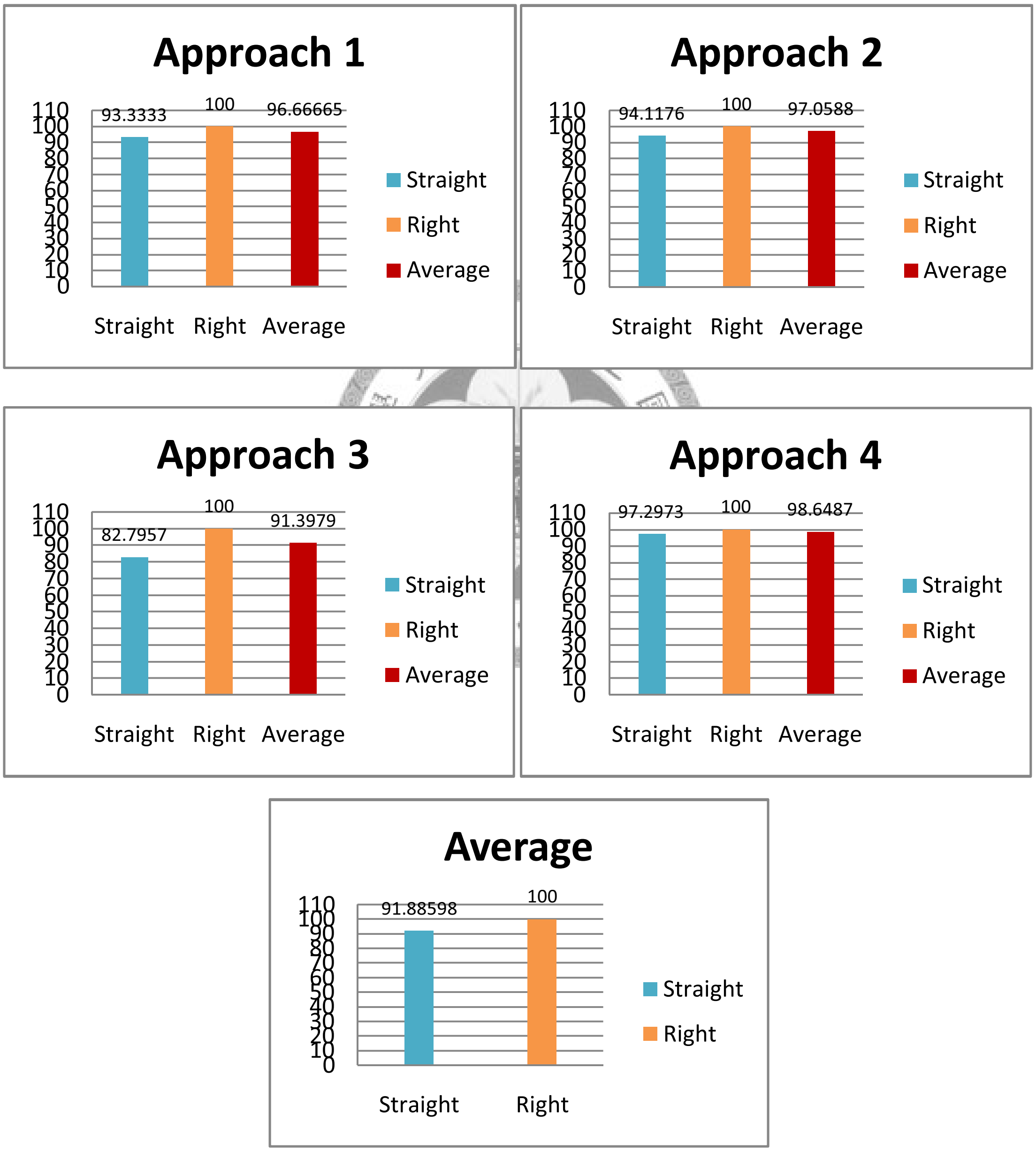


Figure 4.15 The accurate rate of motorcycle volume on each approach in the morning.

B. Small vehicle

The small car estimation of traffic flow and turn ratio in the morning are displayed in table 4.4 and table 4.5. Except for right turn, other directions of accurate rate are more than 80%.

Table 4.4 Traffic flow of small car in the morning.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	34	34	100	58	54	92.59	3	2	50
Approach 2	4	5	80	100	106	95.24	9	12	75
Approach 3	41	41	100	39	38	97.37	5	4	75
Approach 4	24	24	100	87	90	96.67	6	6	100

Table 4.5 Turn ratio of small car in the morning.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	0.3579	0.3778	94.73	0.0316	0.0222	57.66
Approach 2	0.0354	0.0406	87.19	0.0796	0.0975	81.64
Approach 3	0.4824	0.5061	95.32	0.0588	0.0482	78
Approach 4	0.2051	0.2	97.45	0.0513	0.05	97.74

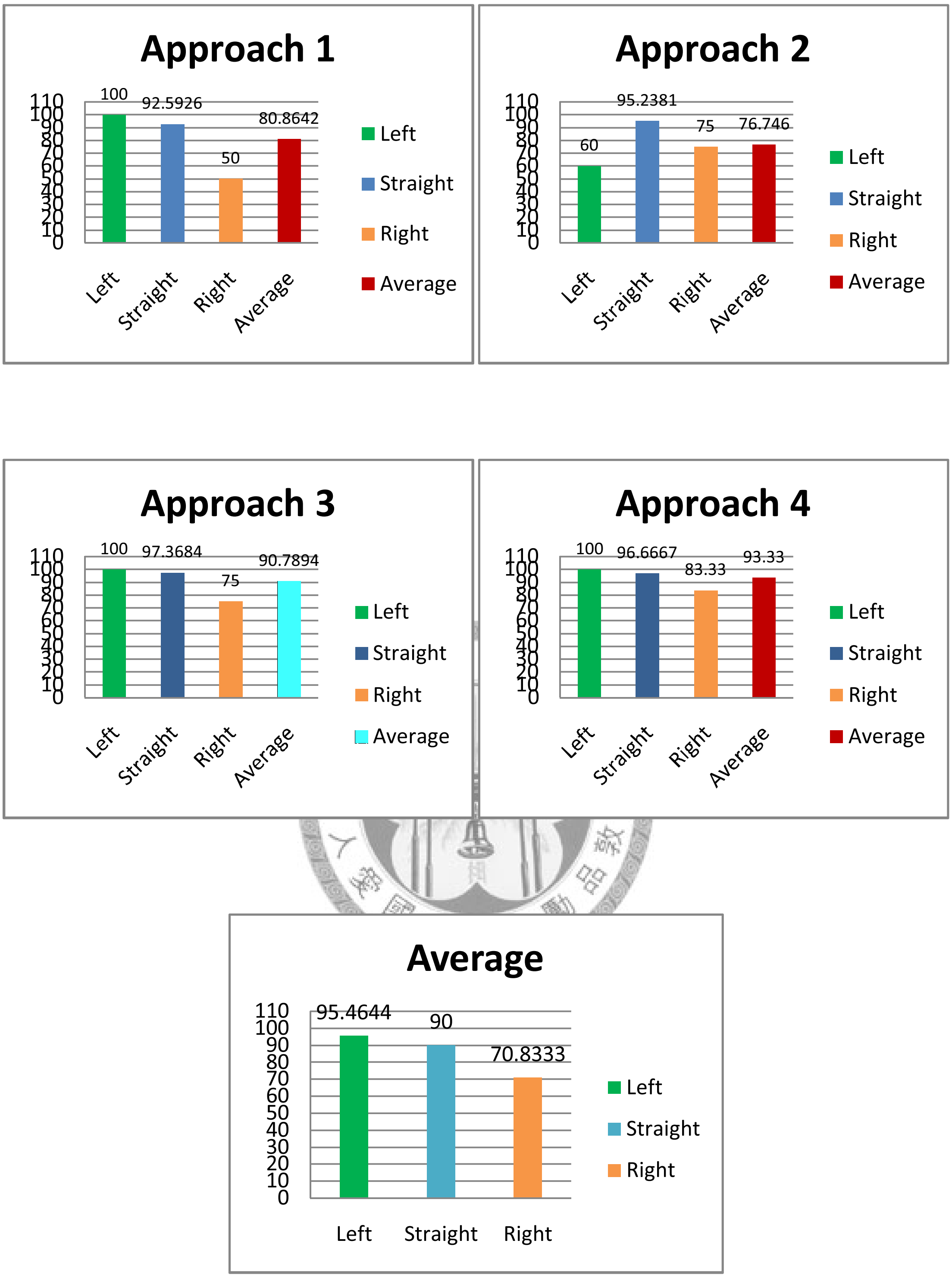


Figure 4.16 The accurate rate of small car volume on each approach in the morning.

