# Distance estimation and vehicle position detection based on monocular camera

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# Distance Estimation and Vehicle position detection Based on Monocular Camera

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***Abstract*— This paper describes systematically two methods used in intelligent transportation systems: Distance Estimation using an onboard camera and car position detection. Distance estimation is a method for detecting distance for the preceding vehicles based on monocular camera. Vehicle position detection is a method of specifying the vehicle position relative to the road that can serve as Lane Departure Warning system. These two approaches have been discussed and implemented in this article. For lane detection and tracking, Hough Transform and Kalman filter were adopted. A brief introduction about both lane detection system and object detection is given. Finally, both approaches have been evaluated on a large dataset of videos.**

***Keywords*— Distance estimation, vehicle position, lane departure warning system, driver assistance systems, onboard vehicular camera**

## I. INTRODUCTION

According to Global status report published by the (WHO) World Health Organization on the road safety, the eighth leading cause of death is the road traffic injuries [1]. Current research suggests that by 2030, it will become the fifth leading cause of death [1]. One way to reduce the traffic accidents is by developing computer vision systems that is used in intelligent transportation systems.

Accidents that are caused by the involuntary lane departure keep representing a significant part of the accident prone traffic conditions. Seeing the importance of the application, a significant number of driver assistance systems (especially in the United States, Europe and Japan) have been developed recently [2] [3]. The main objective of these researchers is to assist the drivers by discharging them from doing some tasks. The most important part of these types of systems is analyzing the frame sequences that are recorded with the cameras on-board. All these frames have been analyzed for a specific reason, which is supporting the drivers in realistic traffic situations.

Two important aspects of the vision based applications have been discussed and implemented in this paper: Distance Estimation based on the monocular camera and car position detection. As soon as the geometry information of the road and the environment objects (Vehicles and traffic signs) is detected accurately, these two approaches can be applied to the system.
Both approaches can serve a great deal in intelligent transportation systems. For distance estimation approach, detecting the distance of preceding vehicles can play an important role in emergency braking systems. These types of systems work with or without the driver's attention. This can provide significant protection to drivers in situations when they lose attention temporary.

The paper is organized as the following: Section (II) presents the modeling of distance estimation approach, section (III) describes the vehicle position detection and section (VI) presents the conclusion.

## II. DISTANCE ESTIMATION BASED ON MONOCULAR CAMERA

Distance estimation is an important approach that is used in automatic driving vehicles. It gives "estimated" distances to all the surrounding objects that are already detected around the vehicle. These objects can be traffic signs, vehicles, pedestrians...etc. This approach was mainly presented by [4] In order to make this approach work, some steps are needed.

As a preprocessing step to distance estimation, objects such as vehicles, traffic signs and pedestrians should be detected and tracked. Despite the existence of a significant variety of approaches, we had adopted the model that is proposed in [5] due to its simplicity and robustness. For tracking purposes, Kalman filter has been used in this approach [6].

In the following sections (A) through (C), the modeling of the distance estimation approach is discussed in details:

## A. Distance Estimation Method in an Image

The geometrical relations of the point K imaging in a two dimensional plane of the CCD camera can be shown in the figure (1).

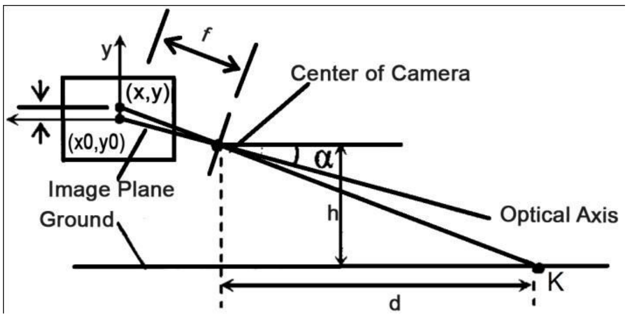


Figure (1): Geometrical relations of the model

The distance between the K point and the camera center can be described in next equation:

$$d = h/\tan(\alpha + \arctan(\frac{y - y0}{f})) \ldots\ldots\ldots (1)$$

In equation (1), f refers to the focus of the CCD camera, alpha is the camera slope of the horizon which is measured in degrees; h is the vertical distance from the camera to the ground. The point of intersection that is about the image plane and the optical axis is ($x_0$, $y_0$), it is the origin of the image plane and it is set to (0 ,0). The projection coordinate of the point K in the image plane is (X,Y).

