IMPROVEMENT OF COLLISION WARNING SYSTEM FOR FRONT MOVING VEHICLE DETECTION

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ABSTRACT

Immature behavior, fatigue, and inattentional driving have been mainly identified as major issues in safety. Such human behaviors are considered to be the core problem for the occurrences of traffic accidents. As a result, Intelligent Transportation System including Safety Driver Assistance Systems plays an important role in traffic safety and this system becomes the focused research topics recently. In order to develop front collision warning system, there are four main subsystems reqiured such as front moving vehicle detection, front vehicle tracking, inter distance estimation, and collsion warning system.

Front Moving Vehicle Detection for Collision Warning System is a technique used to find front vehicles which appear in the region of interest of each frame in a video. The proposed detection method has four main partial steps which are Segmentation of ROI (Region of Interests), Three Frame Difference with Sobel Edge method, BLOB Detection with morphological operation, and Shifting Frame. The shifting idea is to ensure the application can be well performed in real time and to reduce the computational load.

Next, front vehicle tracking; the proposed research scenario assumes that the front moving vehicle will only appear in the ROI. Therefore, a single object tracking with Kalman Filter is established. In the process of Kalman Filter there are two main stages, i.e., prediction state and correction state. Futhermore, this research use the prediction step to minize the ROI for noise removal and computation reduction. The result has been proved that the detection of front moving vehicle is increase about 4% after applying tracking with Kalman Filter Algorigthm.

After having detection and tracking of the front vehicle, the inter distance estimation is applied. This distance is base on trigonometric technique which is computed with pixel distance information in 2D image plane and the camera's characteristics such as field of view, height of camera, and camera's angle. Since the distance estimation is relied on these parameters, we

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propose the simple linear regression model to predict the distance instead of using camera's characteristics. However, there are some assumptions of this model such that, the road's angle of the two different video should be similar and the distance in metter and distance in pixel of between these videos should be linear. The result shows that, the trigonometric technique with simple linear regressiong model are moderate accurate compared to the ground trust information **??**.

Lastly, front collision warning system is a subsystem which the main objective is to compute the collision risk by identifying the safety distance to assist a distracted driver, prior to occurrence of an imminent crash. In order to compute the impact collision, this proposed system is to utilize the estimated distance information to calculate the impact collision then actively give warning to the driver. To produce the accurate warning, we assume that the vehicle driving with the constance velocity and having the system monitor the front warning zoone with about 2 to 3 second ahead. According to the experimental result, the collision warning system is able to give the warning to the driver accurately, However, there are two major problems which are the distance estimation and monitoring area. If the result of these two majors is not accurate, it then will lead the wrong warning activation.

Finally, The improvement of collision warning system for front vehicle detection is improved when the kalman filter is applied. In addition, the front collision warning system is activated correctly to give warning to the driver. However, there are some limitations which required to improve futher.

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Bangkok, June 2019

Vannat RIN

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TABLE OF CONTENTS

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This material is reserved for educational use only, not allowed for commercial use.
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Forbidden to modify the content, and cite the document when use.

LIST OF FIGURES

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Forbidden to modify the content, and cite the document when use.

Figure		Page

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Forbidden to modify the content, and cite the document when use.

LIST OF TABLES

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, a major problem for Asian countries as well as other part of the glob is road accident. This tragedy road traffic death has plateaued at 1.25 million per year reported by World Health Organization (WHO) on global status report of road safety 2015. Furthermore, If the current trend continues, traffic accidents are predicted to increase by 65% and become the fifth major cause of death by 2030 [1]. According to Global Status Report on Road Safety, the inattention driving, fatigue and immature behavior are the main causes for traffic accidents. The National Highway Traffic Safety Administration (NHTSA) reported that nearly 25% of crashes implicate some kind of driver inattention , distraction, fatigued, drunk, asleep or lost in thought. Since the drivers are the main occurrence of such issue, safety system has been equiped to vehicles in the purpose of increasing the passengers' safety and assisting drivers.

In the safety system, there are two main type of systems which are active and passive as shown in Figure 1.1. In this proposed work, the author focus on the acitve safety system which is named Collision Avoidance System (CAS). Serveral inventions and improvements of CAS were concerning on active and passive safety of vehicles. Most of active vehicle safety approaches make use of active sensors, such as lasers, radar, sonar, or millimeter-wave radar, to detect vehicle. These active sensors could detect the distance between own vehicle and target vehicle by measuring the travel time of the signal emitted by the sensors and reflected by the target vehicle. In another way, the passive vehicle safety approaches make use of passive sensors, such as cameras due to acquiring data in a non-intrusive way.

In reality, this CAS have been equipped on vehicles such as Volvo, Ford, Honda, Subaru, and Mercedes-Benz to utilize its potentiality for assisting drivers in reduction of traffic accident. With this existing, CAS have shown their effectiveness to the road safety, however they still have their limitation in hardware such as sensor quality (optical sensors) and software including algorithm development.

1.2 Objective of the Research

The main purpose of this research study, is to develop a novel sofware approach for front moving vehicle detection and tracking for collsion warning system in assisting drivers and pas-

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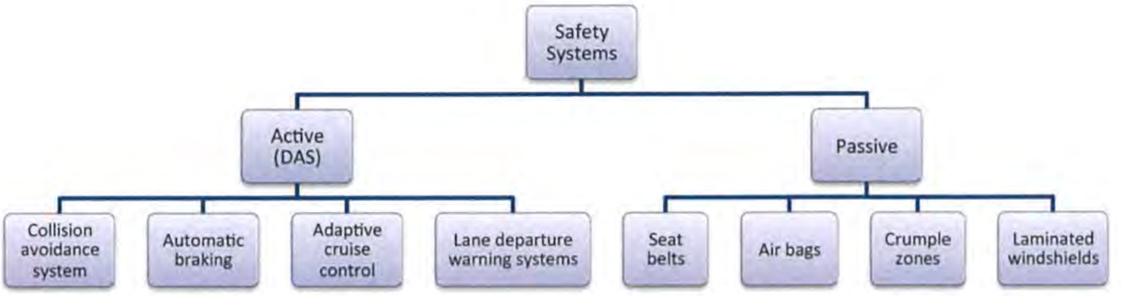

Figure 1.1: Safety-System-Diagram [1]

sengers' safety accurately. The approach for the system is made used of shifting three frame difference method with edge detection. The combination of these two methods has more advantages than shadow underneath technique and it fills the important information for extracting boundary object. Additionally, the shifting frame means to reduce the computation and it is also well fed in the process of tracking. In order to track the front moving vehicle, this work makes use of Kalman filter which is a classic state estimation algorithm. There are two main advantages in application of Kalman filtering.

Kalman filter provides the state prediction of position after the first detected object. This prediction result can be used for minimizing area of the detection for the next coming frame, This will lead to the reduction in computation, overcome the obstruction of noise, and less uncertainty of measurement.

Kalman Filter provides the auto-correction state by using measurement which is obtaining by vision base detection to update the prediction state. Consequently, the predictor will provide an estimation of whereabout the object will appear in the next frame.

Finally, after having detection and tracking of the front vehicle, the collision warning system uses the inter vehicle distance estimation base on pixel distance information in 2-D image plane with margin ratio for the collision risk prediction. Pixel distance estimation is estimated by Kalman Filter from sequences frames of a video with particular speed of driving and frame rate. With the out put of tracking, the inter vehicle distance is computed base on the camera' properties and adjustment of camera's angle error. The front collision is then verfied by the margin rato which is monitored the collision zoon about 2 second in advance. Since the computation time is high the author set up the monitor area about 3 second for driver reaction.

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1.3 System Overview

This research work proposed a vision-based vehicle forward collision warning system for intelligent vehicle highway applications. The proposed application has three main modules. Firstly, object detection used to find moving vehicle in front from image sequences. Secondly, object tracking with kalman filter is applied for position prediction and inter vehicle distance estimation base on pixel information in 2-D image. Finally, inter distance estimation with margin ratio is ultilized for collion monitoring Figure 1.2 is shown about the process flow of propsed system.

Module 1: Object Detection

Firstly, video is captured by front camera mounted on a wide screen of vehicle with the specific setting of camera's properties. The videos have serval different size that used for the experiment and the frame rate is (25-30) fps. In this detection method, there are three main partial steps as follow.

1. Selecting Region of Interest(ROI) is an early step before finding the front obeject. Specifically, the main idea of extracting ROI is to reduce the compuational consumption and to locate the detection zoon. To select this area the system need to find the vanishing point from every image frame. In order to extract the point, the author has applied two difference approaches.

weighted average is done on the denset area (most intersection point). These points are found by using houg tranform on canny edged image with computing the interception of hougl-ines as shown in Figures 1.4 and 1.3 illustrated the vanishing point detection. The lines are the result from houg tranform extraction. they have start point and end point and the red star points are the interception of each line and the black point is the vanishing point. However, this method seem not to be well fed in the system.

Interception of correct lane marking is the vanishing point. First of all, Sobel edge detection algorithm is applied for detecting all edges on the grayscale converted image. The Hough transform technique is then used to extract the left and right lines which are connected to the vanishing point. Finally, the system utilizes of he third component of cross product vector which identifies the leftmost or the rightmost of lines for computing the interception.

2. This partial step is to determin the front object from the ROI selection. The proposed system makes used of computer vision techniques with shifting three frame difference algorithm on video sequence and combines with edge detection operation. The idear of shifting frame is to

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ensure the propose system is reliable to perform in real time scenario.

3. In the proposed work, the system extracts boundary object by utilizing blob detection with morphological operation. Morphology is a mathematical image processing operation which operates images based on geometrical structures This operation is to carry on removing noise and adding pixel for improving the information of shape in image. The proposed study makes use of the morphological dilation operations due to the objects pixels obtained from the detection are not well enclosed. Blob Detection is a method which aims to find the region differed in properties, such as brightness or color, compared to surrounding regions In this case, the authors use the white pixel value as the boundary object. Since the pixels value of every frame in a video scene are dynamically changed, the noises still exist even though morphological dilation is applied. Such reason, this work uses three main attributes, i.e. a ratio value between perimeter and round length of objects bounding box, a ratio value between objects area and the bounding boxs area and an objects area value to extract the true boundary object

Module 2: Object Tracking

Object Tracking is the main complicated task which is to find the moving intention of the detected vehicle. In this third phase, the system make use of Kalman Filtering Algorithm which provided a prediction and correction state of selected object of every five frames successively. The proposed research scenario assumed that the front moving vehicle will only appear in the region of interest (ROI) which describes in the above section. Therefore, a single object tracking is established.

Module 3: Inter Vehicle Distance Estimation

The main idea of this phase is to find the distance from len of the camera mounted on a wide screan vehicle to the detected object. Naturally, cameras are projective devices which map our 3D world onto a 2D image. The camera measures the intensity of the light emitted or reflected from a certain direction; however, the depth information is lost. The projective process also implies that, in the absence of any external reference, the scale of the observed objects is undeterminable. In spite of these limitations, Inter Vehicle Distance Estimation is used.

Module 4: Margin Ratio for Warning System In order to judge for the front collision, the proposed system monitors the front area ahead about 2 to 3 second including with additional computational time. In this case, the system computes the margin ratio for alarming driver to react on time.

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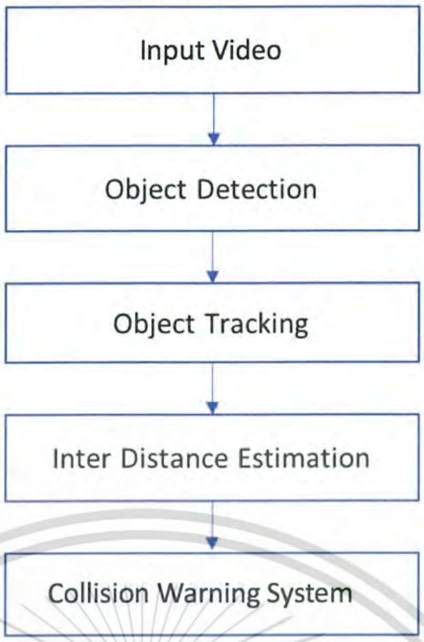

Figure 1.2: System Overview

Figure 1.3: Example of interception-detection

Figure 1.4: Example of upper part removal

1.4 Thesis Organization

This thesis proposal consists of 5 chapters such as introduction, literature review, research methodology, experiment and discussion, significance and conclustion of project. In this chapter is the chapter of introduction and the rest are outline as follow. Chapter 2 gives the information of literature review showed about the previous work related to front vehicle detection, object tracking, inter vehicle distance estimation by 2-D image information, and finally collision risk judgement. Chapter 3 describes about the methods which will be used in this research study. Chapter 4 illustrates the some experimental set-up, and result in each step. Additionally, this part is also include the discussion. The last chapter presents the conclusion of the thesis proposal and expected outcome.

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CHAPTER 2

LITERATURE REVIEW

Literature review is the most important part in conduting a research study due to avoidance of wheeling works and to exten or improve the previous study more advance. For such reason, this part is to review some previous work which are related to this undertaking project.

2.1 Front Moving Object Detection for Collision Warning System (CWS)

Object Detection in video scence of high-way application is a crustial task for Intelligent Traffic Safety System (ITSS). those kinds of system are the application which is applicable incorporates Electronic, Computer and Communication technologies into vehicles for traffic death reduction, assisting drivers, and enhance passenger's safety. Furthermore, not only collision avoidance system but also traffic monitoring system and others traffic surveillance systems require the detection technique.

Many researchers have proposed methods for front moving object detection. For example, Zhou and Hoang [2] proposed background subtraction technique for real time robust human detection and tracking system in video surveillance. In the experiment, they used videos with different environment as the inputs and the results were proved to be robust; however, this method seemed to work only with the stationary camera and not satisfied with non-stationary camera. Moreover, there were also false detection if the foreground was affected by the shadow.

Another cooperative work from Srilekha et.al [3] introduced a new technique for detecting, tracking as well as counting the vehicles based on Kalman filtering approach. The proposed method utilized an updating state estimation of Kalman filter to update the background model over time. The results had better accuracy compared to background subtraction method. However, its major limitation was inability to manage dynamic background pixels and a non-stationary camera.

Yadav et.al [4] presented a real-time vision based method for detecting vehicles in both rear and forward collision warning system. The proposed work consisted of two different modules as shown in Figure 2.1. One was corresponded for vehicle in the forward path and the other for passing-by vehicle. For the localizing forward path vehicle, the authors utilized Profiling and Edge detection techniques while the passing-by vehicle detection they made use of temporal differencing method. The results had been demonstrated high performance of the system and low false positive rate for the in-path vehicle. However, it was degraded under rainy weather scenarios because of improper segmentation obtained from multiple edges and reflections from

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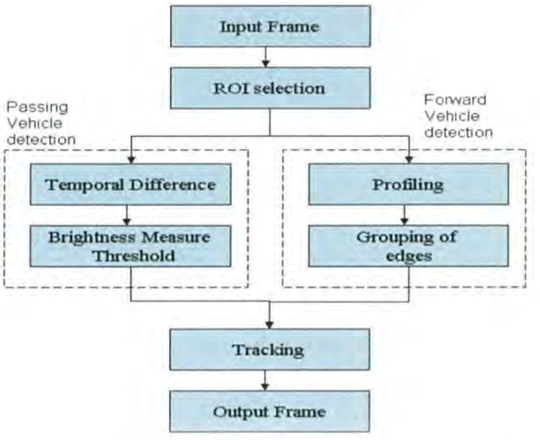

Figure 2.1: Block diagram for vehicle detection

various objects.

Zhang et.al [5] proposed front vehicle recognition, in which the context information of the images and machine learning method were integrated to improve the performance of recognition. The vehicle detection was carried out using histogram of gradient (HOG) which counted occurrences of gradient orientation in localized portions of an image. This method had good performance on the structural road, however the limitation was that this method could not work well in the case of bright light

SenMa et.al [6] proposed a vision optical flow based vehicle forward collision warning system for intelligent vehicle. The detection of vehicle in this work was done by frame difference method. The main advantage of this method was that it had well performance of recognizing moving objects without modeling the background. However, its limitation was that if the object pixel of sequence frames were not much different, the result of this method did not provided enough information to extract boundary object. Additionally, the authors further used Optical Flow algorithm to track a front vehicle from selected object and applied Harris algorithm, a corner detection, with Lucas and Kanade (LK) for determining the moving intention of the vehicle. Figure 2.2 shows the proposed literature diagram.

Yanzhu et.al [7] introduced Three-Frame-Different Method with mathematical morphology of object detection. Their research made use of dilation and erosion in order to improve the original method of frame different. As a result of this, they can remove noise, fill the empty of target, get the best consequence with the less time consumption.

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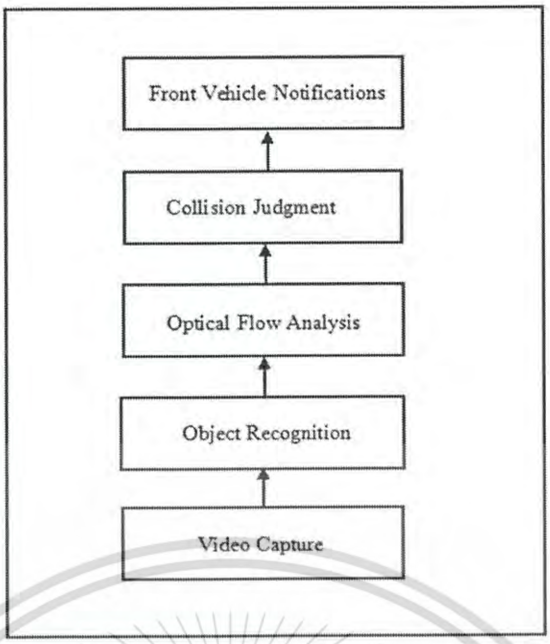

Figure 2.2: The flowchart of the proposed vehicle collision warning system

2.2 Front Vehicle Tracking

Finding moving intention of front vehicle is another complex work in video scence. In this part is to review some of techniques used for tracking object senario.