C. Full-size vehicle

The full-size vehicle estimation of traffic flow and turn ratio in the morning are displayed in table 4.6 and table 4.7. Full-size vehicle has high accurate rate in this system.

Table 4.6 Traffic flow of full-size vehicle in the morning.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	0	0	100	0	0	100	0	0	100
Approach 2	0	0	100	2	2	100	0	0	100
Approach 3	0	0	100	0	0	100	5	5	100
Approach 4	4	4	100	1	1	100	0	0	100

Table 4.7 Turn ratio of full-size vehicle in the morning.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	0	0	100	0	0	100
Approach 2	0	0	100	0	0	100
Approach 3	0	0	100	1	1	100
Approach 4	1	1	100	0	0	100

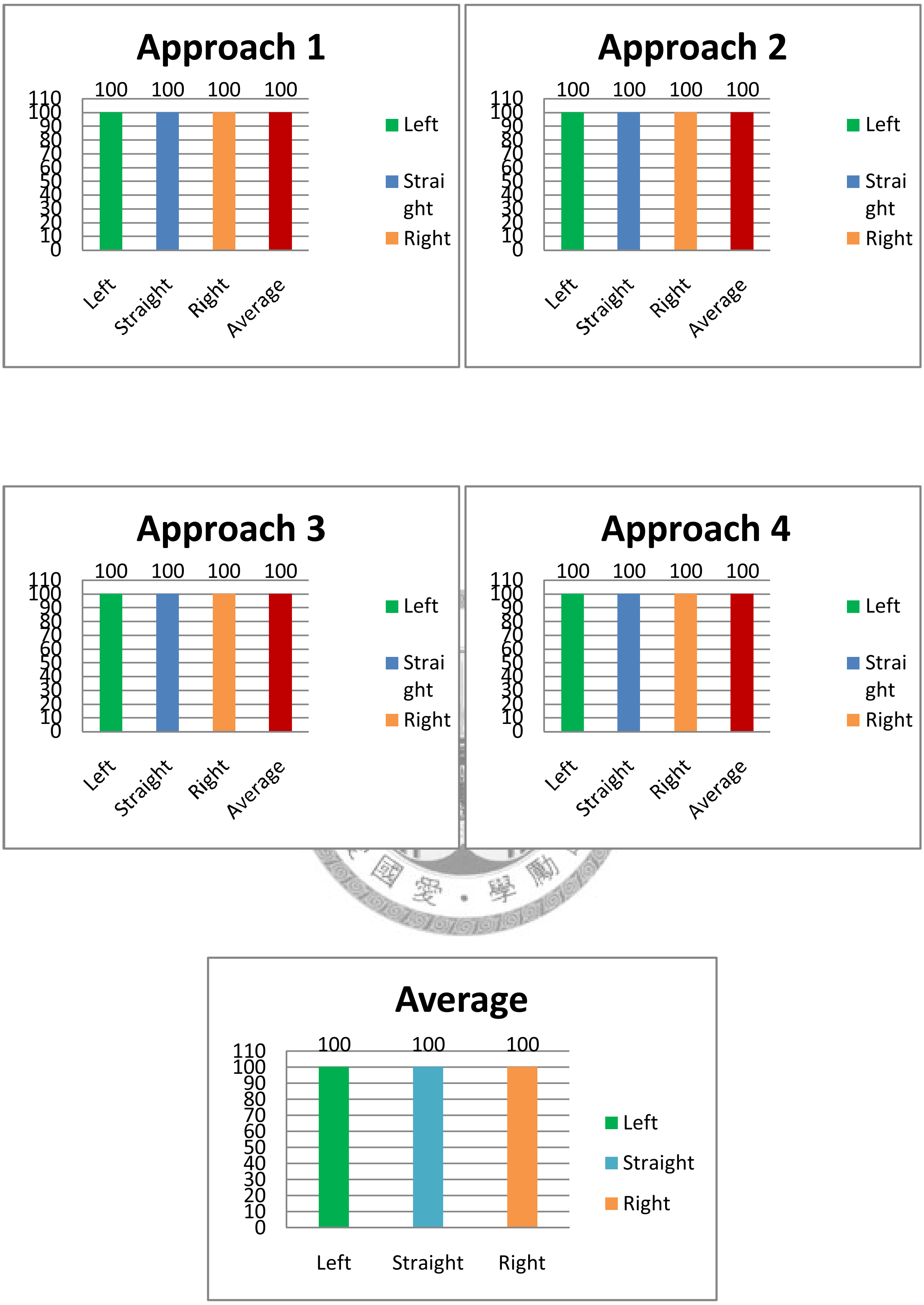


Figure 4.17 The accurate rate of full-size vehicle volume on each approach in the morning.

2. Afternoon

The time of Tested video in the afternoon has 14 minutes. Table 4.10 display the total traffic flow of motorcycle, compact and full-size vehicle at intersection The accurate rates of three type vehicles are more than 95%.

Table 4.10 Total traffic flow of three types vehicles in the afternoon.

	Motorcycle	Small car	Full-size vehicle
Detection data	218	308	12
Actual data	227	319	12
Accurate rate	95.04%	96.55%	100%

A. Motorcycle

The motorcycle estimation of traffic flow and turn ratio in the afternoon are displayed in table 4.11 and table 4.12. Accurate rate of motorcycle volume are all more than 70%.

Table 4.11 Traffic flow of motorcycle in the afternoon.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	X			65	67	97.01	0	0	100
Approach 2	X			42	44	95.45	0	0	100
Approach 3	X			85	81	95.06	0	0	100
Approach 4	X			26	35	74.29	0	0	100

Table 4.12 Turn ratio of motorcycle in the afternoon.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	X	X	X	0	0	100
Approach 2	X	X	X	0.	0	100
Approach 3	X	X	X	0	0	100
Approach 4	X	X	X	0	0	100