## B. Analysis of the Model Parameters

In equation (1), once the CCD camera is installed, h and alpha will be known parameters. F is the focus of the camera that is held by the interior parameters of the camera; y is a coordinate which is the projection of the point K on the y axis for the plane of the image, it is called as the image plane coordinate. The image plane coordinates are measured in millimeters. That is because the digital images are stocked in the computer's memory; the ( u ,v) coordinate is called "the store frame coordinate", it is used in processing of the images. The unit of this coordinate is in pixel. While detecting the distance, the store frame coordinate should be converted into the coordinate system of the image plane

The stored frame coordinate of intersection points ($x_0$, $y_0$) of the optical axis of the camera with the image plane is u0, v0.

The transformation between the image plane coordinate and the stored frame coordinate are as the following:-

$$u = \frac{x}{dx} + u0,\ \ v = \frac{y}{dy} + \ v0 \ldots\ldots\ldots (2)$$

In equation(2), dy and dx are the width and the length of each pixel consecutively .v is obtained in above the identifying vehicle, it is the projection line of vehicle on the ground in the frame and the intersection coordinate about the symmetrical axis of the vehicle . The dy, dx, $v_0$ and $u_0$ result from the off-line calibration operation of the camera. After the calibration of the camera is done offline, these parameters will be known. The distance that is detected is going to be real-time operation.

Equation (2) can be transformed into the following:-

$$x = (u - u_0)\, dx \qquad \ldots (3)$$
$$y = (v - v_0)\, dy$$

In equation (3), values of v and u are obtained from proceeding image.

$x0 = y0 = 0$

The equation can be transformed into equation

$$d = h\ /\tan(a + \frac{\arctan(\mathrm{v} - \mathrm{v0})}{\mathrm{ay}}))$$

$$ay = f/dy$$

## C. Vehicle Detection

An efficient way of detecting objects is the method that is proposed by Paul Viola and Michael Jones at [5]. It basically based on the use of Haar-like features cascade classifiers. Viola and Jones method is a machine learning way where the cascade function is trained according to number of negative and positive images of the object itself so it can be used to detect the object in other images. The method was the first to be used in real time object detection. Each Haar like feature describes a pattern of contrast in adjacent regions in an image. Vertices, lines and vertices, each of those can generate different distinctive feature. For each photo, features are varied depending on the regions' size which is called the window size. Different images with different scale should be capable of yielding similar different window sizes.

Open source computer vision (OpenCV) provides a detector as well as trainer for Haar cascade classifier. The trainer needs positive and negative samples so that it can be trained. Positive samples are collection of images that contain only objects of interest faces. While negative samples are the images that does not contain he objects of interest. A collection of 950 positive samples have been used to train the classifier, where as the number of negative samples used were 1900. Figure -2- shows some positive samples. A 25×15 pixel was the size of the positive and the negative samples.


Fig -2- Positive samples of the training data for Haar Cascade classifier

## D. VERIFYING THE MODEL

The CCD camera calibration results the following interior parameters:
U0 = 143.3 v0 = 89.15 ay = 254.64

The intersection point about the optical axis of the stored frame coordinate and the image plane is (136, 99). The size of the store frame image is 480×360 pixel, which its center coordinate is (240,180). These two centers are different. The distance detection is carried out using the above method; the detecting range is 4 meters up to 50 meters. The following table shows a comparison between actual and measured values for distance.

TABLE I: Actual and measured distances comparisons

| | | | | | |
|---|---|---|---|---|---|
| Order | 1 | 2 | 3 | 4 | 5 |
| Actual Distance (m) | 5 | 10 | 15 | 20 | 25 |
| Measured Distance (m) | 5.8 | 9.3 | 14.2 | 18.7 | 23.0 |

A simple formula can be applied in order to measure the error rate in distance estimation, which is:

$$\text{Error Rate} = \frac{|\text{measured distance} - \text{actual distance}|}{\text{actual distance}} * 100\% \ldots (4)$$

The average error rate for all cases represents the overall error rate of the system. For distance estimation, the percentage error rate of the system was 9.71%, which means that the system has an accuracy of 90.29%.