A study based image processinig, Su et.al [8] designed a new tracking algorithm by fusing Kalman prediction and Mean Shift Search together for moving objects in Unmanned Aerial Vehicle. Figure 2.5 is indicated of fusing Mean-Shift-Search with Kalman-Prediction. Mean Shift tracking algorithm is a bottom-up appearance based tracking method, while Kalman is totally a top-down process. Kalman is an optimal recursive data processing algorithm, which consists of two steps: prediction and correction. Considering the advantages and disadvantages of the Mean Shift and Kalman, they combined Mean Shift search and Kalman prediction together to track fast and robustly. The experimental result of this research illustrated that their proposed method was general and computationally inexpensive which was fit for aerial video surveillance. However, the computational consumption was heavy and it had limitation on retrieving depth information, since they use camera alone is not rich enough to construct full 3-dimensional models of moving objects.

Fang et.al [9] proposed a real-time collision warning system which contained lane marking detection, vehicle detection, and vehicle distance estimation. For marking the lane, the authors used the Sobel edge detector and Hough transform. This work divided vehicle detection into two parts, i.e. one was for daytime detection and another one was for nighttime. In day time they

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made use of shadow detection and edge detection together. However, for nighttime they used Cr component of the YCrCb color model to verify the location of the vehicle. Experimental results showed that the system was well performed and stable. However, at night time the performance was not accurate.

Zhang et.al [10] observed the main problem in front vehicle detection and tracking base image processing. This work used improved HOG (Histogram of Gradient) for feature extraction and recognized object by carrying on Adaboost classifier then applied the Kalman filter for multiple objects tracking and enhancement of the detection rate.

Another finding from Li et.al [11] established object motion model for multiple object tracking based on Kalman filter algorithm to choose centroid and track window. The authors used the matching results of sequence frames as the measurement for updating the state prediction of Kalman filter. From the estimated result with detection information, their system were able to judge whether there was a block between objects.

Dai et.al [12] presented an integrative approach to vision-based lane departure detection and collision warning system with overtaking vehicle detection (rear vehicle detection). For lane departure of this presented work, the authors used low- level image features, Hough transform, and Sobel for calculating the gradient. In the detection scenario, this work applied the shadow detection for daytime; however, for the nighttime they proposed a symmetry analysis technique to improve the detection rate. The evaluation had showed the effectiveness of their proposed work.

2.3 Inter-Vehicle Distance Estimation

J.Lalonde et.all [13] presented a 3D reconstruction of the scene using a single camera for obstacle detection of smart back-up camera systems as shown in Figure 2.3. Experimental result of this work, indicated that the proposed system successfully met the objectives of reliability and efficiency. However, the accurate obstacles detection was done with 1m distance. Hence, This method is not applicable with long rang detection and in short period of time.

I.S.Yoo and S.W.Seo [14] proposed a new method for providing accurate distance measurements through frequency-domain analysis based on a stereo camera by exploiting key information obtained from the captured images as shown in Figure 2.4. The result showed that the proposed method obtained depth value of an object accurately in less time than the semi-global matching (SGM) as shown in Table 2.1. The proposed algorithm performed 10% better on average than SGM. The proposed method was also illustrated to be suitable for use in real-time applications such as autonomous vehicles.

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A study on Vehicle Detection and Distance Estimation Under Challenging Lighting Conditions [15], proposed Inter-Vehicle Distance Estimation based on homogeneously distributed pixel distances in the new 2D transformed imaged. In this method, the authors assuming an almost planar road surface with knowing the camera optic parameters, camera high, and camera angle. Experimental result showed that Distance estimation by the camera-pose-based trigonometric method provieded more accurate results compared to the birds-eye view approach. Furthurmore, the authors identified two common sources error of the proposed approache:(1) The error of vehicle localization from the vehicle detection; (2) changes in camera height due to activities of the vehicle shock absorber.

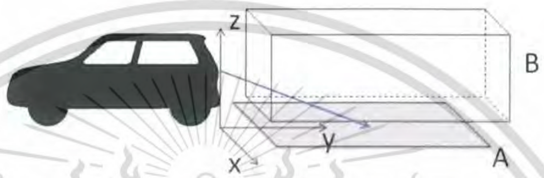

Figure 2.3: A rear-mounted parking camera setup. (A) is the region in which ground features are used for motion estimation. Any feature located in the collision volume (B) is determined to be an obstacle. The blue arrow indicates the cameras optical axis.

Table 2.1: Distance accuracy comparison

Distance, m	SGM, m	Proposed algorithm, m
510	0.8	0.7
1015	2.0	1.4
1520	3.4	1.5
2025	4.8	2.4
2530	6.2	2.7
3035	8.5	2.9

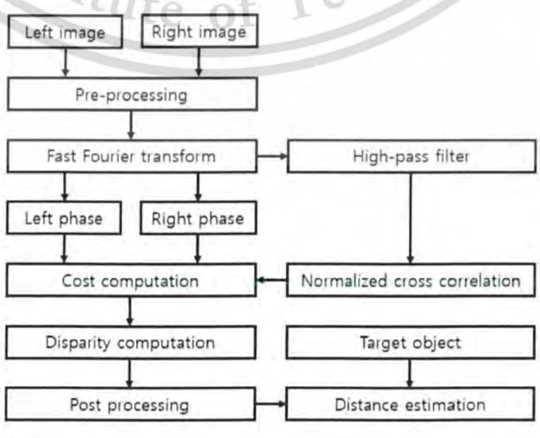

Figure 2.4: System architecture of the proposed algorithm

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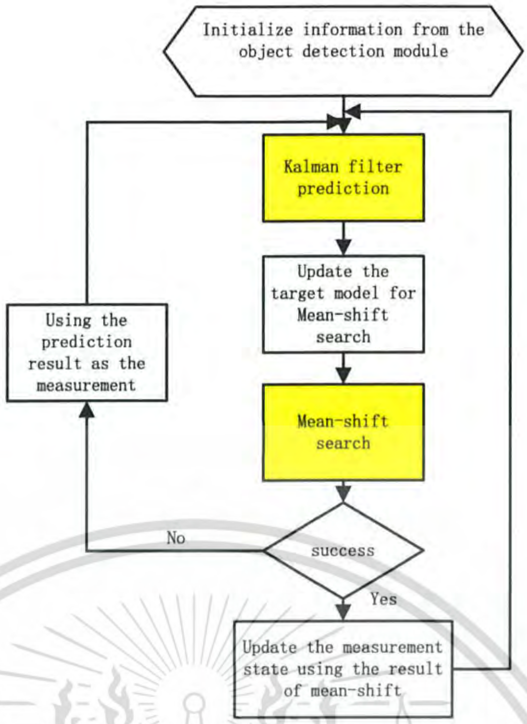

Figure 2.5: New tracking algorithm of fusing Mean Shift search and Kalman prediction

2.4 Collision Risk Prediction

The work from [6] was carried out using optical flow and time-to-contact (TTC) algorithms for finding the collision risk. The proposed system first defined the origin, which can fix reference position in the image frame. Generally, the midpoint of the bottom line was selected as reference in differrent environment. The location information of a vehicle object was relative to its speed and direction. In addition, the time-to-contact (TTC) was considered for calculating the potentail collision. However, the proposed TTC is depend on distance and speed which were extracted from deriver recorder machine of the vehicle. That mean the system lack of distance estimation and a dynamic monitoring zone.

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CHAPTER 3

METHODOLOGY

In this chapter of the project is to explain more detail on the methods which the authors make use in this undertaking research. the prosed project aimes to develop a novel sofware approach for collsion warning system in assisting drivers and increasing passengers' safety in real time senario. The system captures image sequences of front moving vehicle then performs front object detection by utilizing shifting three frame difference method with Sobel edge operator. The tracking process is then carried out using Kalman Filter for position prediction and noise reduction for better detection accuracy. Finally, the system computes the collision risk by applying Margin-Ratio based on inter vechicle distance estimation in 2-D image plane.

3.1 Front Moving Object Detection

Front moving object detection for collision warning system is a technique used to find front vehicles which appear in the monitoring zone of each frame in a video. The proposed detection method has three main reasons which enhance the perfomance of the system:

- Less computational consumption compared with background modeling methods.
- Less complication operation in both mathematical process and implementation.
- Background modelling is not required for extracting foreground object.

This proposed detection technique illustrated in Figure 3.1 consists of five main partial steps which are descriped in sub-section below.

3.1.1 Segmentation of ROI (Region of Interests)

Figure 3.2 illustrates the process of how the system generate the region of interest (ROI). First of all, Sobel edge detection algorithm is applied for detecting all edges on the grayscale converted image. The Hough transform technique which prominently explains in [16], is then used to detect the lines. After that, the system is able to extract the left and right lines which are connected to the vanishing point. Since the left and right lines of the road always appear on the lower part of the input frames, only the middle bottom of the input frames is necessary for the Sobel edge operator and Hough transform for finding the lines. The upper part of the input image frame is cut for the reason of noises effect avoidance and computational load reduction. After having applied the Hough transform technique on the detected edges, those lines are judged to be the left most or the right most of the frame. The system is then generate the vanishing

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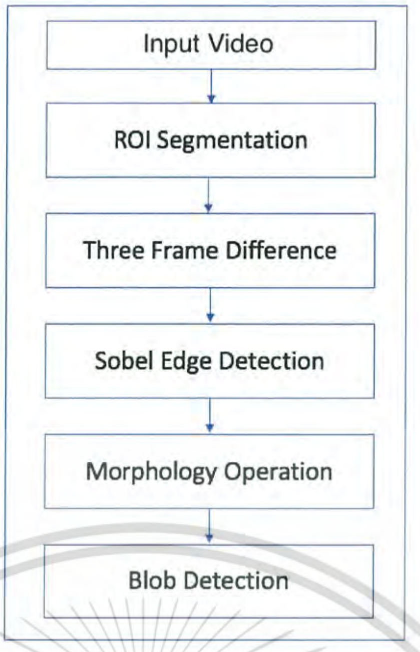

Figure 3.1: Front Moving Object Detection Scenario

point for marking the region of interest. In order to generate the ROI, the system create the mask binary according to the marking area from vanishing point then the system applies the element multiplication between the mask and the frames.

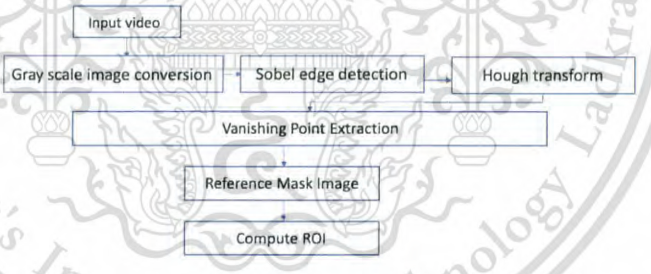

Figure 3.2: Flow process of ROI selection

3.1.1.1 Gray Scale Image Conversion

In this part of the detection process, the proposed system requires to convert every color image frames into grayscale. In order to obtain this grayscale images the system makes use of build-in function in Matlab which is based on this equation $(0.3 \times R) + (0.59 \times G) + (0.11 \times B)$. Where R, G, and B represent Red, Green, Blue color respectively. Figure 3.3 shows example of obtaining gray images.

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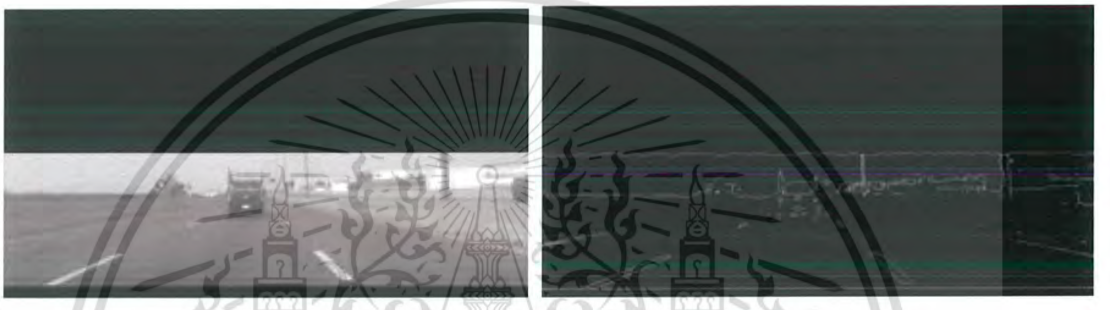
(a) (b)

Figure 3.3: Example of converting a color image to grayscale image



(a) (b)

Figure 3.4: Simulation Result of Sobel Operator

3.1.1.2 Sobel Edge Detection

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene. Classical methods of edge detection involve convolving the image with an operator, which is constructed to be sensitive to large gradients in the image while returning values of zero in uniform regions. There is an extremely large number of edge detection operators available, each designed to be sensitive to certain types of edges. Additionally, The process of edge detection significantly reduces the amount of data and filters out unneeded information, while preserving the important structural properties of an image.

The Sobel filter is used for edge detection. This method works by calculating the gradient of image intensity at each pixel within the image. It finds the direction of the largest increase from light to dark and the rate of change in that direction. The sobel filter uses two 3 x 3 kernels. One for changes in the horizontal direction, and one for changes in the vertical direction. The two kernels are convolved with the original image to calculate the approximations of the derivatives. Figure 3.4 illustrates the experimental result of sobel operator on the gray scale images.

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3.1.1.3 Line and Vanishing Point Extraction with Hough Tranform

Hough Tranform is robust method to find a shape in an image. The shape can be described in parametric form and an accumulating scheme is used to determine the correct line segment. In the proposed system, the result of sobel edge detector method is the input of hough tranform algorithm with the set up of some thresholds value to filter the lines.

After having applied hough transform the system is able to extract the left and right lines which are connected to the vanishing point Since the left and right lines of the road always appear on the lower part of the input frames, only the middle bottom of the input frames is necessary for the Sobel edge operator and Hough transform for finding the lines. The upper part of the input image frame is cut for the reason of noises effect avoidance and computational load reduction. Front the hough result, lines are judged to be the left or the right side of the frame in which rely on the equation (3.1) and (3.2).

$$(x_1 > \frac{w}{2})\ \&\ (x_2 > \frac{w}{2})\ \&\ \theta \in [-83, -20]\ (Right\ line) \tag{3.1}$$

$$(x_1 < \frac{w}{2})\ \&\ (x_2 < \frac{w}{2})\ \&\ \theta \in [\ 20,\ 83]\ (Left\ line) \tag{3.2}$$

Where x_1 and x_2 are the x-components of (x_1, y_1) and (x_2, y_2) which are the start and the end points of a line, w is the width of the input frame and θ is the angle resulting from Hough transform technique. Based on these criterion, the system generates the left and right lines of the input frame. However, two of those lines are selected to be on each side. In this case, the system will choose the best right and left line by utilizing the third component of cross product vector well descripted in [17] identifies the leftmost or the rightmost of the lines as shown in equation (3.3).

$$S = (x_m - x_1)(y_2 - y_1) - (y_m - y_1)(x_2 - x_1) \tag{3.3}$$

where (x_m, y_m) is the midle point of another line on the same side. If $S < 0$ then the point lies on one side of the line, and if $S > 0$ then it lies on the other side. If $S = 0$ then the points lies exactly line. The vanishing point is the intersection of the left and right lines which are extracted from the input frame. According to both lines and vanishing point, the system is then able to mark the interest region of the frame. Figure 3.5 shows the simulate result of hough tranform technique after appied on the detected edge image and the result of selecting the fittest lines for marking the ROI and vanishing point.

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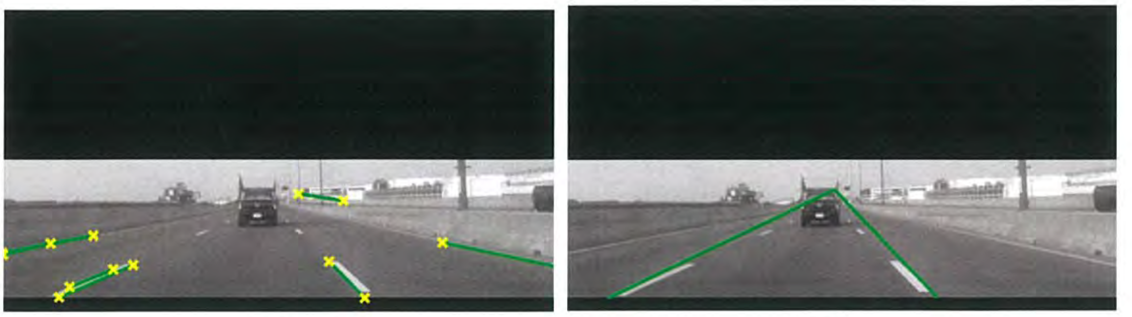

(a) (b)

Figure 3.5: Simulation example of finding the left and the right line by Hough Transform

3.1.1.4 Generate Refference Mask Image

After having marked the monitoring zoon, The next process is to generate the targeted region from the marking area. In order to generate the required area, a reference binary image (mask binary) is created, then the ROI is shaded white and the leftover region as black, as indicated in Figure 3.6(a). In order to obtain a mask binary, this work also makes use of cross product vector which satisfies the condition that if the coordinates of the image pixel are in the selected area, those pixels are then set to 1 else they are set to 0.

3.1.1.5 Generate ROI

In this final stage, the element multiplication of the grayscale image with the reference mask results in the final desired target area which is illustrated in Figure 3.6(b).