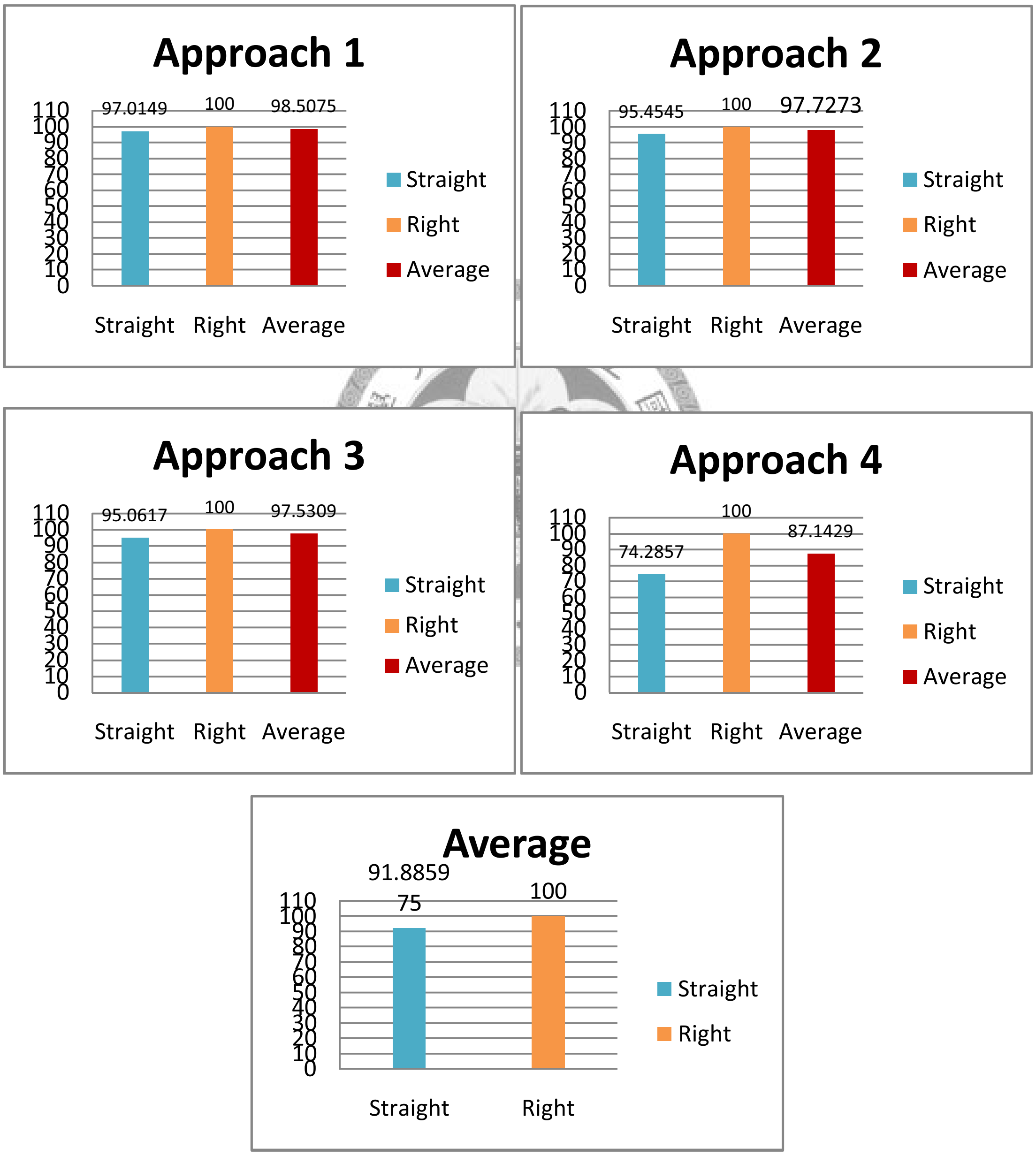


Figure 4.18 The accurate rate of motorcycle volume on each approach in the afternoon.

B. Small car

The small car estimation of traffic flow and turn ratio in the afternoon are displayed in table 4.13 and table 4.14. Accurate rate of compact vehicle volume are all more than 70%.

Table 4.13 Traffic flow of small car in the afternoon.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	9	7	71.43	38	37	97.3	4	5	80
Approach 2	7	7	100	77	82	93.9	1	1	100
Approach 3	28	28	100	50	53	94.34	7	7	100
Approach 4	16	16	100	69	74	93.24	2	2	100

Table 4.14 Turn ratio of small car in the afternoon.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	0.1765	0.1429	76.49	0.0784	0.1020	76.86
Approach 2	0.0824	0.0778	94.09	0.0118	0.0111	92.79
Approach 3	0.3294	0.3182	96.48	0.0824	0.08	97
Approach 4	0.1839	0.1739	94.25	0.023	0.0217	94.01

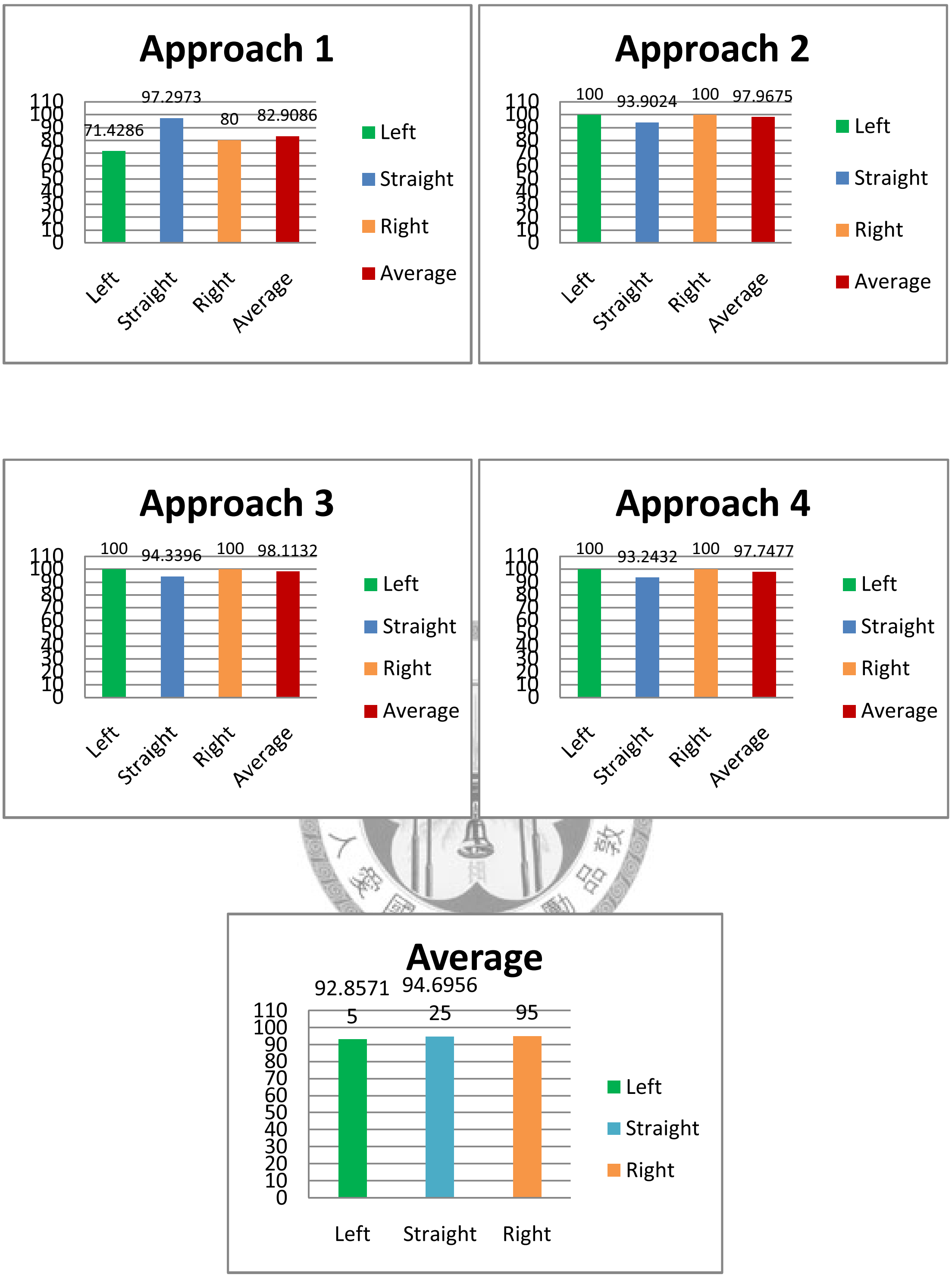


Figure 4.19 The accurate rate of small car volume on each approach in the afternoon.

C. Full-size vehicle

The full-size vehicle estimation of traffic flow and turn ratio in the afternoon are displayed in table 4.15 and table 4.16. Full-size vehicle has high accurate rate in the afternoon. Accurate rate of full-size volume are 100%.