Figure (3) below shows some experimental results for the presented method:-

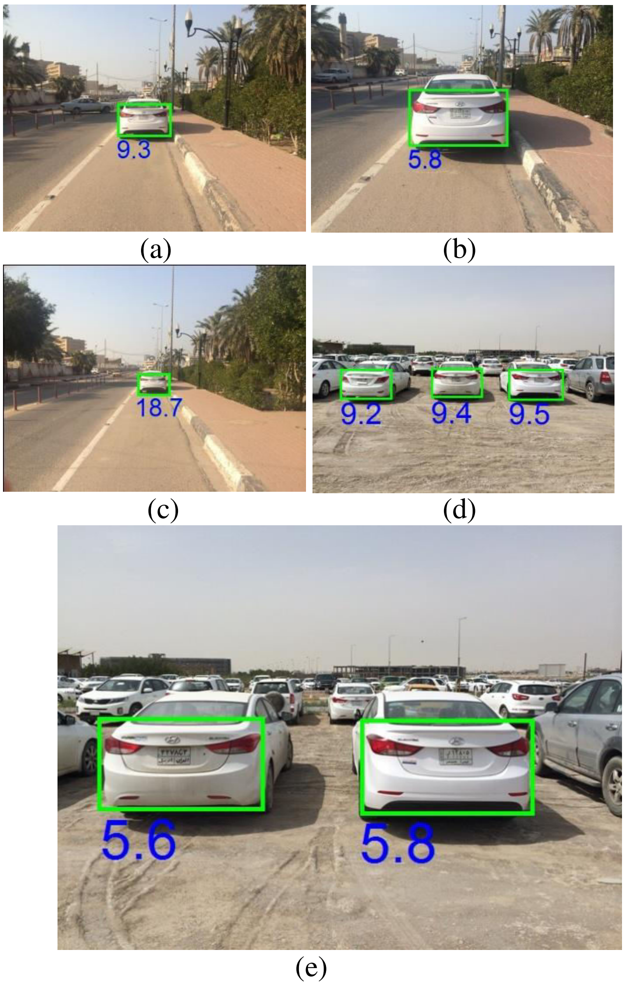


Figure (3) (a through e): experimental results of distance estimation

## III. VEHICLE POSITION DETECTION

A task of a vision based Lane departure warning systems (LDWS) is to warn the driver when the vehicle begins to move out of its lane. These types of systems are designed to prevent accidents from happening by addressing some main causes of collisions which are: driver error, drowsiness and distractions. One way to implement LDWS is by determining the vehicle position on the road.

Mariut et al [7] provide a method for estimating mid-lane using vertical histograms of the video frames. [7] has an accuracy rate of 82%.

In order to implement this approach, there are several steps that have to be done in order to specify the vehicle position. The first step of our approach is to detect the lane markings of the road and track them. Despite the existence of a large variety of approaches that detect and track the lane markings, the model proposed by Assidiq in [8] was adopted. That is, due to the simplicity and the robustness of such an approach. In such an approach, lane markings are detected using the Hough Transform (HT) method. Hough Transform is a global feature extraction algorithm.

It is a very efficient way to detect straight lines that are in an image, even when a missing data and noise are presence. It can find the lines that are dominant of an

image by calculating a unique equation for each possible line in the image. In order to track lanes markings that have been found by the HT, Kalman filter has been adopted. Basically, a Kalman filter is a predicting framework. It is used to predict a process's state, and using the previous measurement of that process, it can correct or what is called "update" these predictions [6].
It is assumed that CCD camera on the vehicle is positioned in a straight line to the road.

In our approach, we used multiple independent objects as an input to the Kalman filter to predict their state. Specifically: Lane markings, detected vehicles and traffic signs, vehicle estimated distance and the vehicle position. In this way, we can remove the short impulse noise that can affect the results.

For declaration purposes, a line which is called a "Mid-line" is drawn vertically which splits the frames into two sides. This line defines the current position of the vehicle irrelatively to the lane markings.

Once the lanes markings are detected, car position can be specified. The following steps show the main idea of how this can be done.

The first thing to do is to find the average distance between all the opposite points of the two detected lane markings. If the average distance values are subtracted from the vehicle center which is called the "Mid-line", this will end up with getting the final value of the vehicle position to the road center. The unit of the vehicle position is measured in pixels. Figure (4) shows how this is done.