(a) (b)

Figure 3.6: Simulation example of creating a mask image and output after applying element the multiplication

3.1.2 Three Frame Difference

After having extracted the ROI, the system applies three frame difference method to find the front moving object. Let $f_{k-1}(x,y)$, $f_k(x,y)$, and $f_{k+1}(x,y)$ are the consecutive grayscale

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images where x, and y are the coordinates of input frame, then the algorithm is specified in equation (4) and (5).

$$f_1'(x,y) = \begin{cases} 1, & |f_k(x,y) - f_{k-1}(x,y)| \geq T \\ 0, & |f_k(x,y) - f_{k-1}(x,y)| \leq T \end{cases} \tag{3.4}$$

$$f_2'(x,y) = \begin{cases} 1, & |f_{k+1}(x,y) - f_k(x,y)| \geq T \\ 0, & |f_{k+1}(x,y) - f_k(x,y)| \leq T \end{cases} \tag{3.5}$$

$$f'(x,y) = f_1'(x,y) \cap f_2'(x,y) \tag{3.6}$$

$$D(x,y) = f_1'(x,y) \cup f'(x,y) \tag{3.7}$$

Where f_1' *and* f_2' are the binary image resulting from consecutive substaction as shown in equation (3.4)-(3.5). f' is is the final output of an intersection operation as shown in equation (3.6) and the result is illustrated in Figure 3.7(a).

3.1.3 Sobel Edge Operator

Since the three frame difference method produces an object without edge information, this paper utilizes the Sobel edge detector on the selected area. Equation (3.7) shows the combination of three frame difference and edge detector where $D_k(x,y)$ defines the edge detection of image frame $f_k(x,y)$. Therefore, the system has adequate information to extract the boundary object. Figure 3.7(b) illustrates the example of Sobel edge detection, and Figure 3.7(c) shows the example of three frame difference with edge detection.

3.1.4 Morphology Operation

In the proposed work, the system extracts boundary object by utilizing blob detection with morphological operation.

Morphology is a Mathematical image processing operation which operates images based on geometrical structures. This process is to carry on removing noise and adding pixel for improving the information of shape in image. This study made use of two basic morphological operations dilation and erosion. Dilation operation is shown in Equation (3.8) which this operation adds pixels to the boundaries of objects in an image while erosion is shown by Equation (3.9) which it removes pixels on object boundaries. The proposed study makes use only the morphological dilation operations due to the objects pixels obtained from the detection are not well enclosed. The technique to test fit or hit is shown in figure 3.8

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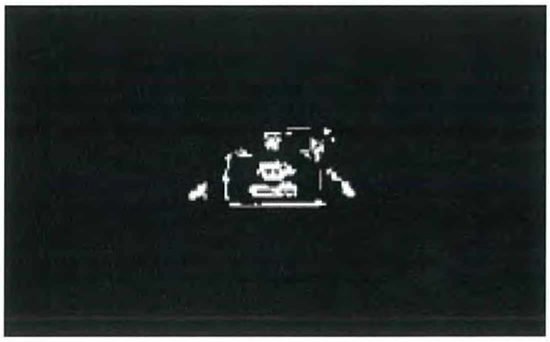
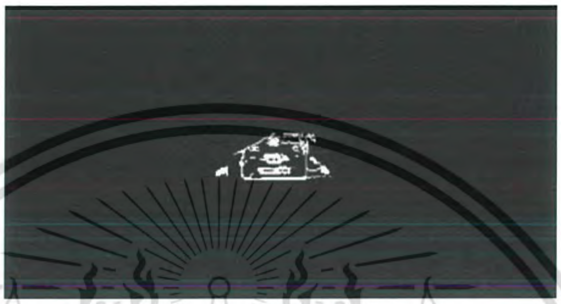


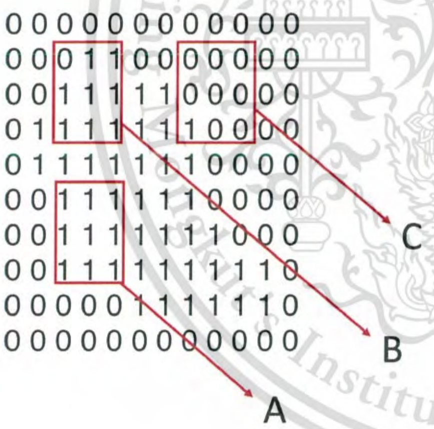
(a)

(b)



(c)

Figure 3.7: Simulation Result of three frame difference with edge detection method



		A	B	C
Fit	s_1	Yes	No	No
	s_2	Yes	Yes	No
Hit	s_1	Yes	Yes	Yes
	s_2	Yes	Yes	No

$$s_1 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}, s_2 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

Figure 3.8: Fitting and hitting of a binary image with structuring elements s1and s2

$$g = f \oplus s \tag{3.8}$$

$$g = f \ominus s \tag{3.9}$$

Where g is the output image, f is input image, and s is the structure element.

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3.1.5 Blob Detection

Blob Detection is a method which aims to find the region differed in properties, such as brightness or color, compared to surrounding regions [12]. BLOB stands for Binary Large OBject and refers to a group of connected pixels in a binary image. The purpose of BLOB detection is to isolate the BLOBs (objects) in a binary image. The images pixels are then labeled to extract or detect the BLOB by performing the labelling technique. In order to label images pixels, labelling technique marks the image pixels with value 1, which are connected, with the same number.

Structure element is an important component for labelling technique. It can be 8-connectivity or 4-connectivity used to process the labelling of the object in the image. The 8-connectivity is more accurate than the 4-connectivity, but the 4-connectivity is often applied since it requires less computational resources. The chosen connectivity, however, can affect detection results. Figure 3.9 shows that the result image contains either one or two BLOBs depending on the chosen connectivity. From the advantage and disadvantage of choosing connectivity, 4-connectivity is chosen. So that structure element with 4-connectivity is implemented for labelling technique. The object can be labelled by applying Recursive Grass-Fire Algorithm. The algorithm starts in the upper-left corner of the binary image. It then scans the image from left to right and top to bottom by using structure element with 4-connectivity. Figure 3.10 shows the process of labelling the object in the image while Figure 3.11 illustrates the result of the labelling process. As a result, the objects are labelled into two differences labels. This means there are two different objects in this image.

Since the pixels value of every frame in a video scene are dynamically changed, the noises still exist even though morphological dilation is applied. Such reason, this work uses three main attributes, i.e. a ratio value between perimeter and round length of objects bounding box, a ratio value between objects area and the bounding boxs area, Figure 3.12(a) shows the image result obtained after applying morphological dilation operation. Figure 3.12(b) illustrates the result after applying blob detection with ratio thresholding. Since one-third of the real object in a video is cut for the reason of region of interest (ROI) selection, the threshold value is added to the height of the objects bounding box as illustrated in Figure 3.12(c) .

3.1.6 Shifting Frame

The main purpose of shifting frame is to reduce the computational load of the system due to processing on the real-time environment. However, to select the number of shifting frame is based on the frame rate of the input video and also the collision time interval over the frames. In

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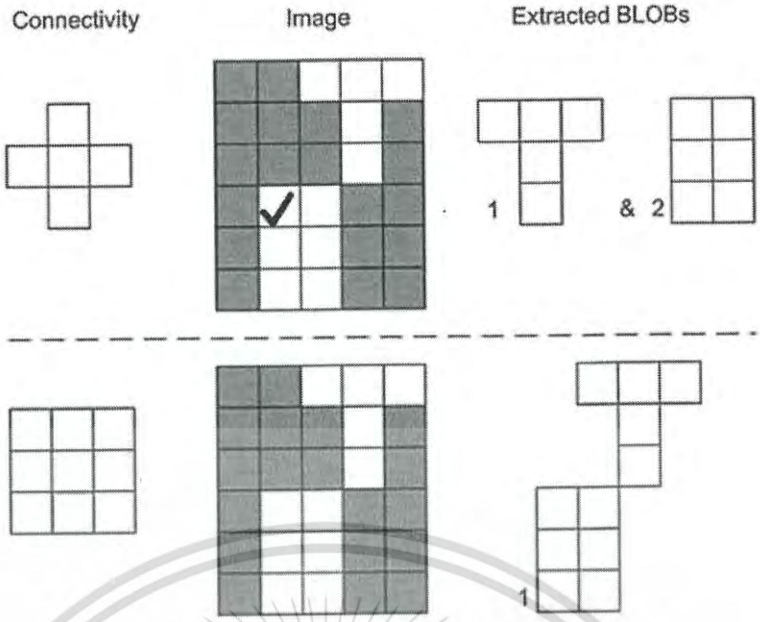

Figure 3.9: Different number of objects caused by different chosen connectivity

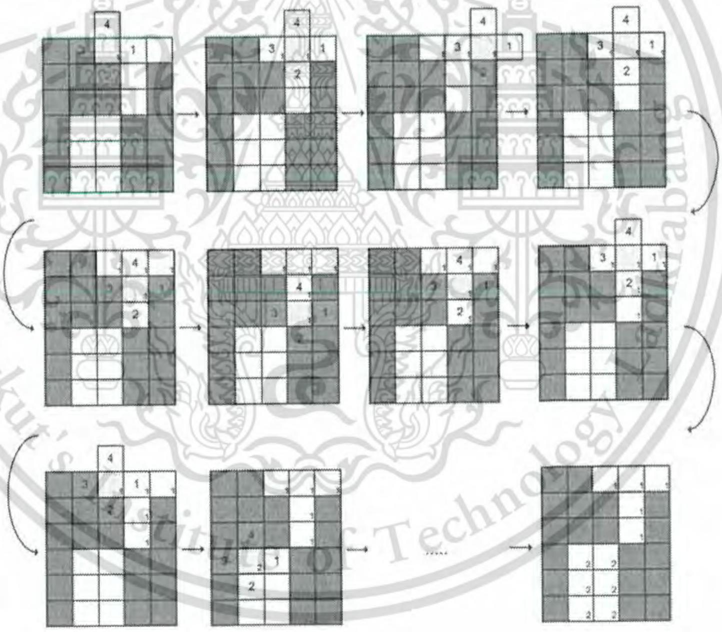

Figure 3.10: Process of BLOB labeling

this work the interval is shifted by 5 frames because in the experiment the frame rate of videos are 25 frame per second (fps). Additionally, the system also monitors the collision time before 2s for driver reaction, as a result; the proposed system has sufficient time for computing and alerting the driver to react on time to the situation. Figure 3.13 illustrates the example of detection by shifting 5 frames.

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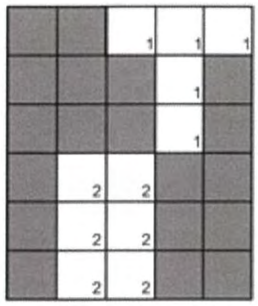
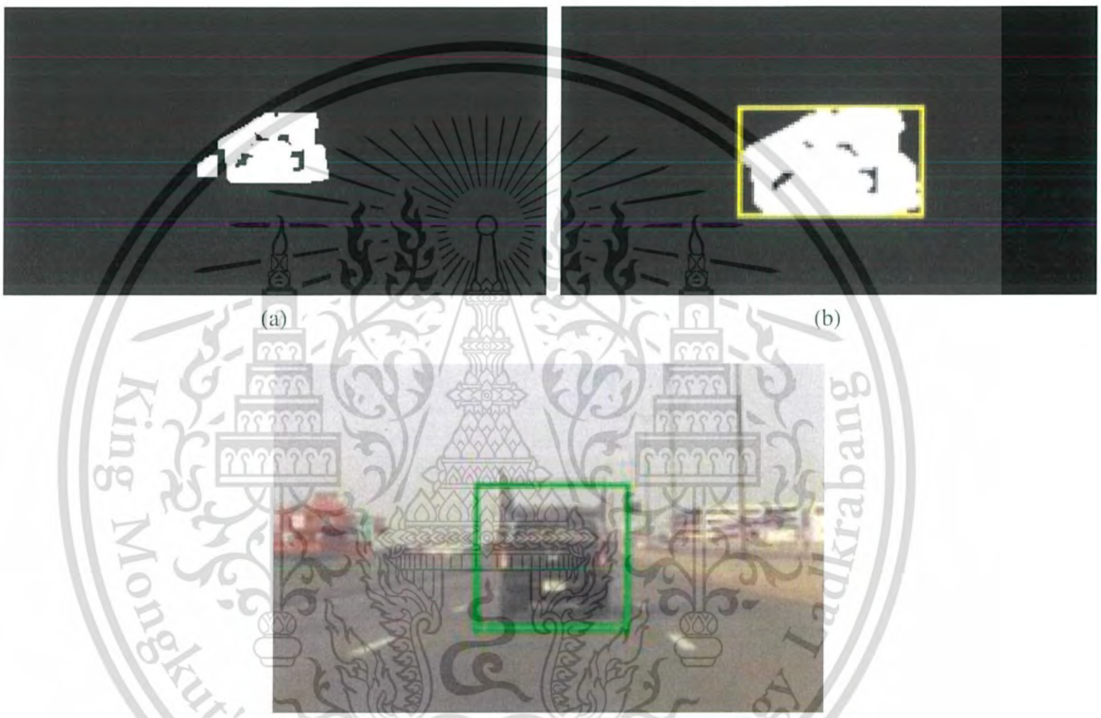


Figure 3.11: Example after labeling algorithm



(a) (b)

(c)

Figure 3.12: Simulation Example of three frame difference with edge detection method

(a) Frame 5th (b) Frame 10th

Figure 3.13: Example of detection with shifting 5-fames

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3.2 Object Tracking with Kalman Filter

In the proposed research scenario, it is assumed that the front moving vehicle will only appear in the region of interest (ROI) which describes in the above section. Therefore, a single object tracking is established. Mathematically, Kalman filter is a recursive least square estimator which predicts and automatically corrects the states [18]-[19]. Generally, Kalman Filter composes of two main stages which are prediction state and correction. Figure 3.14 shows the proposed tracking front object senario with eight states of a space vector.

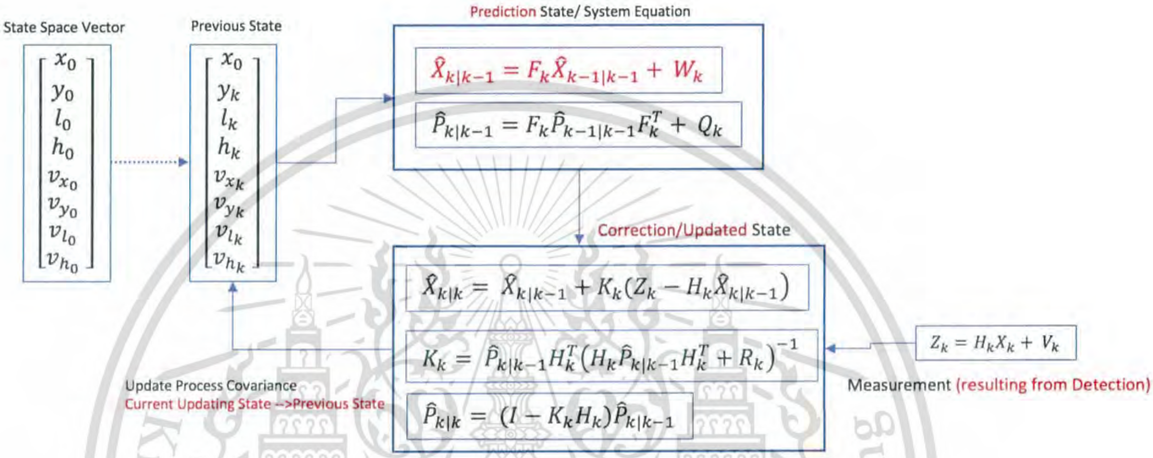

Figure 3.14: Proposed tracking model of kalman filter

3.2.1 Prediction Equation

The predicted state uses the model system equations which is based on the behavior of front moving object and previous state matrix, then the next state object parameter is predicted. When the time updating arrives Kalman filter takes the measurement resulting from the detector to update the prediction state for estimating the position of object. Assuming that, a tracking system where X_k is the state vector represents the front moving object, such that k indicates the discrete time over frame interval. The main purpose of this tracking is to estimate the optimal X_k which updates by the measurement z_k. Following the description, Kalman filer involves two main stages which are prediction and measurement update as correction state. Assumed that the initialization of parameters of state vector has been done, the prediction equations are given as follow:

$$\hat{X}_{k|k-1} = F_k\hat{X}_{k-1|k-1} + W_{k-1} \tag{3.10}$$

$$\hat{P}_{k|k-1} = F_k\hat{P}_{k-1|k-1}F_k^T + Q_{k-1} \tag{3.11}$$

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F_k defines the transition matrix which applies the effect of every state parameter. W_k is a zero mean white prediction noise with covariance Q_k. $\hat{P}_k$ is process noise covariance between terms in the state vector.

3.2.2 Correction Equations

At this stage Kalman filter computes the kalman gain, the ratio between covariance of noise prediction and covariance of noise in measurement. Then the prediction model is updated.

$$K_k = P_{k|k-1} H_k^T (H_k P_{k|k-1} H_k^T + R_k)^{-1} \tag{3.12}$$

$$\hat{x}_{k|k} = x_{k|k-1} + K_k (Z_k - H_k x_{k|k-1}) \tag{3.13}$$

$$\hat{P}_{k|k} = (I - K_k H_k) P_{k|k-1} \tag{3.14}$$

$$\hat{z}_k = H_k x_k + v_k \tag{3.15}$$

Where H_k is the measurement matrix and v_k is a zero mean white measurement noise with covariance R_k.

3.2.3 Kalman Motion Model for the Target Object Tracking

Describing the parameters of object moving on two dimensional image can be done by defining the coordinate of center, size, and velocity of object. Since position, size, and velocity of a vehicle in Kalman filter are represented by (x, y), (l, h), and (v_x, v_y, v_l, v_h) respectively, the state vector is then expressed $X_k = (x_k, y_k, l_k, h_k, v_{x_k}, v_{y_k}, v_{l_k}, v_{h_k})^T$. Since the measurement consists of position and size of the object, the measurement vector can be expressed $z_k = (x_k, y_k, l_k, h_k)^T$. Followings are the transition matrix F_k and measurement matrix H_k of the tracking system which are specified in equation (3.16) and (3.17). Finally, The Kalman filter based on the scene is established.