Table 4.15 Traffic flow of full-size vehicle in the afternoon.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	0	0	100	1	1	100	1	1	100
Approach 2	0	0	100	3	3	100	0	0	100
Approach 3	1	1	100	2	2	100	0	0	100
Approach 4	3	3	100	1	1	100	0	0	100

Table 4.16 Turn ratio of full-size vehicle in the afternoon.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	0	0	100	0.5	0.5	100
Approach 2	0	0	100	0	0	100
Approach 3	0.3333	0.3333	100	0	0	100
Approach 4	0.75	0.75	100	0	0	100

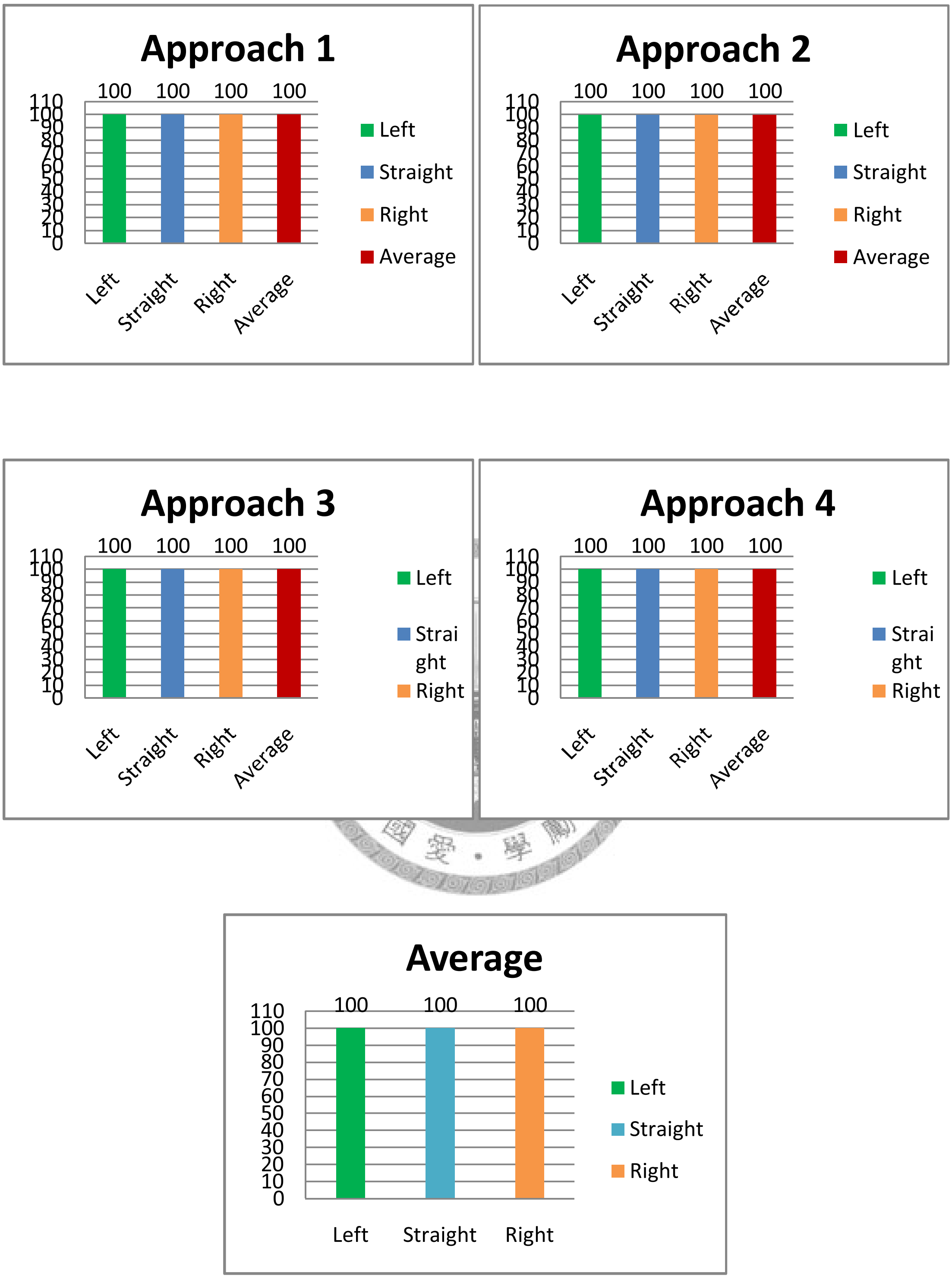


Figure 4.20 The accurate rate of full-size volume on each approach in the afternoon.

3. Nightfall

The time of Tested video in the afternoon has 9 minutes. Table 4.19 display the total traffic flow of motorcycle, compact and full-size vehicle at intersection. The accurate rates of three type vehicles are more than 88%.

Table 4.19 Total traffic flow of three types vehicles in the nightfall.

	Motorcycle	Small car	Full-size vehicle
Detection data	245	288	5
Actual data	267	307	5
Accurate rate	91.76	93.81	100%

A. Motorcycle

The motorcycle accurate rate of traffic flow and turn ratio in the nightfall are shown in table 4.20 and table 4.21. The right turn of motorcycle in the nightfall obtain bad result.

Table 4.20 Traffic flow of motorcycle in the nightfall.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	X			84	101	83.17	8	0	0
Approach 2	X			16	46	34.78	0	0	100
Approach 3	X			76	78	97.44	0	0	100
Approach 4	X			61	42	54.76	0	0	100

Table 4.21 Turn ratio of motorcycle in the nightfall.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	X	X	X	0.2222	0	0
Approach 2	X	X	X	0	0	100
Approach 3	X	X	X	0	0	100
Approach 4	X	X	X	0	0	100

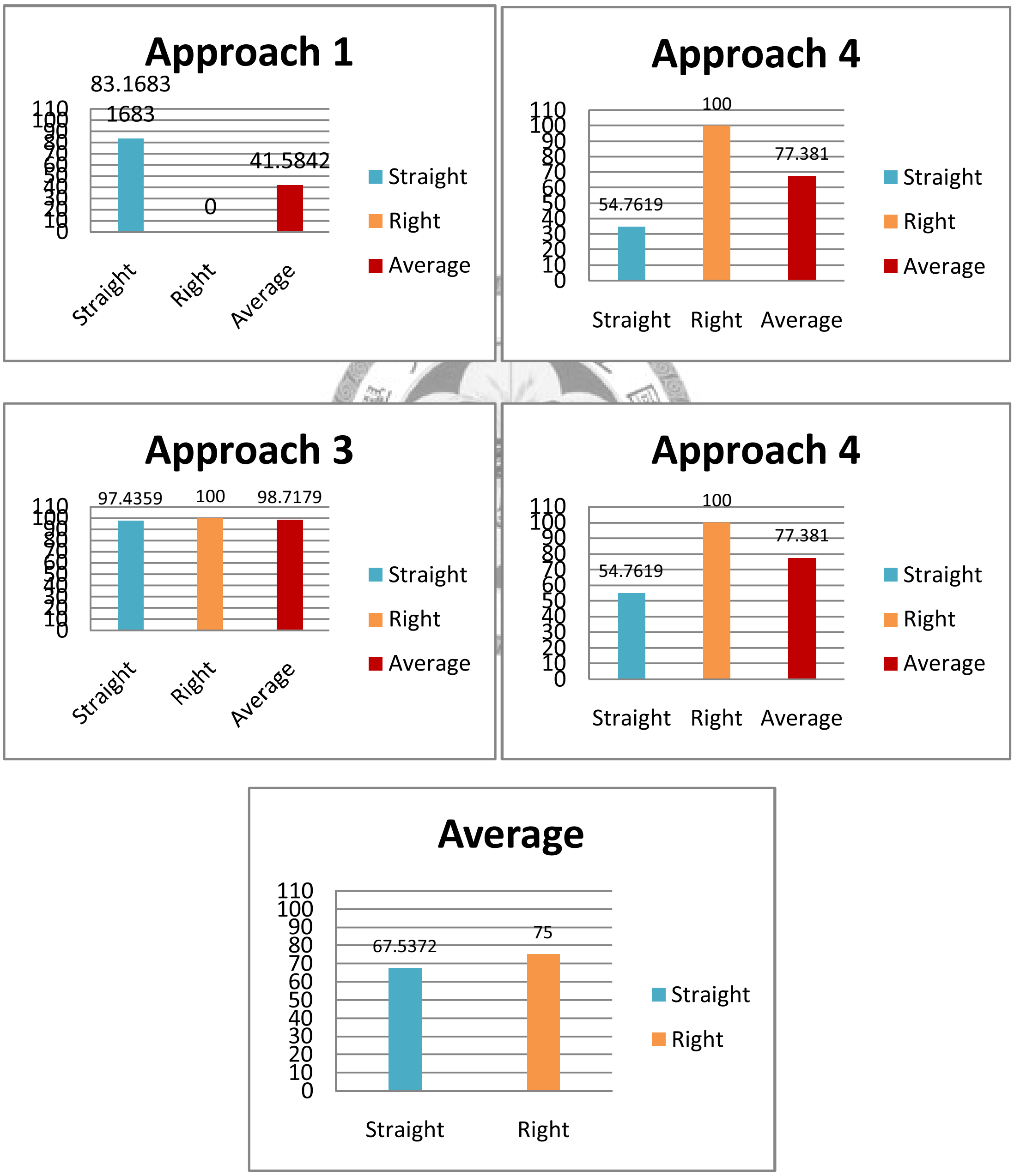


Figure 4.21 The accurate rate of motorcycle volume on each approach in the nightfall.

B. Small car

The compact vehicle estimation of traffic flow and turn ratio in the nightfall are displayed in table 4.22 and table 4.23. Accurate rate of compact vehicle volume are all more than 70%.

Table 4.22 Traffic flow of small car in the nightfall.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	15	16	93.75	51	41	75.61	5	4	75
Approach 2	9	13	69.23	77	78	98.72	5	6	83.33
Approach 3	19	21	90.48	21	25	84	1	3	33.33
Approach 4	29	31	93.55	53	77	79.22	3	2	50

Table 4.23 Turn ratio of small car in the nightfall.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	0.2113	0.2623	80.56	0.0704	0.0656	92.68
Approach 2	0.0989	0.134	73.81	0.0549	0.0619	88.69
Approach 3	0.4634	0.4286	91.88	0.0244	0.0612	36.60
Approach 4	0.3412	0.2818	78.92	0.0353	0.0182	6.04

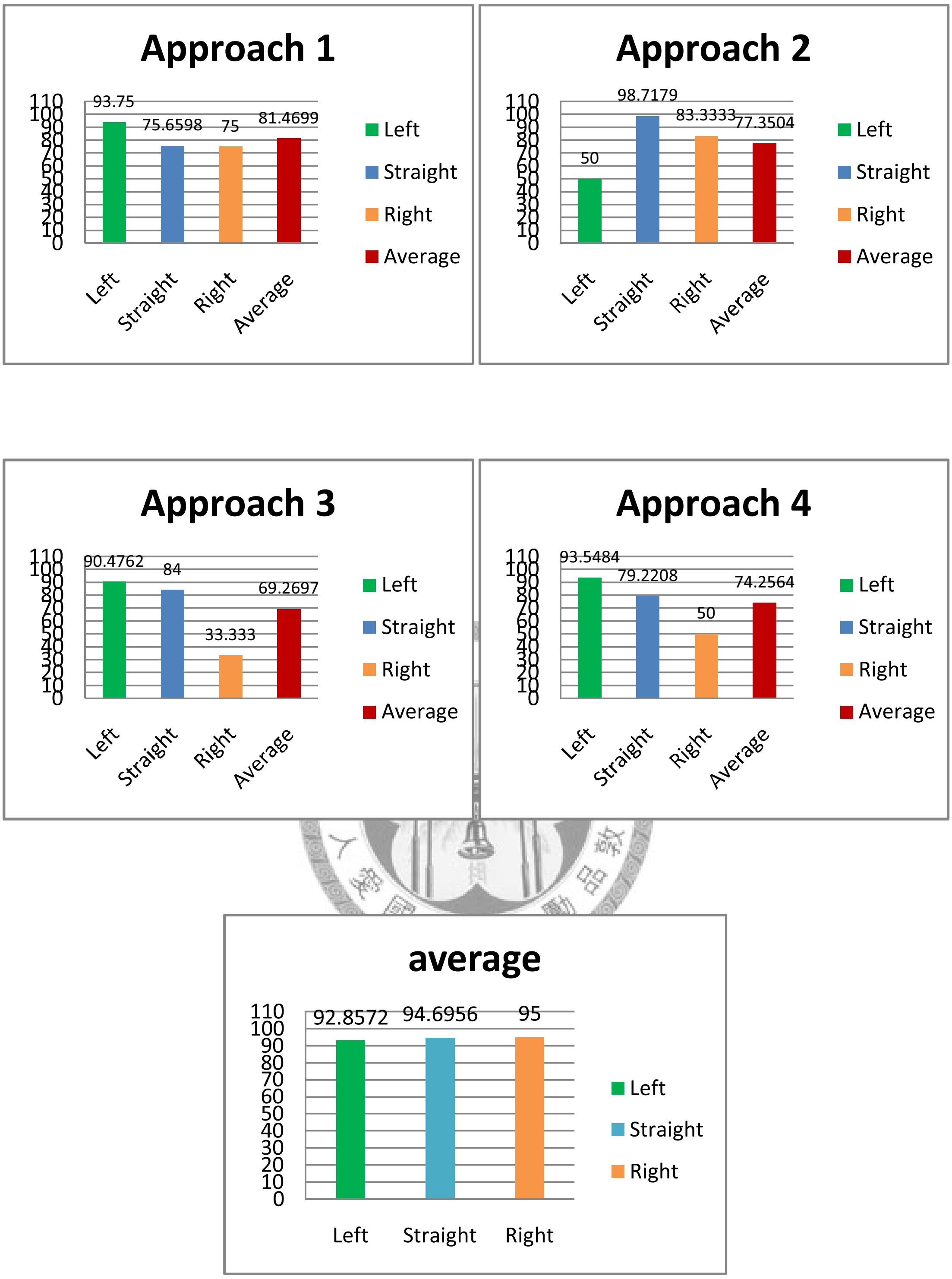


Figure 4.22 The accurate rate of small car volume on each approach in the nightfall.

C. Full-size vehicle

The full-size accurate rate of traffic flow and turn ratio in the nightfall are shown in table 4.24 and table 4.25. Even vehicle has shadow, it also obtain good result.

Table 4.24 Traffic flow of full-size vehicle in the nightfall.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	0	0	100	0	0	100	0	0	100
Approach 2	0	0	100	0	0	100	0	0	100
Approach 3	0	0	100	0	0	100	3	3	100
Approach 4	2	2	100	0	0	100	0	0	100

Table 4.25 Turn ratio of full-size vehicle in the nightfall.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	0	0	100	0	0	100
Approach 2	0	0	100	0	0	100
Approach 3	0	0	100	1	1	100
Approach 4	1	1	100	0	0	100