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$$F_k = \begin{bmatrix} 1 & 0 & 0 & 0 & \Delta t & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & \Delta t & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & \Delta t & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & \Delta t \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{3.16}$$

$$H_k = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{3.17}$$

3.2.4 Front Moving Vehicle Tracking Process

The main objective of the time-life-cycle of vehicle tracking is to monitor the front moving vehicle such that the vehicle might be lost from the vision or it might be replaced by other vehicles. With this problem, the proposed work sets the monitoring process to verify each status condition of the tracking procedure. Figure 3.15 shows that after having first detected the front object, the system sets the status in a stack as appeared and begins initialization of state parameters for the tracking process. This iterate process is verified by the measurement output. If the verified condition is true, the system then sets the status as tracked else the system sets the status as lost. In order to check the status properly, the first loss of status tracking is not yet set to be disappeared unless the system cannot verify for tracking twice in a view. In this case, the system clears up the stack and starts detecting the object over the next time frames. Furthermore, at the first detected object, the prediction value is used for minimizing the ROI. This is not only leading to the reduction in the error of the detection rate but it also reduces the computational load as in Figure 3.16 shows the data flow of using the prediction value $x_{k|k-1}$for minimizing the ROI and the measurement value z_k which is obtained by vision base detection uses to update the prediction state. Consequently, the predictor provides an estimation of whereabout the object will appear in the next time frame.

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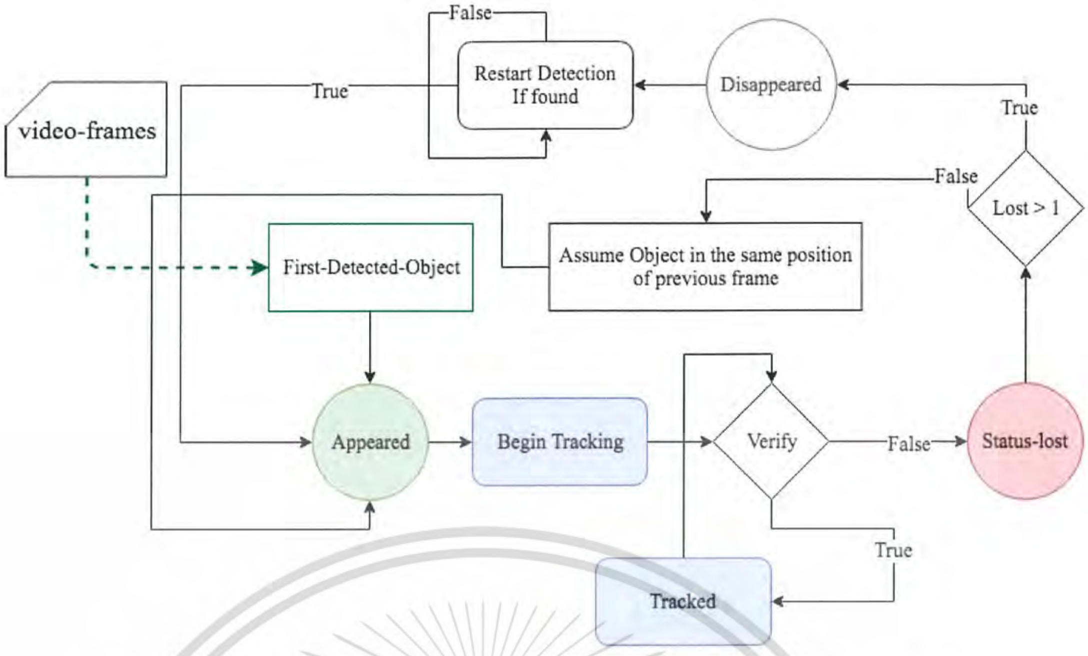

Figure 3.15: Flow process for detection and tracking of front moving object

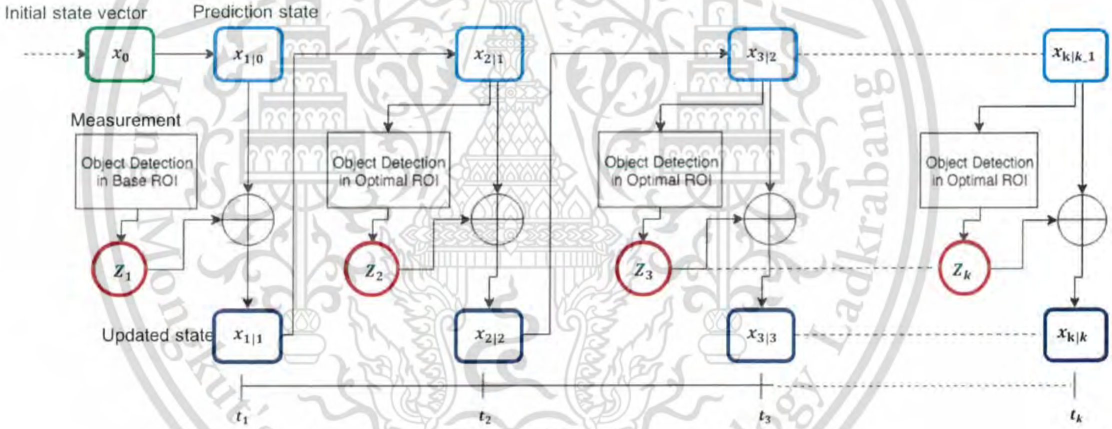

Figure 3.16: Data flow of kalman filter over time frame

3.3 Inter Vehicle Distance Estimation

Since the proposed system equips with a single camera we must estimate the range using perspective. There are two cues which can be used: size of the vehicle in the image and position of the bottom of the vehicle in the image. Since the width of a vehicle of unknown type (car, van, truck etc) can vary anywhere between 1.5m and 3m. Hence, a range estimation based on width will only be about 30% accurate [20]. A much better estimation can be achieved by using the road geometry and the point of contact of the vehicle and the road. Furthermore, after having extracted the inter pixel distance (in pixel) and the correspoinding inter distance (in metter), the authors proposes linear regression model for predicting the inter distance knowing a prio inter

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pixel disance only. For unknown camera property dataset, we propose linear regression model to predict the inter vehicle distance.

3.3.1 Distance Estimation Based on Trigonometric Technique

First of all, We start at first assuming a planar road surface, knowing the camera optic parameters, camera-high, and camera-angle so that the optical axis is parallel to the road surface. As illustrated in Figure 3.17 we assumed to have a forward looking camera (close to the rear-view mirror) with knowing the camera field-of view defined by angle α, the height H of the camera above road level, and the camera angle θ_c in $X_cY_cZ_c$ coordinate. Suppose a detected vehicle in the road scene at an (unknown) position (X_w, Y_w, Z_w). Let θ_v be an angle of a projection ray (for the camera) pointing to the intersection of the planar rear-part approximation of the detected vehicle with the planar road surface (top figure). The actual distance D between ego-vehicle and preciding vehicle is equal to $d_2 - d_1$ and can be computed by geometrical theory.

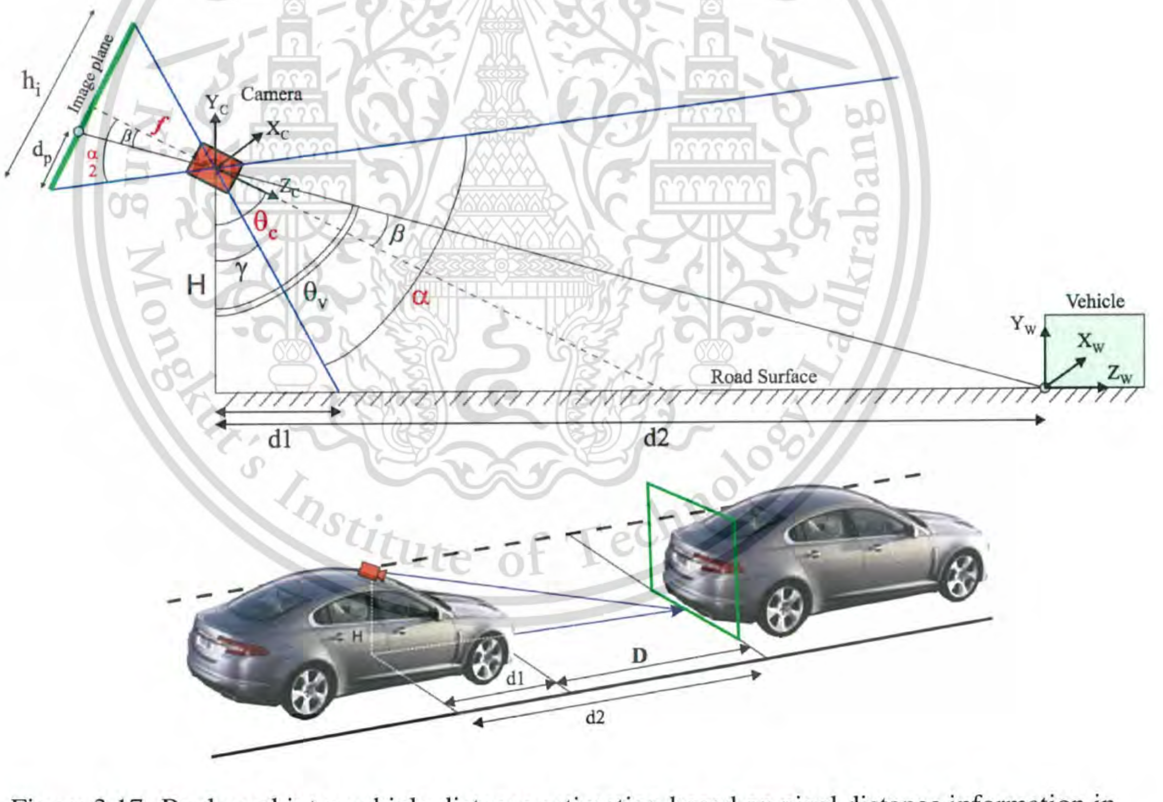

Figure 3.17: Real-worl inter vehicle distance estimation based on pixel distance information in 2D image [15]

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$$
\begin{aligned}
D = d_2 - d_1 = H.\tanh(\theta_v) - H.\tanh(\gamma) \\
\equiv D = H(\tanh(\theta_v) - \tanh(\gamma)) \\
Since\ \ \theta_v = \theta_c + \beta\ and\ \gamma = \theta_c - \alpha/2 \\
Then\ \ D = H.[\tanh(\theta_c + \beta) - \tanh(\theta_c - \frac{\alpha}{2})]
\end{aligned} \tag{3.18}
$$

With knowing the value of θ_c and α, then only β is needed to calculate D.

$$
\tanh(\beta) = \frac{\frac{h_i}{2} - d_p}{f} \tag{3.19}
$$

were h_i is the height of the recorded image plane (in pixel unit), d_p is the distance from the bottom side of the detected vehicle to the bottom of the image plane (also in pixel unit), and f is the cameras focal length equation 3.20 is the relation between field of view and focal length. Equation 3.21 is the final formular to calculate the inter distance. Figure 3.19 illustrates the result of distance estimation by the above method.

$$
f = \frac{h_i}{2.\tanh(\frac{\alpha}{2})} \tag{3.20}
$$

$$
D = H.[\tanh(\theta_c + \tanh^{-1}(\frac{\frac{h_i}{2} - d_p}{\frac{h}{2.\tanh(\frac{\alpha}{2})}})) - \tanh(\theta_c - \frac{\alpha}{2})] \tag{3.21}
$$

3.3.2 Distance Estimation Based on Simple Linear Regression Model

In this section, the main objective is to model a simple linear regression for predicting the inter-distance between rear and host vehicle. Furthermore, Linear regression is an extremely simple method which is an intuitive to use and precisely understandable [21].Rather then that this model also allows us to find the nature of the relationship between two variables (pixel distance and real distance). In addition, there are three main more factors which is applicable to linear model.

1. Some testing dataset in experimental section missed important parameters such as Height between camera and road surface, and Field of View (FOV).
2. Based on human eyes' view and angle of lane line from hough's transform in sampling video

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(literature's dataset knowing camera parameter) comparing to other, those have simillar characteristics as shown in Figure 3.18.

3. The relationship between pixel dinstance in image and distance in real world should be linear

(a) A sampling frame with angle $-53 \leq \theta \leq -50$ (b) A comparable frame with angle $-55 \leq \theta \leq -51$

Figure 3.18: A comparable camera parameters between two obtained videos

3.3.3 Finding the Fit Line for Simple Linear Regression

From the result of distance estimation, D is a inter distance between host vehicle and rear vehicle which has the relationship to d_p, a pixel distance obtained from detection step. This relationship is written as $D = f(d_p) \longleftrightarrow Y = f(X)$. Additionally, a simple linear regression model defines the relationship between a dependent variable and a single independent predictive variable using a line defined by an Equation 3.22

$$Y = \alpha + \beta X \tag{3.22}$$

With the intercept,α, describes where the line crosses the axis, while the slope, β, describes the change in Y given and increase of X. With having datset for two variables X (pixel distance), and Y (Real distance estimation) then α and β is obtained as shown in Equation 3.23. Figure 3.19 shows example of linear regression model for the dataset extracted by detection and distance estimation method.

$$\alpha = \frac{(\sum y \times \sum x^2) - (\sum x \times \sum xy)}{n(\sum x^2) - (\sum x)^2}$$

$$\beta = \frac{n(\sum xy) - \sum x \times \sum y}{n(\sum x^2) - (\sum x)^2} \tag{3.23}$$

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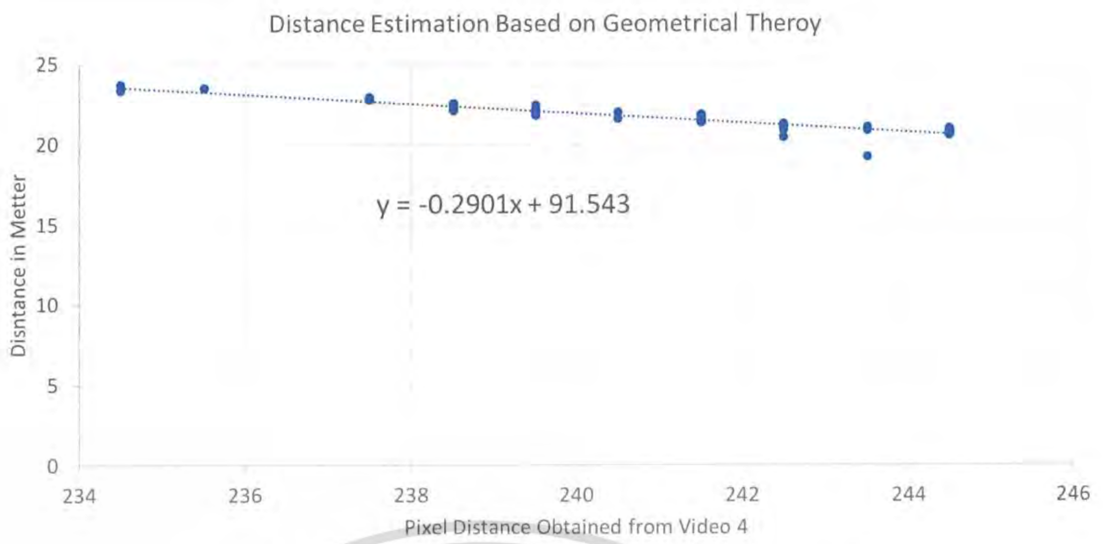

Figure 3.19: Distance Estimation Based on Trigonometric Technique

3.4 Collsion Warning System Based on Magin Ratio

The main objective of this section is to compute the collision risk by identifying the safety distance to assist a distracted driver, prior to occurrence of an imminent crash. In order to compute the impact collision, this proposed system is to utilize the estimated distance information obtained in the previous section to calculate the impact collision then actively warn the driver. To produce the accurate warning, we make use of margin-ratio. Assuming that, the vehicle driving with the constance velocity, the system then monitor the front warning zoone with about 2 second ahead plus with the processing time. This period of time is accordance to a Forward Collision Warning which is issued when the time-to-contact is lower than a certain threshold typically 2 second [22].

Figure 3.20 illustrates how the proposed system gives warning to the driver. Supposed a vehicle drive with a constance velocity about 50km/h and the recorded video is 30fps. S_k is defind as ratio distance between the front and monitoring area. Since, we try to compute the impact collision before 2 second, the monitoring zone is approximately $27.22m$ a head. Hence $S_k = D_k - 27.77m$. Table 3.1 shows the summary of monitoring zone corresponse to each relative velocity.

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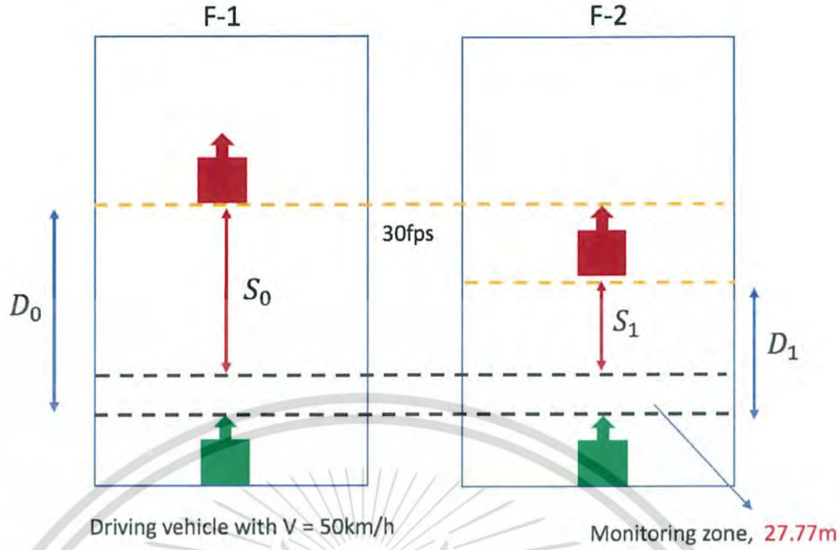

Figure 3.20: Monitoring area which vehicle drives with 50km/h, margin-ratio S_k, and estimated distance D_k

Table 3.1: Summary of monitoring area with the relative speed

Monitoring Zone Distance for 2 and 3 seconds ahead		
Speed in (km/h)	Distance in (m)	
	2 sec	3 sec
40	22.22	33.33
45	25	37.5
50	27.76	41.64
55	30.5	45.75
60	33.33	50m
65	36.11	54.16
70	38.88	58.33
75	41.66	62.5
80	44.44	66.66

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CHAPTER 4

EXPERIMENTAL SET-UP AND RESULTS

After having completed the description of all theory used in this project as well as toolkit for development agent, this chapter is to present the experiment setup for simulation model and come along with result and discussion.