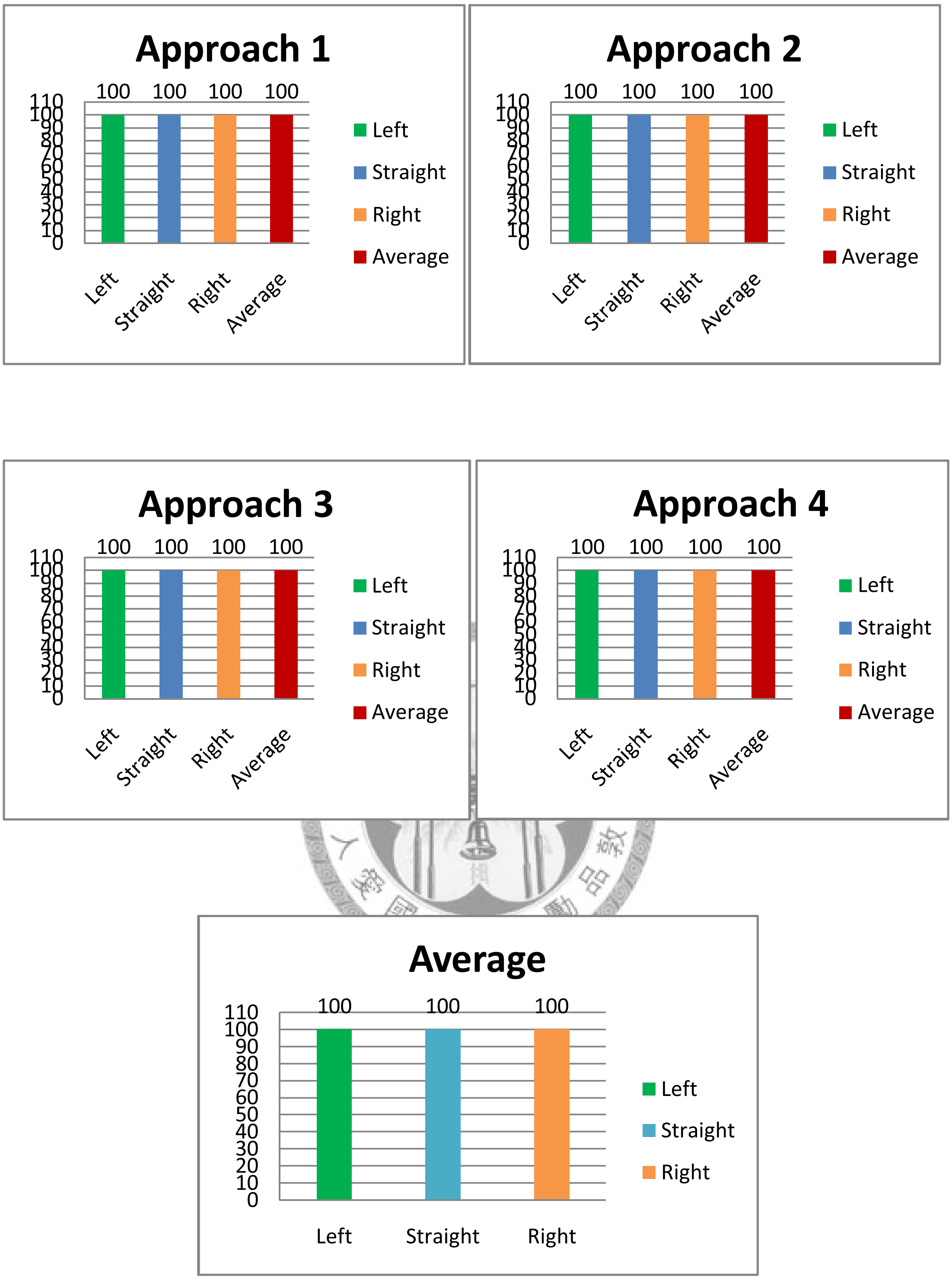


Figure 4.23 The accurate rate of full-size vehicle volume on each approach in the nightfall.

4. Night

The time of Tested video at night has 6 minutes. Table 4.28 display the total traffic flow of motorcycle, compact and full-size vehicle at intersection.

Table 4.28 Total traffic flow of three types vehicles at night.

	Motorcycle	Small car	Full-size vehicle
Detection data	232	107	2
Actual data	300	131	2
Accurate rate	77.33	81.68	100%

A. Motorcycle

The motorcycle accurate rate of traffic flow and turn ratio at night are shown in table 4.29 and table 4.30. In this experimental video we have consider the left turn motorcycle because this intersection is small.

Table 4.29 Traffic flow of motorcycle at night.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	4	6	66.67	44	35	74.29	4	6	50
Approach 2	6	10	60	46	57	80.70	8	20	40
Approach 3	4	5	80	41	54	75.93	10	13	76.92
Approach 4	12	13	92.31	37	67	55.22	16	14	85.71

Table 4.30 Turn ratio of motorcycle at night.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	0.0769	0.1277	60.22	0.0769	0.1277	60.22
Approach 2	0.1	0.1149	63.27	0.1333	0.2299	58
Approach 3	0.0727	0.0694	95.27	0.1818	0.1806	99.3
Approach 4	0.1846	0.1383	66.51	0.2462	0.1489	34.73

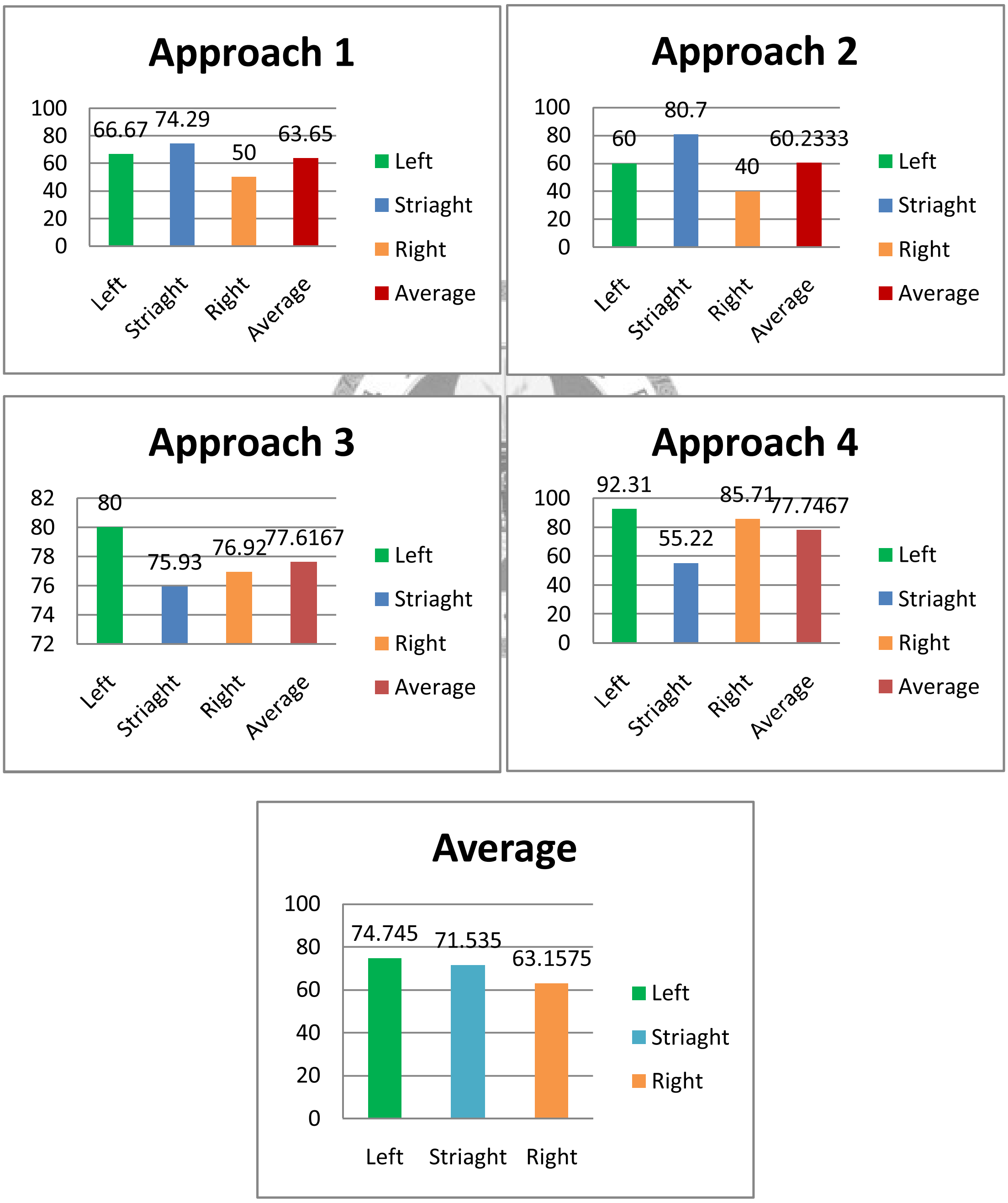


Figure 4.24 The accurate rate of motorcycle volume on each approach at night.