4.1 Experiment Setup

The front moving vehicle detection and tracking system runs on MacBook Pro which has a 2.4 GHz Intel Core i7 processor with graphics Intel HD 4000 1536 MB and has 8 GB memory. Futhermore, this project is implemented on matlab IDE with some image processing libraries. Table 4.1 illustrates the information of input videos. The top three videos are obtained on urban structured road inThailand at daytime, and the rest are from literature [15].

Table 4.1: Description of input videos

Video	Number of Frame	Resolution	Frame Rate	NDVA	Condition
1	150	720x1280	20fps	150	Day time
2	1300	720x1289	25fps	1000	Day time
3	1200	640x480	25fps	1200	Day time
4	400	360x640	25fps	400	Raining Day time

4.2 Experiment Result

In this pare the research thesis is to present the result of the experiment on three main parts i.e front moving vehicle detection, vehicle tracking with kalman filter, and distance estimation.

4.2.1 Front Moving Vehicle Detection Result

From the input videos, the system generate the region of interest (ROI) to determine the location of front vehicle. The system then detect the object int the ROI by using three frame difference with Sobel edge operator. The result of this method is converted to binary image to march with the requirement of BLOB detection. Since the system assumed that the front vehicle must be in the (ROI), the evaluation of detecting the object is then based on equation 4.1 where the term TPR is (True Positive Rate), and FNR is (False Negative Rate). TP is the number of correction detection, and FN is a false number of detection. Top three videos in Table 4.1 are tested for the proposed method. Table 4.2 shows the accuracy of detection without applying Kalman filter. Video 3 of evaluation table has high false detection rate due to the illumination of

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the light and roadside signs.

$$\begin{cases} TPR = \frac{TP}{TP+FN} * 100 \\ \\ FNR = \frac{FN}{TP+FN} * 100 \end{cases} \tag{4.1}$$

Table 4.2: Evaluation of Detection Method Without Applying Kalman Filter

Video	TP	FN	TPR	FNR
1	137	13	91.33%	8.66%
2	921	56	92.1%	5.73%
3	1064	123	88.66%	10.36%
4	335	60	83.54%	14.965%
Average	707.33	64	90.69%	8.25%

4.2.2 Front Moving Vehicle Tracking Result

The first video in Table 4.1 is used as the sample of the data for initializing of the parameters of the state vector X_0, process covariance associated with the uncertainty of prediction model P_0 , the noise covariance matrix of the prediction Q_k, and covariance of uncertainty in measurement R_k. The initialization of the parameters is done by manually selecting the center of object position over the 150 frames then computes the sum of squares error over the detected results. Then these initialized values are applied in other videos for tracking.

After having initialized the parameters of kalman filter with the first detection, the system is then able to minimize the ROI and to predict the next position of front object. In this case, the detection accuracy has sinigicantly improved about 4.2% in average compared to the original detection technique. Table 4.3 shows the evaluation result of detection with applying Kalman Filter algorithm.

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$$Q_k = \begin{bmatrix} 225 & 0 & 0 & 0 & \Delta t & 0 & 0 & 0 \\ 0 & 110.25 & 0 & 0 & 0 & \Delta t & 0 & 0 \\ 0 & 0 & 156.25 & 0 & 0 & 0 & \Delta t & 0 \\ 0 & 0 & 0 & 182.25 & 0 & 0 & 0 & \Delta t \\ 0 & 0 & 0 & 0 & 6.25 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 6.25 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 2.25 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2.25 \end{bmatrix} \tag{4.2}$$

$$P_0 = \begin{bmatrix} 144 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 225 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 114 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 121 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 9 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 9 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 6.25 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 6.25 \end{bmatrix} \tag{4.3}$$

$$R_k = \begin{bmatrix} 107.02 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 51.24 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 86.86 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 77.96 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{4.4}$$

Table 4.3: Evaluation of Detection Method with Applying Kalman Filter

Video	TP	FN	TPR %	FNR %
2	934	46	93.4	4.70
3	1104	96	91.75	8.02
4	377	23	94.25	5.75
Average	802.6	55	93.31	6.15

Figure (9) shows the result of object position which is tracked in video 2 and the shifting interval is 5-frames. This graph proves that the estimated values are adequate in real time vehicle tracking for collision avoidance system. Furthermore, Figure (10) demonstrates the results of tracking object window with the detection of shifting 5-frames in video 2. From the graph, the

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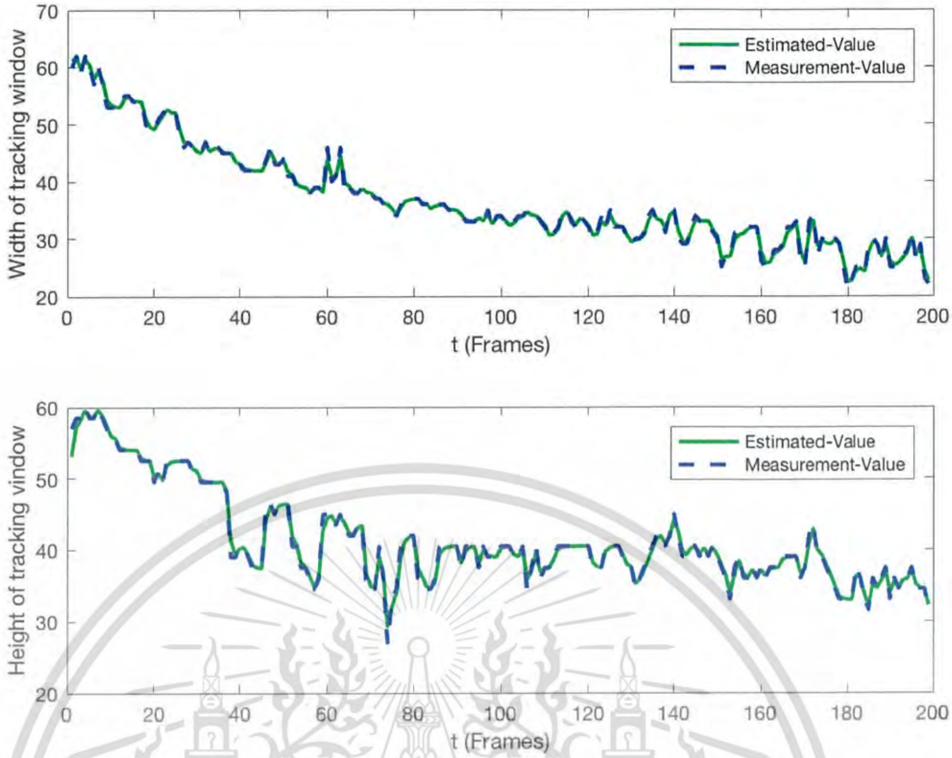

Figure 4.1: Result of tracking object position with shifting 5-frames of video 2 in Table 4.1

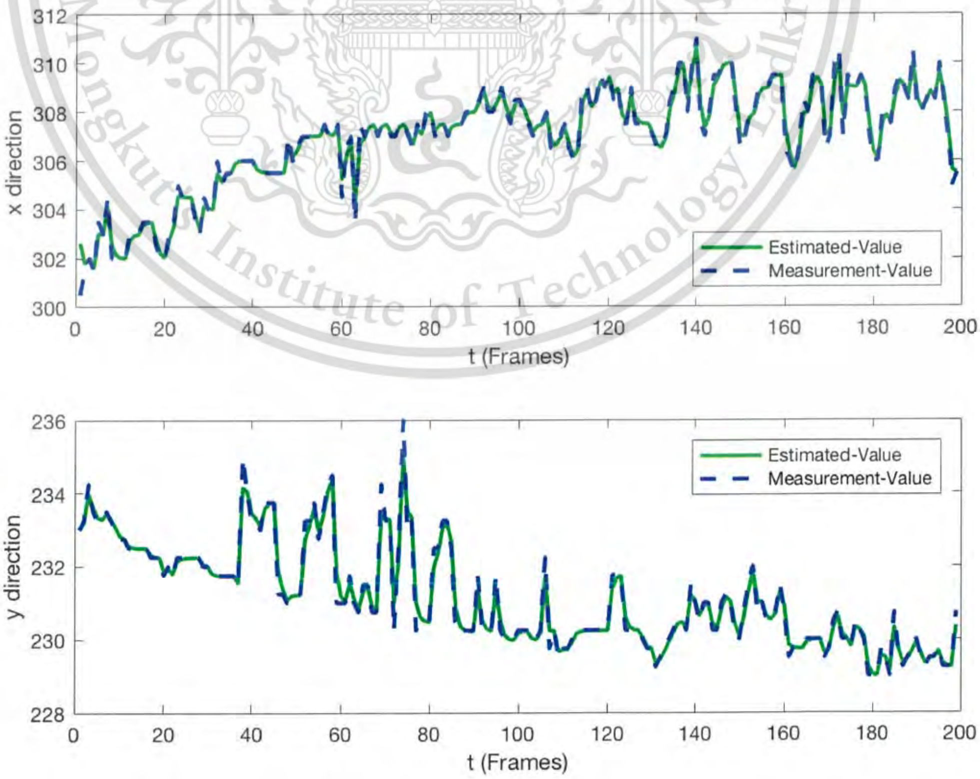

Figure 4.2: Result of width and height tracking with shifting 5-frames of video 2 in Table 4.1

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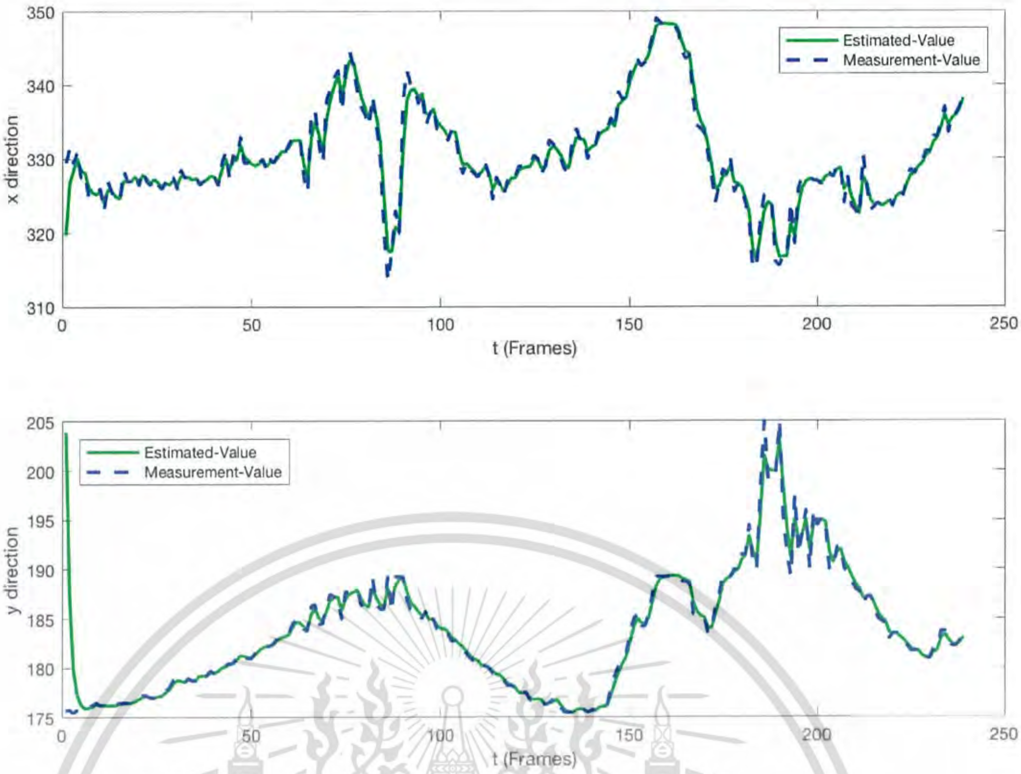

Figure 4.3: Result of tracking object position with shifting 5-frames of video 3 in Table 4.1

system is able to tell that in case the surrounding box of the object is getting smaller it means the object is moving away from the scene else the host object is closed to the front object.

4.2.3 Inter Vehicle Distance Estimation Result

In this part, the authors make the experimentation of distance estimation based on camera-pose-based trigonometric technique. The experiment is done on video 4 in Table 4.1 which is recorded with an 0.7-megapixel camera (1280 720), a 60○ field of view, and 25 fps recording rate, mounted on the back of a rear-view mirror in a car, with a camera tilt angle of c = 82○ and at a height of about H = 153 cm above the road surface. The result of distance estimation is validated by the ground truth information which knowing that the length of any white marking segment in Japan is $8.0m$, and the length of a gap between two white segments is $12.0m$. Figure 4.7 and 4.8 show real distance estimation based on 2D-image pixel distance information obtained in detection and tracking with kalman filter, the core calcuation of inter-distance is then depened on camera-pose-based geometrical theory technique.

4.2.4 Inter Vehicle Distance Estimation Result Based on Linear Regression Model

This part of the experiment, we extract the dataset from video 4 in Table 4.1 as explained in the above section. Then we train the simple linear regression model based on K-fold traning

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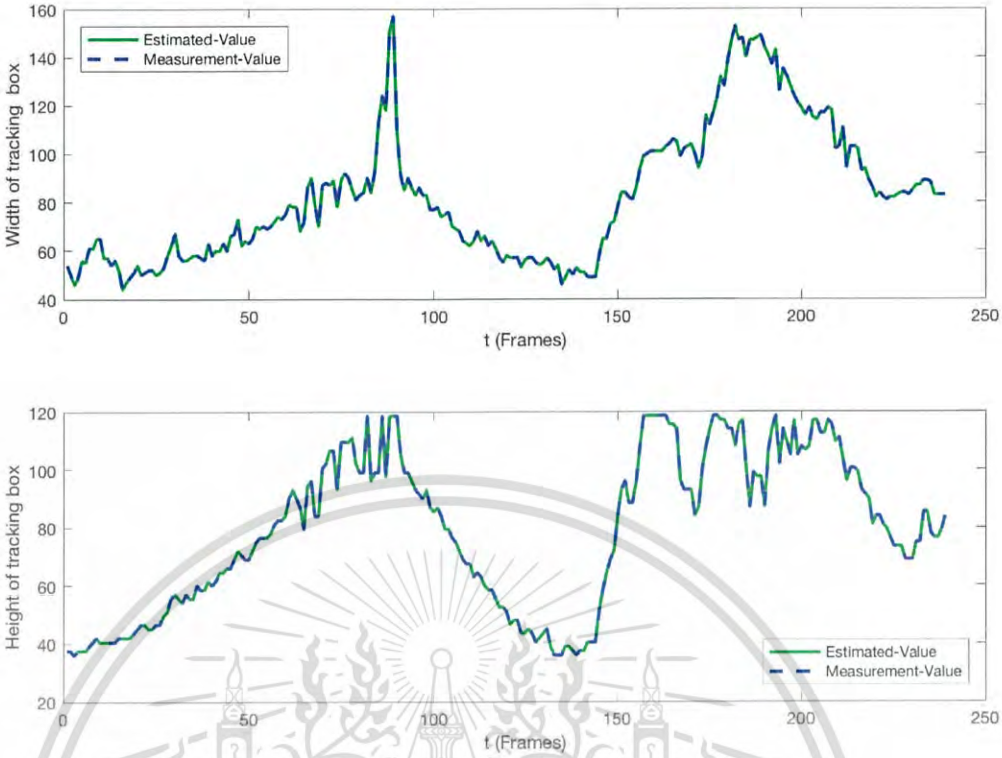

Figure 4.4: Result of width and height tracking with shifting 5-frames of video 3 in Table 4.1

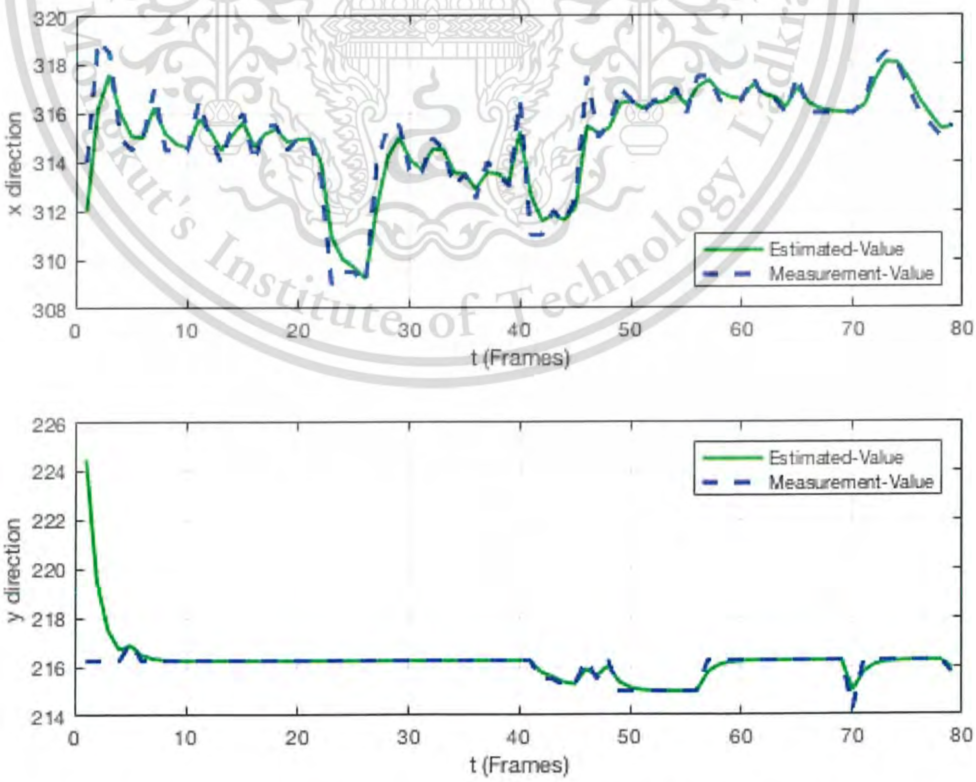

Figure 4.5: Result of tracking object position with shifting 5-frames of video 4 in Table 4.1

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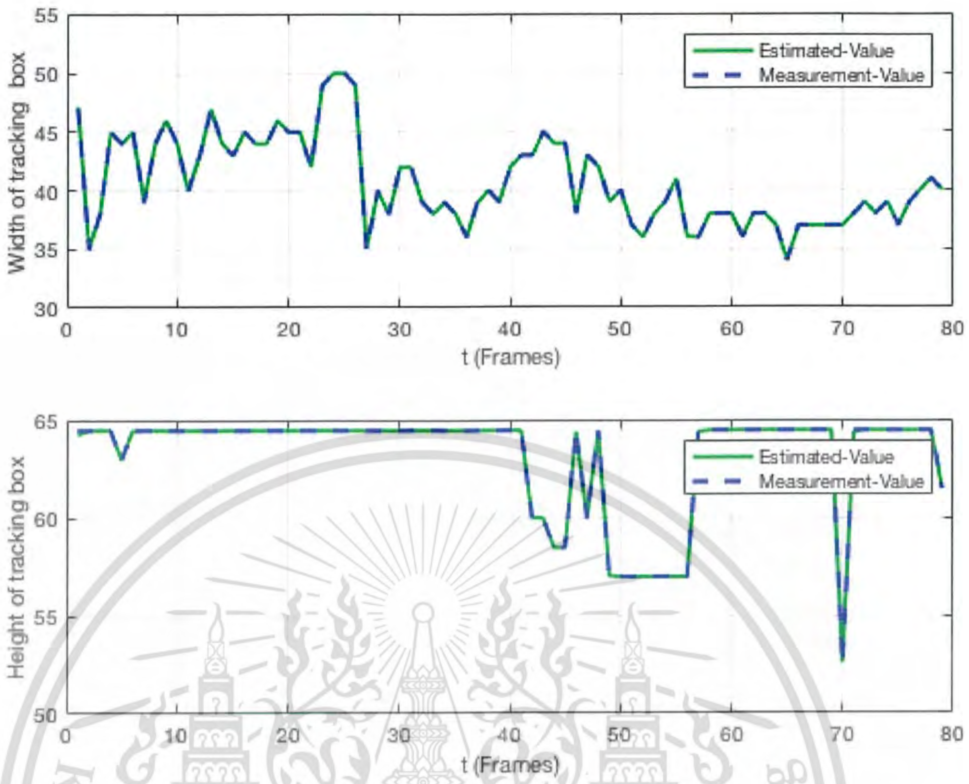

Figure 4.6: Result of width and height tracking with shifting 5-frames of video 4 in Table 4.1

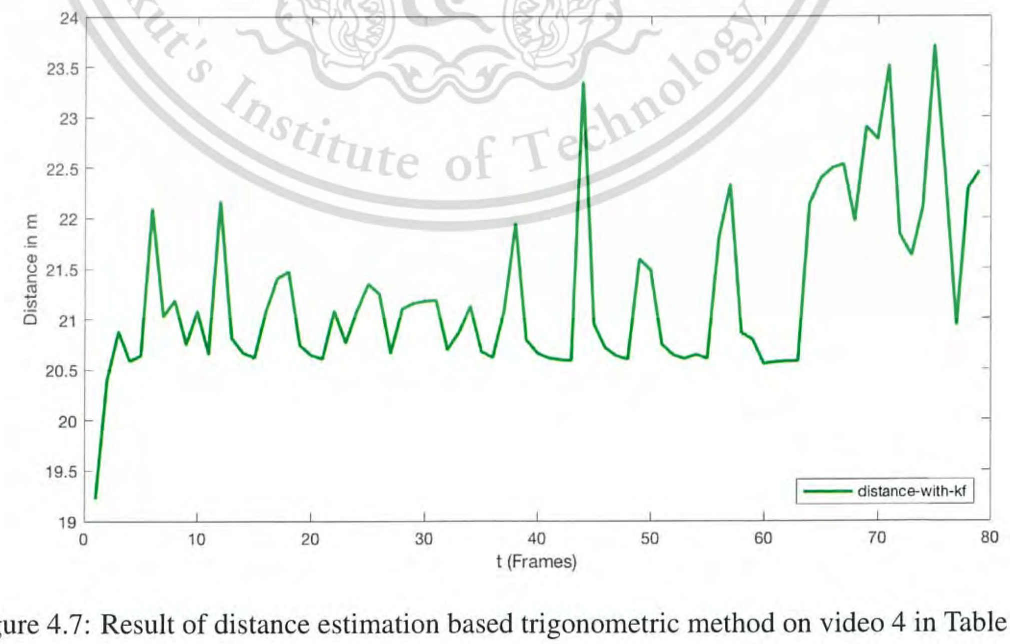

Figure 4.7: Result of distance estimation based trigonometric method on video 4 in Table 4.1

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(a) Distance estimated at frame 50th (b) Distance estimated at frame 100th

Figure 4.8: Result of distance estimation based on camera-pose-based trigonometric technique

where $K = 7$. The dataset consists only two features inter-distance-pixel and inter-distance-in-metter. Table 4.4 shows the training and testing result of the linear model. In colum Errors we got the weighted average about 0.15 which is mean that the simple linear regressiong model has high accurate on distance estimation. Futhermore, the average of R^2 is about 0.90 which is indicated that the relationship between distance in pixel and distance in meter are strong.

Table 4.4: Weighted result and error based on K-Fold-training, where k = 7

K	α	β	R^2	MAE
1	86.1915	-0.2682	0.853	0.3116
2	91.3656	-0.2894	0.8922	0.1267
3	92.3182	-0.2933	0.8979	0.0685
4	93.1887	-0.2969	0.8931	0.1161
5	91.7672	-0.2910	0.9025	0.0585
6	91.9464	-0.2917	0.9012	0.0751
7	91.6919	-0.2905	0.9726	0.3135
Average	91.2099	-0.2887	0.9017	0.1528

4.2.5 Warning System

To implement this concept scenario of the collision warning system, we need a dataset with a danger might be occur. However, we are not able to have those dataset hence we assume video 4 in Table 4.1 having monitoring zoone ($M = 24m$) ahead and video 3 in the same table having $M = 22.22m$ ahead. Figure 4.9 and 4.10 show how the warning system would be activated to give the warning to the driver properly. Futhermore, Figure 4.11, 4.12, and 4.13 indicate the simulation result on alarming the driver when the margin ratio of monitoring zone $S = M - D < 0$.

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According to the experimental result, the collision warning system is capable to give the

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warning to the driver accurately, However, there are two major problems which are the distance estimation and monitoring area. This two majors will lead the wrong warning activation; hence we should improve the system by model the dynamic monitoring and estimate the distance more accurate with moving vehicle detection.

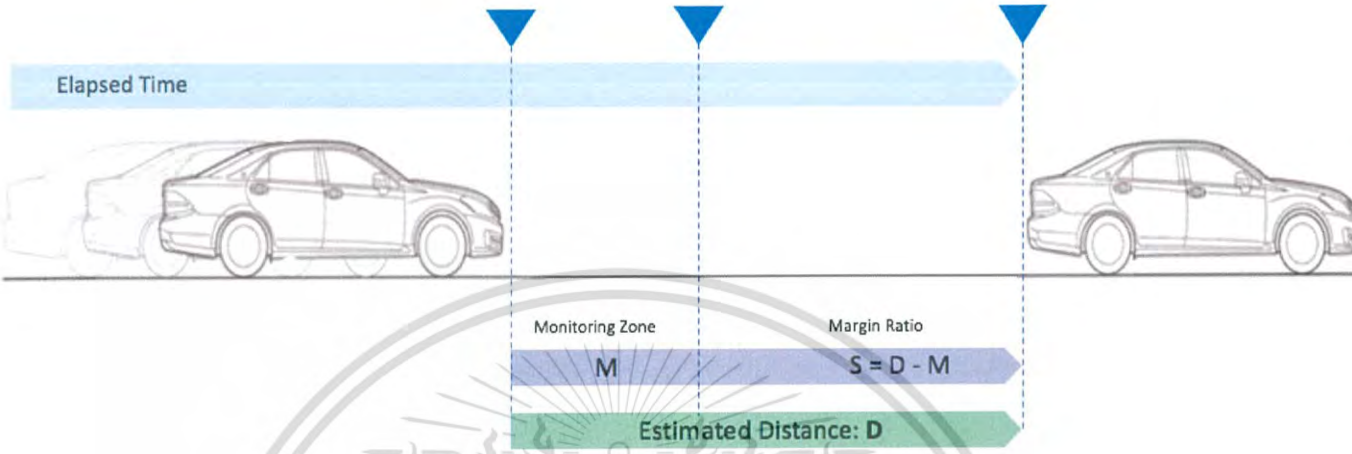

Figure 4.9: Set-up monitoring zone for collision warning system

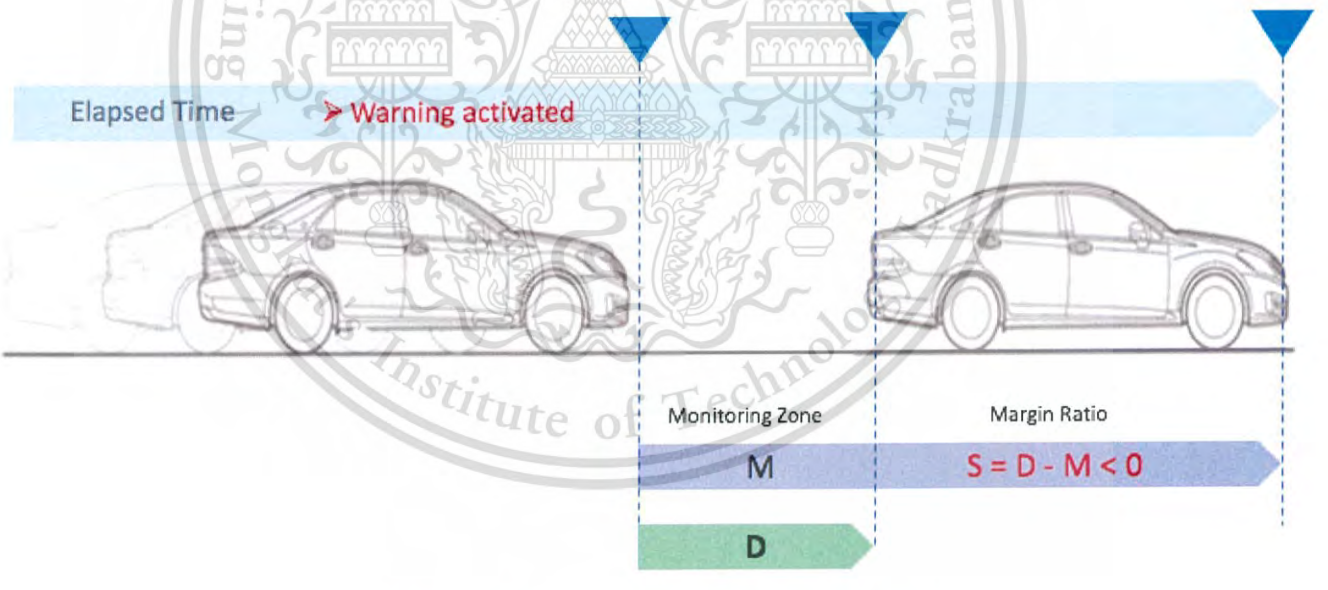

Figure 4.10: Case activation of warning system

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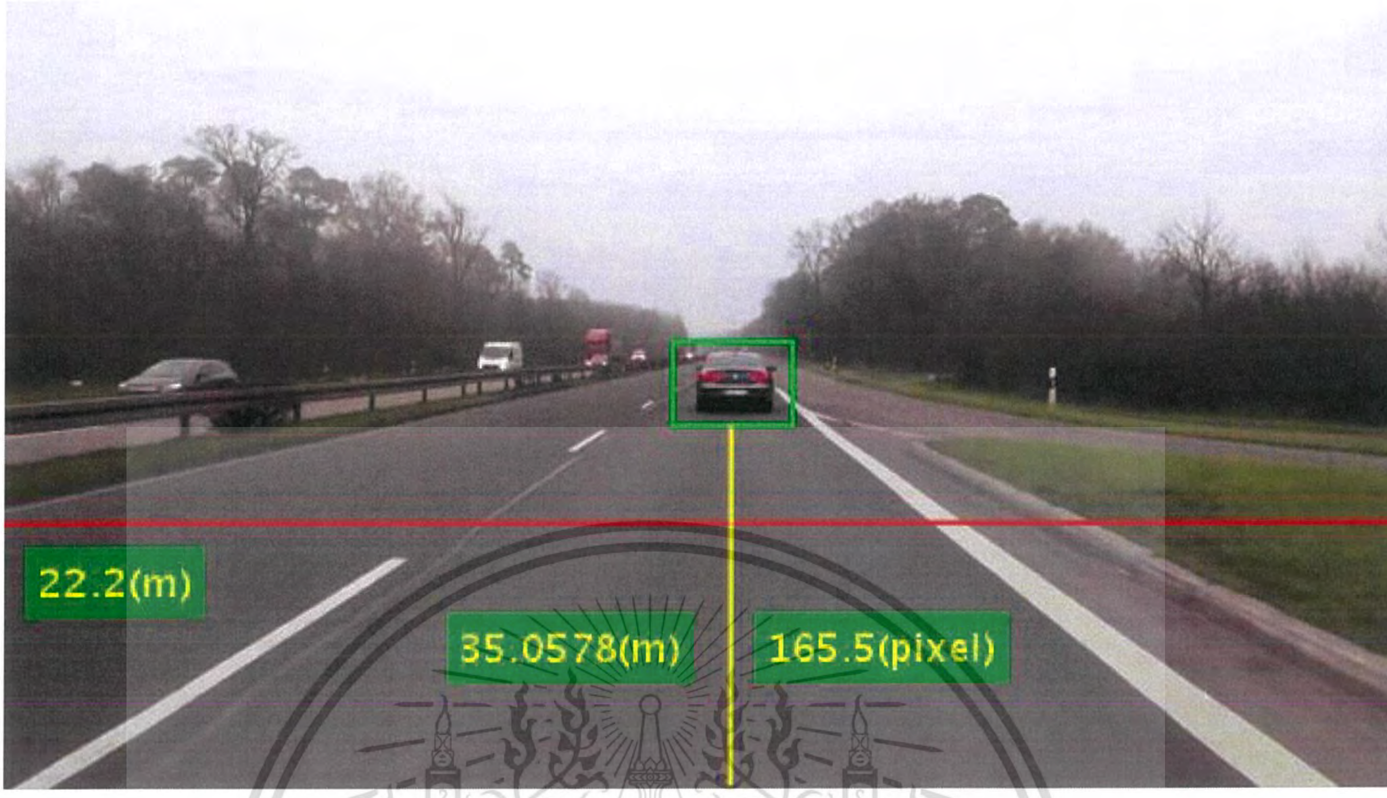