B. Small car

The small car estimation of traffic flow and turn ratio at night are displayed in table 4.31 and table 4.32.

Table 4.31 Traffic flow of small car at night.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	5	5	100	10	8	75	7	10	70
Approach 2	4	5	80	28	34	82.35	4	5	80
Approach 3	3	5	60	4	6	66.67	7	7	100
Approach 4	5	7	71.43	24	33	72.73	6	6	100

Table 4.32 Turn ratio of small car at night.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	0.2273	0.2174	95.45	0.3182	0.4349	73.18
Approach 2	0.1111	0.1136	97.78	0.1111	0.1136	97.78
Approach 3	0.2143	0.2778	77.14	0.5	0.3889	71.43
Approach 4	0.1429	0.1522	93.88	0.1714	0.1304	68.57

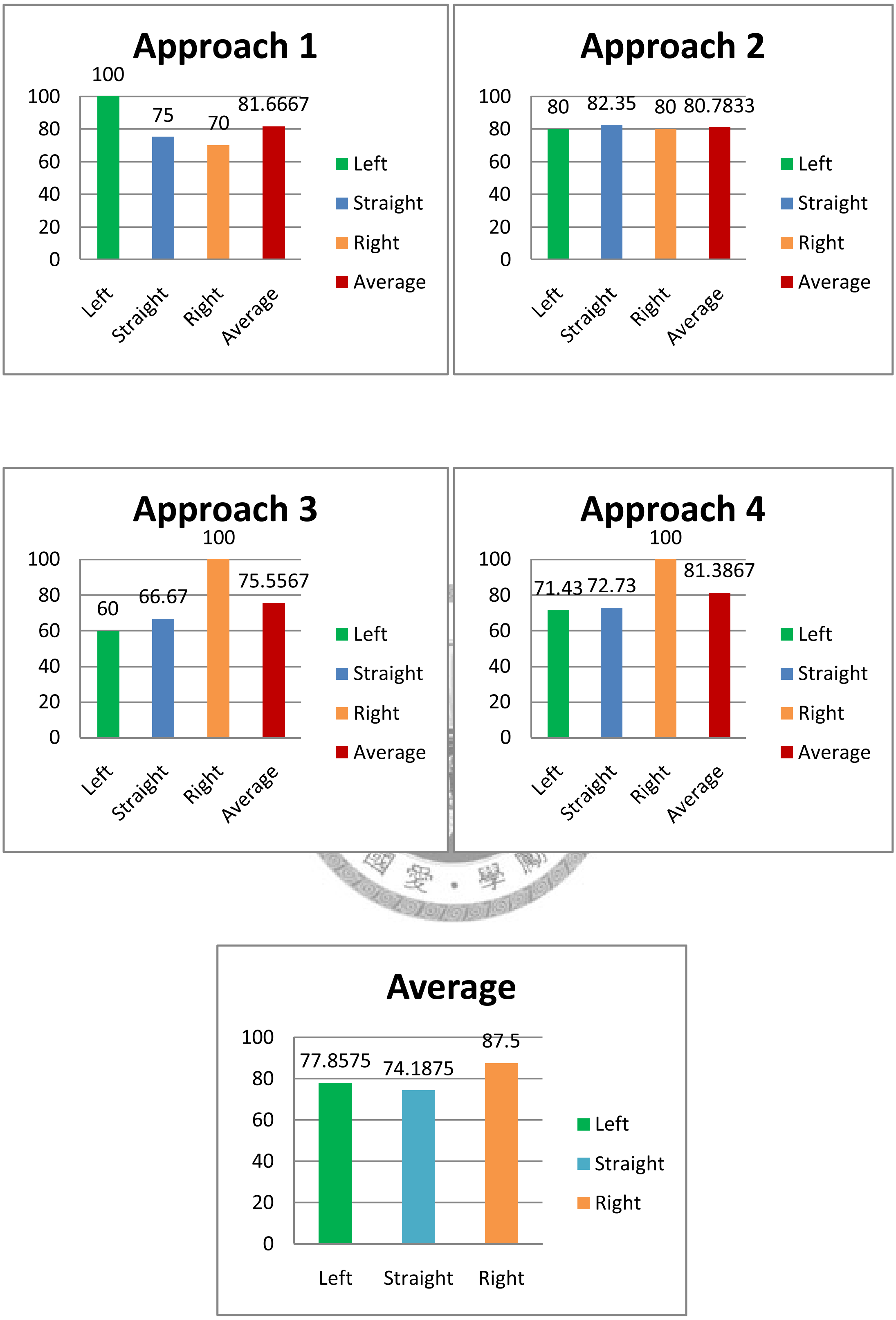


Figure 4.25 The accurate rate of small car volume on each approach at night.

C. Full-size vehicle

The full-size accurate rate of traffic flow and turn ratio at night are shown in table 4.33 and table 4.34.

Table 4.33 Traffic flow of full-size at night.

	Left			Straight			Right		
	D	A	AR(%)	D	A	AR(%)	D	A	AR(%)
Approach 1	0	0	100	0	0	100	0	0	100
Approach 2	0	0	100	0	0	100	0	0	100
Approach 3	0	0	100	0	0	100	0	0	100
Approach 4	0	0	100	2	2	100	0	0	100

Table 4.34 Turn ratio of Full-size vehicle at night.

	Left turn ratio			Right turn ratio		
	D	A	AR(%)	D	A	AR(%)
Approach 1	0	0	100	0	0	100
Approach 2	0	0	100	0	0	100
Approach 3	0	0	100	0	0	100
Approach 4	0	0	100	0	0	100