Figure 4.11: Case warning is not activated when $S = D - M > 0$ on video 3

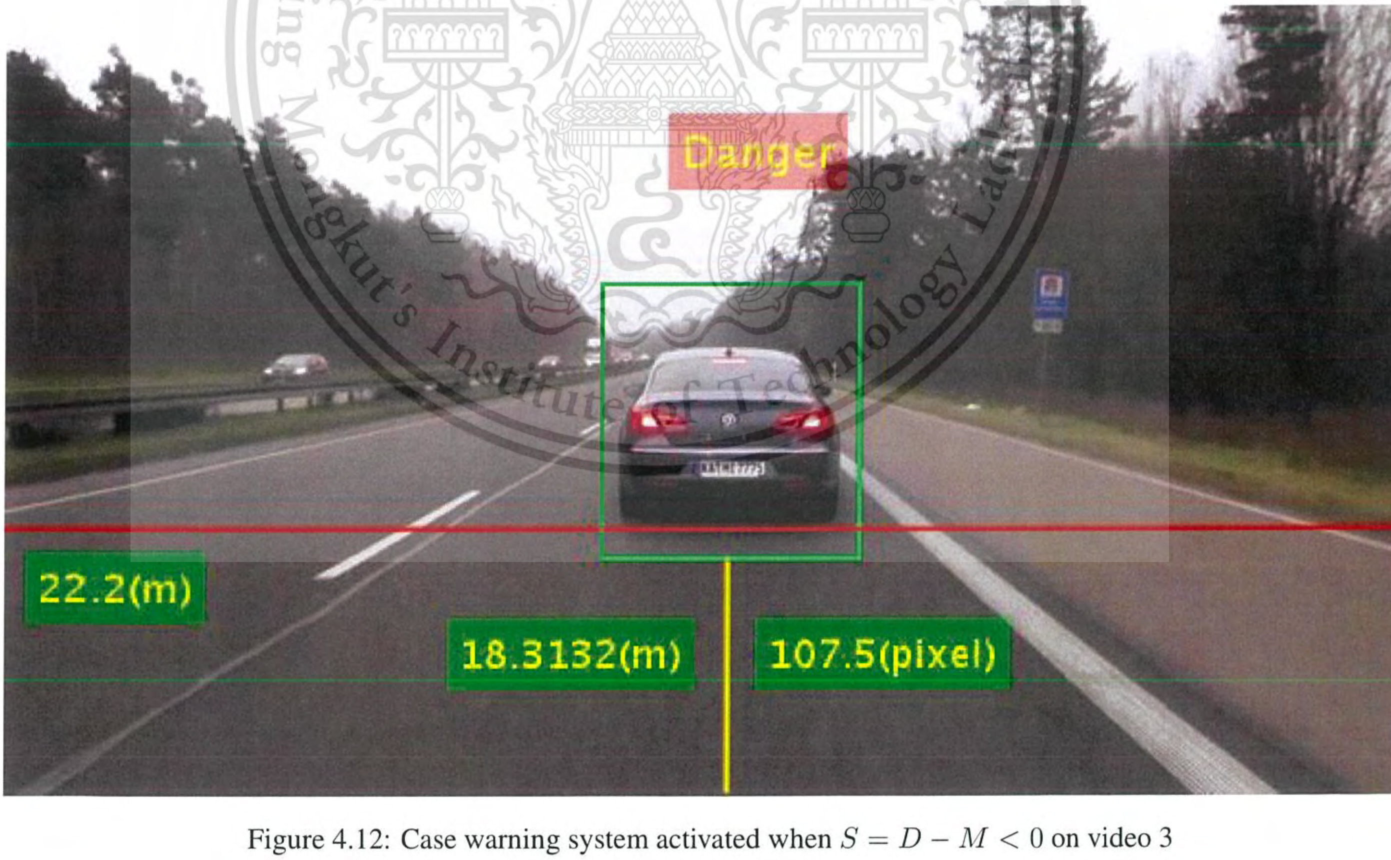

Figure 4.12: Case warning system activated when $S = D - M < 0$ on video 3

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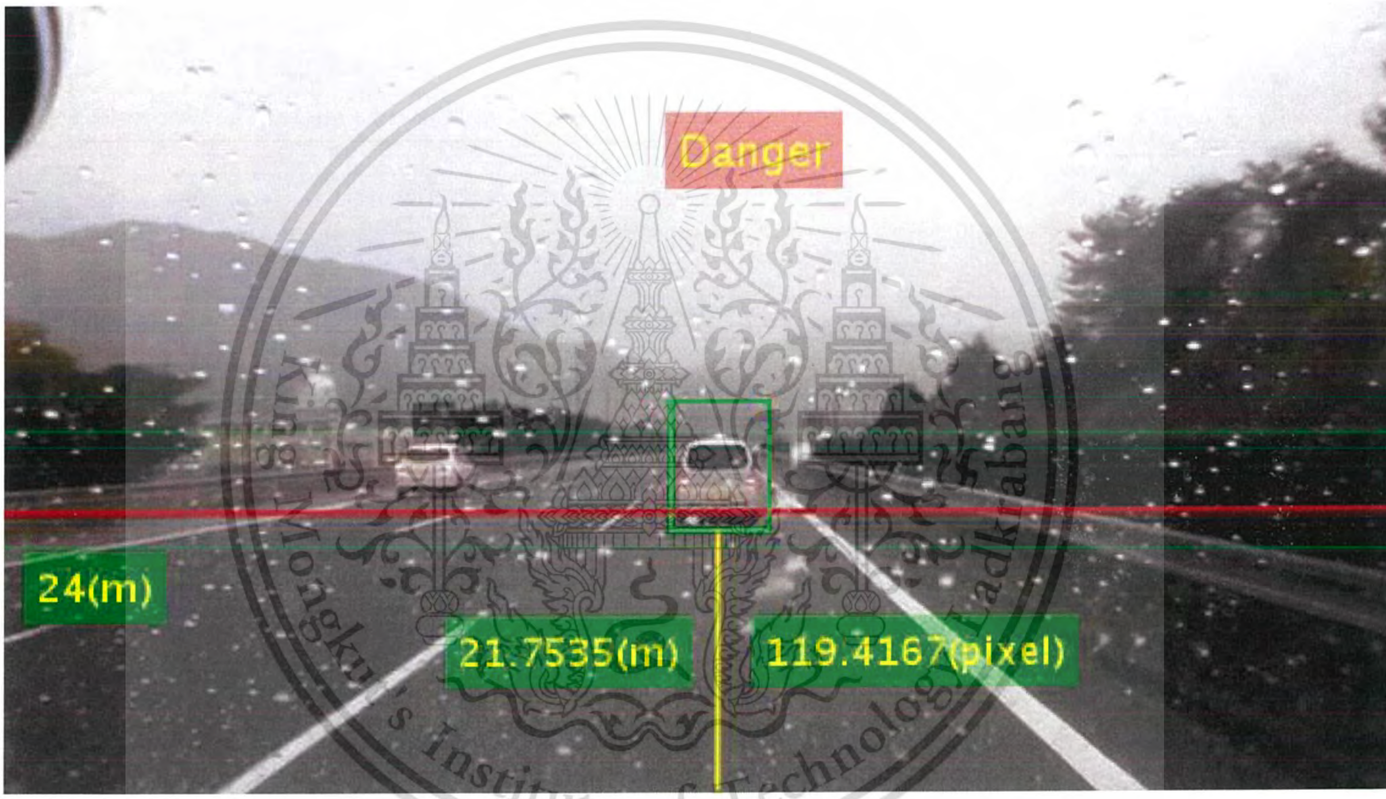

Figure 4.13: Case warning system activated when $S = D - M < 0$ on video 4

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CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

This research study observes the vision-based front moving vehicle detection and tracking for collision warning system approac using videos on urban structured roads in Thailand. This study predicts the next driving state of the front vehicle in order to increase driving safety by predicting the collision risk and warning the driver to avoid them. The works compose of 4 main scenarios which are front moving object detection front vehicle tracking, inter distance estimation and warning system.

In the detection process, the proposed study makes use of shifting three frame difference with a combination of Sobel edge detector algorithm. The shifting frame concept is to ensure that the system performs well in real-time scenario. According to the experimental results, the performance of detection and the correct detection rate are improved when the target object starts tracking with Kalman filter.

For the vehicle tracking process, the system predicts the next state position and surrounding box of the object. This surrounding box is used to minimize the object area which helps the system to reduce the computational load and increase the detection rate. In overall, the system is well performed for the real-time detection and tracking for collision risk prediction.

For inter vehicle distance estimation, the proposed system makes use of Trigonometric Technique which is applied on the video 4 with knowing camera's characteristics such as θ_c angle of camera, H hight of camera, and α field of view angle. From experimental result indicated that the major impact on error of estimation are mainly based on accuracy of detection technique and the road surface. Additionally, for video with unknown camera characteristic we proposed simple linear regression model to predict the inter distance by having d_p a pixel distance in 2D image plane. There are two main reasons which support the machine learning algorithm would work to predict distance. (1): Angle of road line segment by Hough Transform is approximately the same. (2): The relationship between pixel distance in 2D image plan and distance in real world should be linear.

Finally, the warning system is computed by applying margin ratio with monitoring area. To compute the impact collision, this proposed system is to utilize the estimated distance information

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obtained from linear regression model with margin-ratio. The system assumes that, the vehicle driving with the constance velocity, the system then monitor the front warning zoone with about 2 second ahead plus with the processing time. If the case of margin ratio is less then zero the warning system is activated.

5.2 Future Work

With the proposed research methodology, there are requrired some improvement. Belows are some of import technique need to embedded to the proposed system in the future.

1. Detection

    Shadow analysist

    Corner point detection

    Front moving object regconition

    Lane marking analysis

    Occlusion analysist

2. Front Moving Vehicle Tracking

    Dynamic scene modeling object tracking (model with acceleration)

    Multiple object tracking with kf (might be able to extend a none linear model of Kaman filer along with distance estimation algorithm)

3. Inter Distance Estimation

    Seeking new machine learning algorithm to improve the accuracy and compare with current proposed algorithm

4. Collision Warning System

    Since the collsion warning based on distance estimation and monitoring area, there are two main impacts which will lead the wrong warning activation. Hence, in future work we would find the model to define the monitoring zone dynamically instead of assuming the constance velocity and compute the front area ahead of 2 second.

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APPENDICES

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APPENDIX A Publication

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Kracow, Poland | July 11-14, 2017
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Front Moving Vehicle Detection and Tracking with Kalman Filter

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Abstract—**Immature behavior, fatigue, and inattentional driving have been mainly identified as major issues in safety. Such human behaviors are considered to be the core problem for the occurrences of traffic accidents. As a result, Intelligent Transportation System including Safety Driver Assistance Systems plays an important role in traffic safety. This system becomes the focused research topics recently. This paper aims to make an investigation of front moving vehicles detection and tracking for the forward collision warning system. In the proposed system, there are two major parts, i.e. vehicle detection and vehicle tracking for position prediction. For the detection procedure, this paper makes use of computer vision techniques with shifting three frame difference method on video sequence and combines with edge detection. For object's boundary selection, this work applies the blob-detection to extract the center of mass and the bounding box features of the detected object. After having selected those features of the front vehicle the tracking process is carried on by utilizing Kalman filter algorithm in order to improve the accuracy of object detection and position prediction. Three videos obtained on the urban structured road in Thailand are tested. Experimental results show that the detection rate of front moving vehicle performs better when Kalman filter is applied for tracking.**

Keywords-front object detection; object tracking; Kalman filter algorithm

I. Introduction

Front vehicle detection and tracking for position prediction in video scene of high-way application are crucial tasks for Intelligent Traffic Safety System (ITSS). Such system is applicable in incorporating Electronic, Computer and Communication technologies into vehicles for traffic death reduction, assisting drivers, and enhancing passengers safety. Furthermore, not only collision avoidance system but also traffic monitoring system and others traffic surveillance systems require the detection technique.

Many researchers have proposed methods for front moving object detection. For example, Zhou and Hoang [1] proposed background subtraction technique for real time robust human detection and tracking system in video surveillance. In the experiment, they used videos with different environment as the inputs and the results were proved to be robust; however, this method seemed to work only with the stationary camera and not satisfied with non-stationary camera. Moreover, there were also false detection if the foreground was affected by the shadow. A cooperative work by Srilekha et.al [2] introduced a new technique for detecting, tracking, as well as counting the vehicles based on Kalman filtering approach. The proposed method utilized an updating state estimation of Kalman filter to update the background model over time. The results had better accuracy compared to background subtraction method. However, its major limitation was inability to manage dynamic background pixels and a non-stationary camera. Yadav et.al [3] presented a real-time vision based method for detecting vehicles in both rear and forward collision warning system. The proposed work consisted of two different modules. One was corresponded for vehicle in the forward path and the other for passing-by vehicle. For the localizing forward path vehicle, the authors utilized Profiling and Edge detection techniques while the passing-by vehicle detection they made use of temporal differencing method. The results had been demonstrated high performance of the system and low false positive rate for the in-path vehicle. However, it was degraded under rainy weather scenarios because of improper segmentation obtained from multiple edges due to reflections from various objects. Zhang et.al [4] proposed front vehicle recognition, in which the context information of the images and machine learning method were integrated to improve the performance of recognition. The vehicle detection was carried out using histogram of gradient (HOG) which counted occurrences of gradient orientation in localized portions of an image. This method had good performance on the structural road, however the limitation was that this method could not work well in the case of bright light. SenMa et.al [5] proposed a vision optical flow based vehicle forward collision warning system for intelligent vehicle. The detection of vehicle in this work was done by frame difference method. The main advantage of this method was that it had well performance of recognizing moving objects without modeling the background. However, its limitation was that if the object pixel of sequence frames were not much different, the result of this method did not provided enough information to extract boundary object. Additionally, the authors further used Optical Flow algorithm to track a front vehicle from selected object and applied Harris algorithm, a corner detection, with Lucas and Kanade (LK) for determining the moving intention of the vehicle. Su et.al [6] designed a new tracking algorithm by fusing Kalman prediction and Mean Shift Search together for moving objects in Unmanned Aerial Vehicle. The results indicated that their proposed method was computationally inexpensive which was fit for aerial video surveillance. Fang et.al [7] proposed a real-time collision warning system which

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contained lane marking detection, vehicle detection, and vehicle distance estimation. For marking the lane, the authors used the Sobel edge detector and Hough transform. This work divided vehicle detection into two parts, i.e. one was for daytime detection and another one was for nighttime. In day time they made use of shadow detection and edge detection together. However, for nighttime they used Cr component of the YCrCb color model to verify the location of the vehicle. Experimental results showed that the system was well performed and stable. However, at night time the performance was not accurate. Zhang et.al [8] observed the main problem in front vehicle detection and tracking base image processing. This work used improved HOG (Histogram of Gradient) for feature extraction and recognized object by carrying on Adaboost classifier then applied the Kalman filter for multiple objects tracking and enhancement of the detection rate. Another finding from Li et.al [9] established object motion model for multiple object tracking based on Kalman filter algorithm to choose centroid and track window. The authors used the matching results of sequence frames as the measurement for updating the state prediction of Kalman filter. From the estimated result with detection information, their system were able to judge whether there was a block between objects. Dai et.al [10] presented an integrative approach to vision-based lane departure detection and collision warning system with overtaking vehicle detection (rear vehicle detection). For lane departure of this presented work, the authors used low-level image features, Hough transform, and Sobel for calculating the gradient. In the detection scenario, this work applied the shadow detection for daytime; however, for the nighttime they proposed a symmetry analysis technique to improve the detection rate. The evaluation had showed the effectiveness of their proposed work.

This paper proposes a front moving vehicle detection and tracking which is utilized shifting frame different method with edge detection. The combination of these two methods has more advantages than shadow underneath technique and it fills the important information for extracting boundary object. Additionally, the shifting frame means to reduce the computation and it is also well fed in the process of tracking. In order to track the front moving vehicle, this work makes use of Kalman filter which is a classic state estimation algorithm. There are two main advantages in application of Kalman filtering.

- Kalman filter provides the state prediction of position after the first detected object. This prediction result can be used for minimizing area of the detection for the next coming frame, This will lead to the reduction in computation, overcome the obstruction of noise, and less uncertainty of measurement.
- Kalman Filter provides the auto-correction state by using measurement which is obtaining by vision base detection to update the prediction state. Consequently, the predictor will provide an estimation of whereabout the object will appear in the next frame.

This paper is organized as follows. Section II describes an overview of the proposed system. Section III explains the proposed methodology on front moving object detection and tracking scenario. Section IV provides experimental setup and result. Finally, the conclusion is described in section V.

II. System Overview

Figure 1 shows a diagram of the proposed front object detection and tracking for collision warning system. The system contains two main parts. Firstly, the front object detection takes a video as an input then converts every frame of video to the grayscale image. After having selected the first frame, Region of Interest (ROI) segmentation is processed to define the road area of the video scene. Next, when the ROI has been done, three frame difference with Sobel edge detector algorithm is used to find the boundary object. Sequentially, the system utilizes morphological operation with blob detection for extracting features of the boundary. Finally, Kalman filter is applied for tracking in order to predict the position of the detected object.

III. Proposed Methodology

This section discusses about the procedure to detect and track vehicle in each video frames.

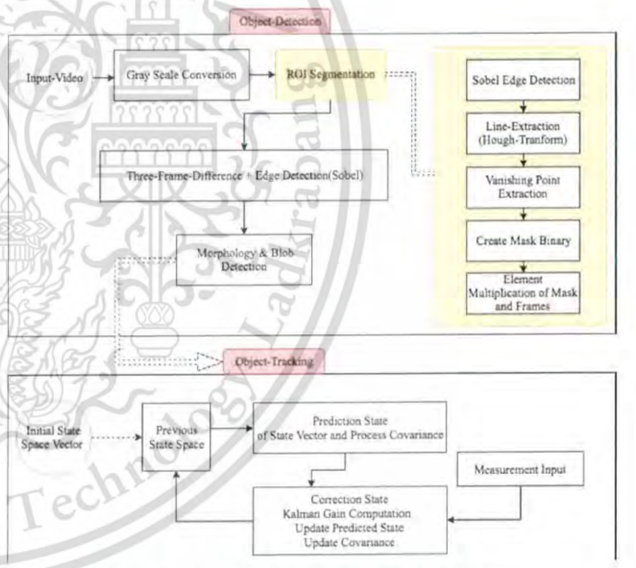

Figure 1. Vehicle detection and tracking system.

A. Front Moving Object Detection

Front moving object detection for collision warning system is a technique used to find front vehicles which appear in the monitoring zone of each frame in a video. The proposed detection method has four main partial steps which are described as follows:

1) Segmentation of ROI (Region of Interests): First of all, Sobel edge detection algorithm is applied for detecting all edges on the grayscale converted image. The Hough transform technique which prominently explains in [10]-[11], is then used to detect the lines. After that, the system is able to extract the left and right lines which are connected to

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the vanishing point. Since the left and right lines of the road always appear on the lower part of the input frames, only the middle bottom of the input frames is necessary for the Sobel edge operator and Hough transform for finding the lines. The upper part of the input image frame is cut for the reason of noises effect avoidance and computational load reduction. Figure 2(a) is the original input image with the upper part is removed and Figure 2(b) shows the corresponding edge detection result of Sobel operation. After having applied the Hough transform technique on the detected edges, those lines are judged to be the left or the right side of the frame in which rely on the equation (1) and (2).

$$\left(x_1 > \frac{w}{2}\right) \& \left(x_2 > \frac{w}{2}\right) \& \, \theta \in [-83, -20] (Right\ Line) \quad (1)$$

$$\left(x_1 < \frac{w}{2}\right) \& \left(x_2 < \frac{w}{2}\right) \& \, \theta \in [20,\ 83] (Left\ Line) \quad (2)$$

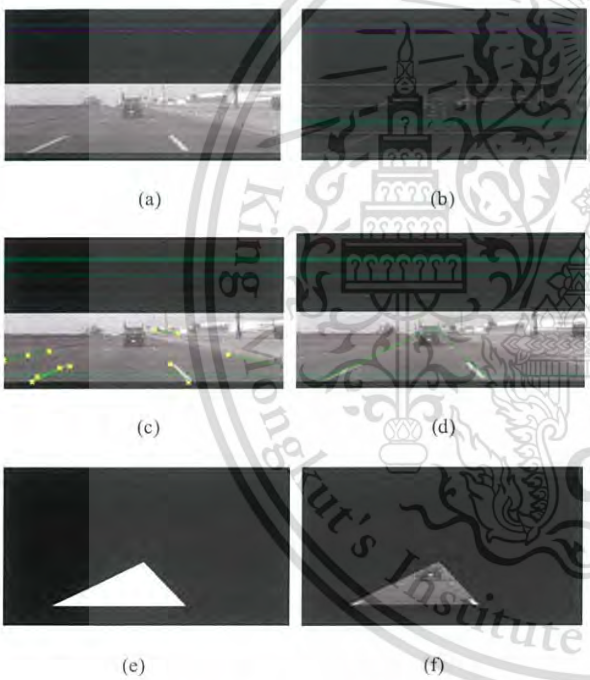

Figure 2. Simulation result.

Where x_1 and x_2 are the x-components of (x_1, y_1) and (x_2, y_2) which are the start and the end points of a line, w is the width of the input frame and θ is the angle resulting from Hough transform technique.

Based on these criterion, the system generates the left and right lines of the input frame. However, two of those lines are selected to be on each side. In this case, the system will choose the best right and left line by utilizing the third component of cross product vector which identifies the leftmost or the rightmost of the lines as shown in equation (3).

$$S = (x_m - x_1)(y_2 - y_1) - (y_m - y_1)(x_2 - x_1) \quad (3)$$

where (x_m, y_m) is the midle point of another line on the same side. If S < 0 then the point lies on one side of the line, and if S > 0 then it lies on the other side. If S = 0 then the points lies exactly line.

The vanishing point is the intersection of the left and right lines which are extracted from the input frame. According to both lines and vanishing point, the system is then able to mark the interest region of the frame as shown in Figure 2(d).

The next process is to generate the targeted region from the marking area. In order to generate the required area, a reference binary image (mask binary) is created, then the ROI is shaded white and the leftover region as black, as indicated in Figure 2(e). In order to obtain a mask binary, this work makes use of cross product vector which satisfies the condition that if the coordinates of the image pixel are in the selected area, those pixels are then set to 1 else they are set to 0. Finally, the multiplication of each element of the image with the mask results in the final desired target area which is illustrated in Figure 2(f).

2) Three Frame Difference with Edge Detection Method: After having extracted the ROI, the system applies three frame difference method to find the front moving object. Let $f_{k-1}(x,y)$, $f_k(x,y)$, and $f_{k+1}(x,y)$ are the consecutive grayscale images where x, and y are the coordinates of input frame, then the algorithm is specified in equation (4) and (5).

$$f_1' = \begin{cases} 1, & |f_k(x,y) - f_{k-1}(x,y)| \geq T \\ 0, & |f_k(x,y) - f_{k-1}(x,y)| < T \end{cases} \quad (4)$$

$$f_2' = \begin{cases} 1, & |f_{k+1}(x,y) - f_k(x,y)| \geq T \\ 0, & |f_{k+1}(x,y) - f_k(x,y)| < T \end{cases} \quad (5)$$

$$f'(x,y) = f_1'(x,y) \cap f_2'(x,y) \quad (6)$$

$$D(x,y) = f'(x,y) \cup D_k(x,y) \quad (7)$$

where f_1' and f_2' are the binary images resulting from consecutive substraction. f' is the final output of an intersection operation as shown in equation (6) and the result is illustrated in Figure 3(a). Since the three frame difference method produces an object without edge information, this paper utilizes the Sobel edge detector on the selected area. Equation (7) shows the combination of three frame difference and edge detector where $D_k(x,y)$ defines the edge detection of image frame $f_k(x,y)$. Therefore, the system has adequate information to extract the boundary object.

Figure 3(b) illustrates the result of Sobel edge detection, and Figure 3(c) shows the result of three frame difference with edge detection.

3) Extracting Boundary Object: In the proposed work, the system extracts boundary object by utilizing blob detection with morphological operation. Morphology is a mathematical image processing operation which operates

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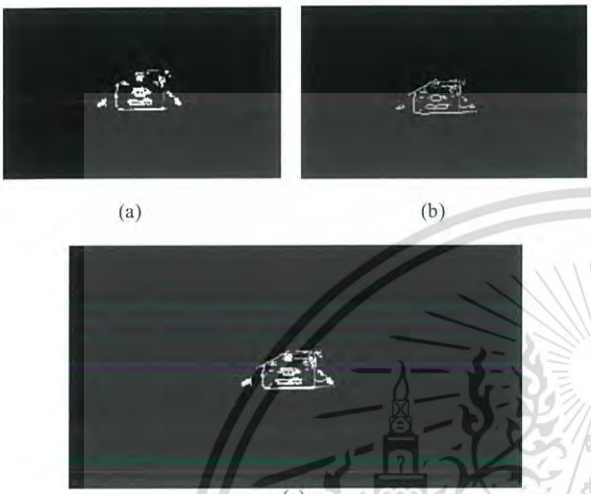
images based on geometrical structures. This operation is to carry on removing noise and adding pixel for improving the information of shape in image. The proposed study makes use of the morphological dilation operations due to the object's pixels obtained from the detection are not well enclosed. Equation (8) shows the implementation of morphological dilation operation.



(a) (b) (c)

Figure 3. Simulation result of three frame difference with edge detection.

$$g = f \oplus s \tag{8}$$

Where g is the output image, f is input image, and s is the structure element. Figure (4) shows the image result obtained after applying morphological dilation operation.

Figure 4. Simulation result of morphology operation.

Blob Detection is a method which aims to find the region differed in properties, such as brightness or color, compared to surrounding regions [12]. In this case, the authors use the white pixel value as the boundary object. Since the pixels value of every frame in a video scene are dynamically changed, the noises still exist even though morphological dilation is applied. Such reason, this work uses three main attributes, i.e. a ratio value between perimeter and round length of object's bounding box, a ratio value between object's area and the bounding box's area, and an object's area value to extract the true boundary object. Figure 5(a) shows a result of blob detection in a binary image. Since one-third of the real object in a video is cut for the reason of region of interest (ROI) selection, the threshold value is added to the height of the object's bounding box as illustrated in Figure 5(b).

(a) (b)

Figure 5. Result of blob detection in binary image and video's image.

4) Shifting Frame: The main purpose of shifting frame is to reduce the computational load of the system due to processing on the real-time environment. However, to select the number of shifting frame is based on the frame rate of the input video and also the collision time interval over the frames. In this work the interval is shifted by 5 frames because in the experiment the frame rate of videos are 25 frame per second (fps). Additionally, the system also monitors the collision time before 2s for driver reaction, as a result; the proposed system has sufficient time for computing and alerting the driver to react on time to the situation. Figure (6) illustrates the result of detection by shifting 5 frames.

Frame-5th frame-10th

Figure 6. Result of detection with shifting 5-fames.

B. Object Tracking with Kalman Filter

In the proposed research scenario, it is assumed that the front moving vehicle will only appear in the region of interest (ROI) which describes in the above section. Therefore, a single object tracking is established.

Mathematically, Kalman filter is a recursive least square estimator which predicts and automatically corrects the states [13]-[14]. The predicted state uses the model system equations which is based on the behavior of front moving object and previous state matrix, then the next state object parameter is predicted. When the time updating arrives Kalman filter takes the measurement resulting from the detector to update the prediction state for estimating the position of object.

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Assuming that, a tracking system where X_k is the state vector represents the front moving object, such that k indicates the discrete time over frame interval. The main purpose of this tracking is to estimate the optimal X_k which updates by the measurement z_k. Following the description, Kalman filer involves two main stages which are prediction and measurement update as correction state.

1) Prediction Equations: Assumed that the initialization of parameters of state vector has been done, the prediction equations are given as follow:

$$\text{Prediction State}: \hat{X}_{k|k-1} = F_k \hat{X}_{k-1|k-1} + W_k \tag{9}$$

$$\text{Process Covariance}: \hat{P}_{k|k-1} = F_k \hat{P}_{k-1|k-1} F_k^T + Q_k \tag{10}$$

F_k defines the transition matrix which applies the effect of every state parameter. W_k is a zero mean white prediction noise with covariance Q_k. $\hat{P}_k$ is process noise covariance between terms in the state vector.

2) Correction Equations: At this stage Kalman filter computes the kalman gain, the ratio between covariance of noise prediction and covariance of noise in measurement. Then the prediction model is updated.

$$\text{Kalman Gain}: K_k = \hat{P}_{k|k-1} H_k^T \left(H_k \hat{P}_{k|k-1} H_k^T + R_k\right)^{-1} \tag{11}$$

$$\text{Measurement}: \quad z_k = H_k X_k + v_k \tag{12}$$

$$\text{Correction State}: \hat{X}_{k|k} = \hat{X}_{k|k-1} + K_k\left(z_k - H_k \hat{X}_{k|k-1}\right) \tag{13}$$

$$\text{Update covariance}: \hat{P}_{k|k} = (I - K_k H_k) \hat{P}_{k|k-1} \tag{14}$$

Where H_k is the measurement matrix and v_k is a zero mean white measurement noise with covariance R_k.

C. Kalman Motion Model for the Target Object Tracking

Describing the parameters of object moving on two dimensional image can be done by defining the coordinate of center, size, and velocity of object. Since position, size, and velocity of a vehicle in Kalman filter are represented by (x, y), (l, h), and (v_x, v_y, v_l, v_h) respectively, the state vector is then expressed $X_k = (x_k,\ y_k,\ l_k,\ h_k,\ v_{x_k},\ v_{y_k},\ v_{l_k},\ v_{h_k})^T$. Since the measurement consists of position and size of the object, the measurement vector can be expressed $z_k = (x_k,\ y_k,\ l_k,\ h_k)^T$. Followings are the transition matrix F_k and measurement matrix H_k of the tracking system which are specified in equation (15) and (16). Finally, The Kalman filter based on the scene is established.

$$F_k = \begin{bmatrix} 1 & 0 & 0 & 0 & \Delta t & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & \Delta t & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & \Delta t & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & \Delta t \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{15}$$

$$H_k = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{16}$$

D. Time Life-Cycle of Vehicle Tracking

The main objective of the time-life-cycle of vehicle tracking is to monitor the front moving vehicle such that the vehicle might be lost from the vision or it might be replaced by other vehicles. With this problem, the proposed work sets the monitoring process to verify each status condition of the tracking procedure. Figure (7) shows that after having first detected the front object, the system sets the status in a stack as appeared and begins initialization of state parameters for the tracking process. This iterate process is verified by the measurement output. If the verified condition is true, the system then sets the status as tracked else the system sets the status as lost. In order to check the status properly, the first loss of status tracking is not yet set to be disappeared unless the system cannot verify for tracking twice in a view. In this case, the system clears up the stack and starts detecting the object over the next time frames. Furthermore, at the first detected object, the prediction value is used for minimizing the ROI. This is not only leading to the reduction in the error of the detection rate but it also reduces the computational load as in Figure (8) shows the data flow of using the prediction value $x_{k|k-1}$ for minimizing the ROI and the measurement value z_k is used to update the predicted state over the frames.

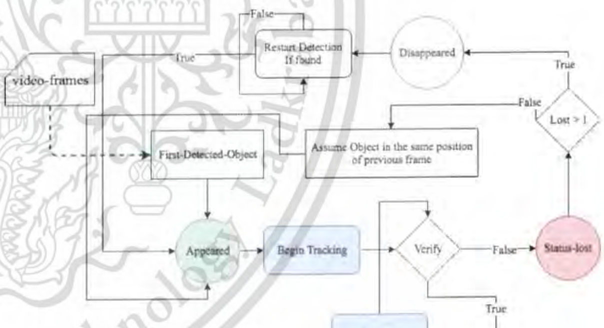

Figure 7. Life-cycle of detection and tracking of front moving object.

IV. EXPERIMENTAL RESULT

A. Experimental Set-up

The front moving vehicle detection and tracking system runs on MacBook Pro which has a 2.4 GHz Intel Core i7 processor with graphics Intel HD 4000 1536 MB and has 8 GB memory. The experiment of this system uses three different videos input as showing in table I. TF, R, FRP and NVDA are Total Number of Frames in a video, Resolution, Frame Rate Per-second, and Number of Vehicle in Detection Area respectively.

The first video is used as the sample of the data for initializing of the parameters of the state vector X_0, process covariance associated with the uncertainty of prediction

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model P_0, the noise covariance matrix of the prediction Q_k, and covariance of uncertainty in measurement R_k. The initialization of the parameters is done by manually selecting the center of object position over the 150 frames then computes the sum of squares error over the detected results. Then these initialized values are applied in other videos.

B. Result

Result of Object Detection: Since the system assumed that the front vehicle must be in the region of interest, the evaluation of detecting the object is then on the term of DR (Detection Rate), and FR (False Detection Rate) in the detection area. DN is the number of correction detection, and FN is a false number of detection. Table II shows the accuracy of detection before applying Kalman filter. However, the overall performance of detection is increase about 4.2% in average when Kalman filter is applied. Video 3 of Table II has high false detection rate due to the illumination of the light and roadside signs.

TABLE I. DESCRIPTIONS OF INPUT VIDEOS

Videos	TF	R	FRP	NVDA
1	150	720x1280	20fps	150
2	1300	720x1280	25fps	1000
3	1200	640x480	25fps	1200

TABLE II. EVALUATION OF DETECTION METHOD

Videos	DN	FN	DR	FR
1	137	13	91.33%	8.66%
2	921	56	92.1%	5.73
3	1064	123	88.66%	10.36%

$$DR = \frac{DN}{NVDA} \times 100\%$$

$$FR = \frac{FN}{DN + FN} \times 100\%$$

1) Result of Object Tracking: Figure (9) shows the result of object position which is tracked in video 2 and the shifting interval is 5-frames. This graph proves that the estimated values are adequate in real time vehicle tracking for collision avoidance system. Furthermore, Figure (10) demonstrates the results of tracking object window with the detection of shifting 5-frames in video 2. From the graph, the system is able to tell that in case the surrounding box of the object is getting smaller it means the object is moving away from the scene else the host object is closed to the front object.

V. CONCLUSION

This study observes the vision-based front moving vehicle detection and tracking approach using videos on urban structured roads in Thailand. This study predicts the next driving state of the front vehicle in order to increase driving safety by predicting the collision risk and warning the driver to avoid them. The works compose of two main scenarios which are front moving object detection and object tracking. In the detection process, the proposed study makes use of shifting three frame difference with a combination of Sobel edge detector algorithm. The shifting frame concept is to ensure that the system performs well in real-time scenario. According to the experimental results, the performance of detection and the correct detection rate are improved when the target object starts tracking with Kalman filter. For the tracking process, the system predicts the next state position and surrounding box of the object. This surrounding box is used to minimize the object area which helps the system to reduce the computational load and increase the detection rate. In overall, the system is well performed for the real-time detection and tracking for collision risk prediction. However, the proposed work might not be able to compare with the state of the art work dude to some limitations.

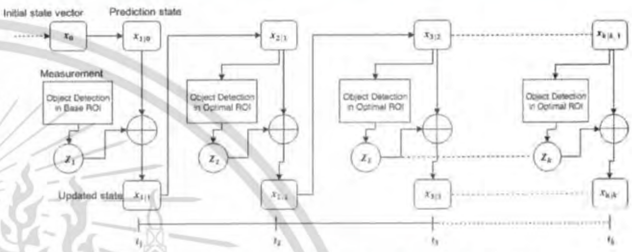

Figure 8. Data flow of kalman filter over time frame.

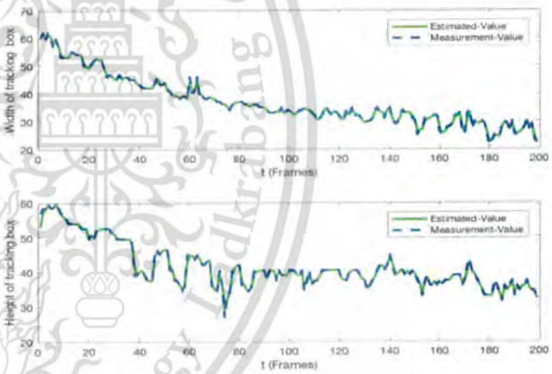

Figure 9. Result of tracking object position with shifting 5-frames of video 2.

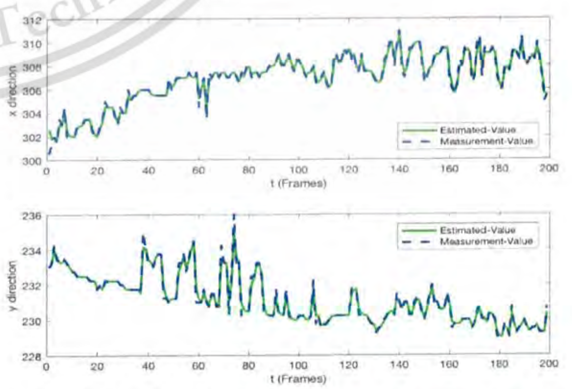

Figure 10. Result of width and height tracking with shifting 5-frames of video 2.

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Education

<u>Bachelor degree</u>

Project	Syncing and Manipulating Acoustic Data
Field of Study	Information Technology
Duration	2011-2016
Department	Department of Information and Communication Engineering
University	Institute of Technology of Cambodia

<u>Master degree</u>

Thesis	Front Moving Vehicle Detection and Tracking with Kalman Filter for Collision Warning System
Field of Study	Computational Intelligence System
Duration	2017-2019
College	International College
University	King Mongkut's Institute of Technology Ladkrabang, BangKok, Thailand

<u>Research Interests</u>

Computer Vision, Machine Learning, and Optimization

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