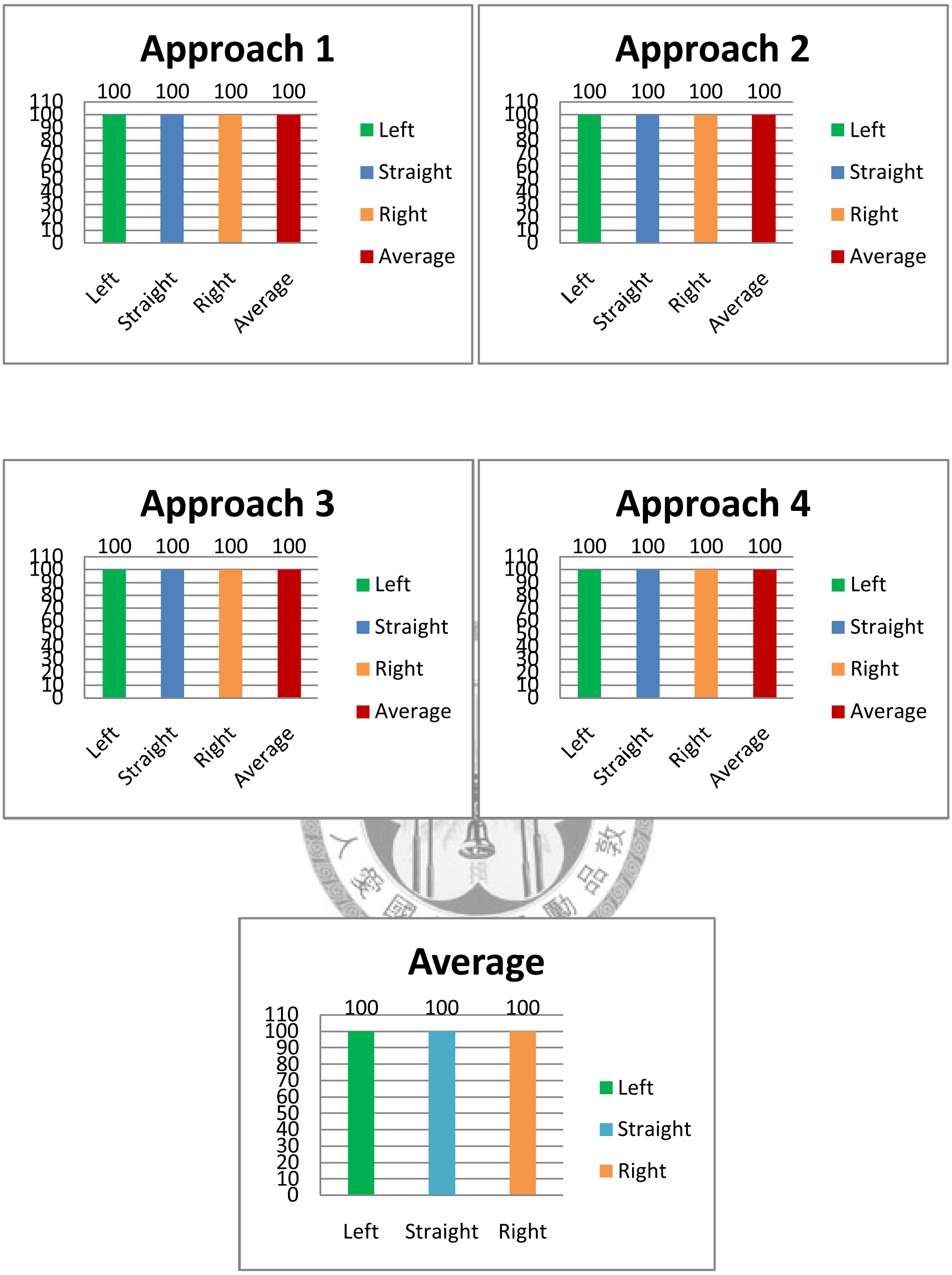


Figure 4.26　The accurate rate of full-size vehicle volume on each approach at night.

4.5 Results Analysis

According to experimental estimation, image detection system proposed in this thesis is worked well in the morning and afternoon. The average accurate rate in these two times could reach more 80% that conformed to the requirement of this system. In the nightfall, small car and full-size vehicle can obtain nice results except for right turn flow. Motorcycle obtained very bad result at night and nightfall. It is necessary to resolve the bad result.

Full-size vehicle in three tested video obtained 100% in all situations that is because the volume in these tested video are very less. Another reason, the speed of full-size vehicles is very slow at intersection and the area of it is big so it can be tracked accurately.

In tested video, the right turn vehicles are very less because the design of channelization. The sample is not enough so once have false detection or missing detection, the error rate would be enlarged. Another reason the trajectory of right turn vehicle is very short that would cause the tracking error or identify vehicle wrong direction. To combine these reasons that is why the accurate rate of right turn is lower than straight and left turn.

In the nightfall, this system obtained unideal result, especially in motorcycle. There are two reasons of bad result. First, the detection zone is too small. Once passing motorcycle leave the zone and enter the zone again, it would cause tracking false. If motorcycle is ridden on the boundary of detection zone that easily to cause over count traffic flow or miss the motorcycle. Second, there is large region shadow at intersection such as building shadow shown in figure 4.20. In the nightfall, vehicle need to be had shadow removal. Once vehicle enter the region of building shadow, the shadow of vehicle is disappear and the illumination of vehicle is changed that would remove the large region of motorcycle. If the region of motorcycle is removed too many that would cause motorcycle be thought as noise and to be removed.

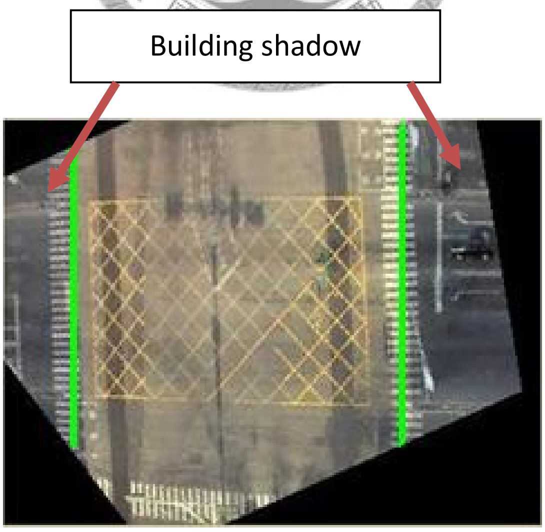


Figure 4.27 Large region of shadow.

According to the results analysis, this system will be influenced by following factors.

1. Intersection Size

   The tested intersection in daytime is too large so it cannot be capture whole view. The tested intersection at night is moderate. It can be capture whole view. The accuracy of right turn flow at night obtained nice result.

2. Camera Setup

   This factor will influence the amount of occluded vehicle on image sequence. A good angle of camera setup will reduce the false detection.

3. Vehicle Size

   If the vehicle size is big that will let tracking be more accurate. The size of motorcycle is small so it causes tracking more difficult and error tracking easily.

4. Vehicle Speed

   Because the tracking approach used in this thesis is region based, once vehicle speed is too fast to over the default region that will cause error tracking.

Chapter 5

Conclusion & Future Work

According experimental result, the image vehicle detection system proposed in this thesis can obtain good result in the morning and afternoon. However, there is still numerous problems need us to resolve. In this chapter, conclusion is presented in section 5.1 and future work is presented in section 5.2. The applicative situation of this system is shown in table 5.1.

Table 5.1 Applicative situation of propose image detection system.

Factor	**Weather**	**Intersection Size**	**Traffic flow**	**Time**
Situation	**Normal**	**Moderate (2~3 lanes)**	**Medium**	**Daytime**

5.1 Conclusion

The most difficult problem in this system is how to identify the direction of each vehicle. Although vehicle could be tracked successfully, once the direction of vehicle was identified wrongly, it still is a false detection. Tracking at whole intersection is more complex than on general urban road section. If we just choose one approach to detect vehicle, the situation would be simpler. However, it will increase the cost of traffic data collection. This is a trade-off problem.

In this thesis, a system had been developed successfully for detecting motorcycle in real time, at the same time it can obtain good accuracy of traffic volume in daytime.

Besides, a proposed approach of dynamic threshold selection can overcome the rapid illumination change soon and obtain good result. It just uses simple calculation.

In this thesis, a simple approach for shadow removal had been proposed. It just uses same characteristics of shadow and statistic analysis but still can obtain nice result for applying to image detection system.

Generally, the proposed system could reach the level (accurate rate 80%) of image detection system used by traffic center. How to improve this system to be applied in all situations is next object we have to do.

5.2 Future work

In the future, we still have numerous works need to do for improving this system. We have to increase its accurate rate to be applied in different time at intersection. This system is far from automatic image detection system because its inner parameters need user to install and the value would influence the effect. So reduce the manpower operation is necessary.

Another problem we should to resolve is the climate problem. How to detection vehicle in the rainy day is also an important issue because there are numerous rainy days in Taiwan. To resolve this problem for improve the robust of system is we need to do in the future.

Traffic flows of tested video in this system are median and low volume. This system is still cannot resolve the heavy traffic volume especially there is traffic jam at intersection that would cause the tracking false. The large group of motorcycle is also another serious problem in this system. When numerous motorcycles occlude each other, it is impossible to split each one.

In order to obtain more accurate information, maybe we can use 3D image to implement image processing. That can resolve the vehicle occlusion accurately even there are numerous occluded vehicles.

Incident detection is also an important issue. In order to let the image system become more complete at intersection, we should add this function in this system in the future.

By integrating above function, the image detection system can have powerful effect for traffic data collection that can have assistance for our urban traffic management.

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