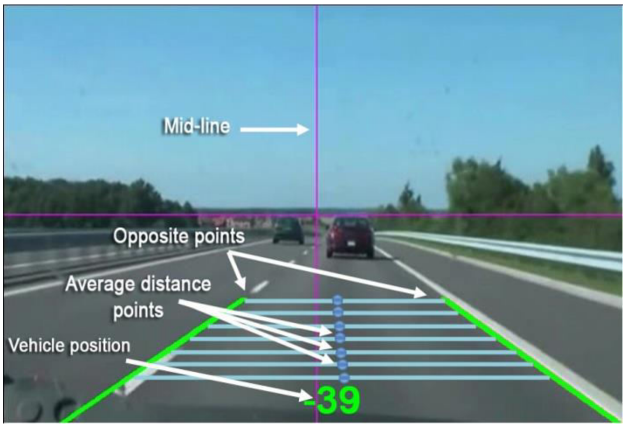


Figure (4)

The following flow-chart shows a step by step procedure to calculate the vehicle position on the road.

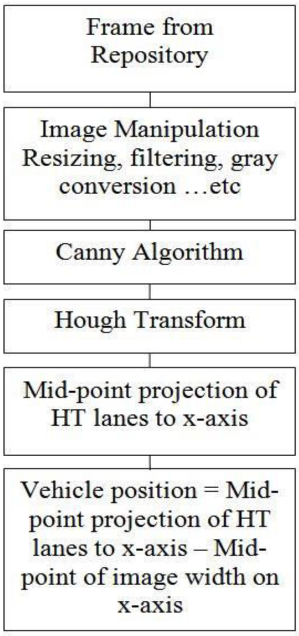


Fig -2- Flow-char representing the method of calculating vehicle position

Figure (5) shows some experimental results of applying this approach to videos dataset. The negative sign besides the vehicle position number indicates that the road center lies to the left side of the vehicle and vice versa.

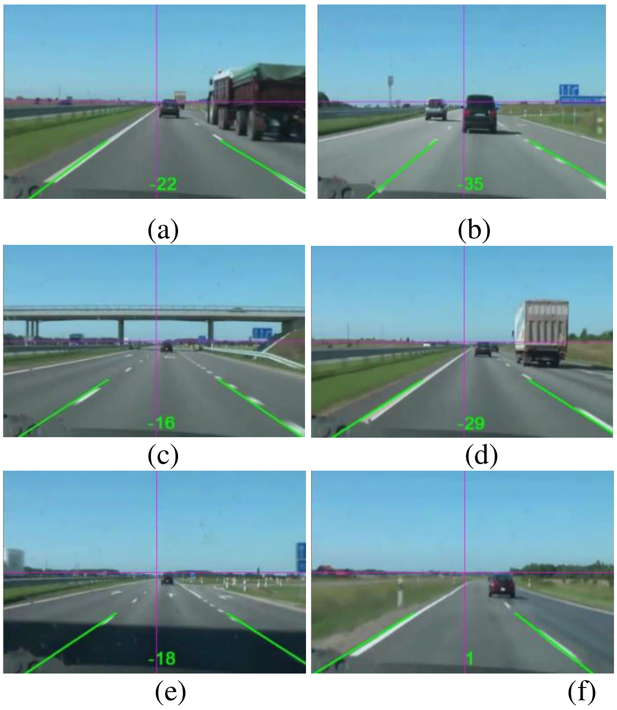


Figure (5) (a through f): experimental results of vehicle position detection.

A simple mathematical transformation can be made on the measured position to transform its unit from pixels into cent-meters. All the experiments were taken on a 3.2 meter lane width. The following table shows a comparison between the measured and the actual positions of the vehicle.

TABLE II: Comparisons of Actual and measured positions

| Order | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Measured Position(px) | 0 | 30 | 60 | 90 | 120 |
| Measured Position(cm) | 0 | 18.3 | 37 | 55.7 | 76.7 |
| Actual position(cm) | 0 | 20 | 40 | 60 | 80 |

Equation (4) is used to calculate the error rate in vehicle position detection. The average error rate for all cases is the overall error rate of the system. For position detection, the percentage error rate of the system was 7.27%, which means that the system has an accuracy of 92.73%.

## IV. CONCLUSION:

In this paper, we have discussed in details two main approaches used in ITS. Namely: Distance estimation and vehicle position detection. The geometrical and computational of the distance estimation approach have been introduced. This approach can be used to specify the distance of the preceding vehicles; the experimental results are preferable in different conditions. A point that is might be counted as a drawback of this approach is that the calibration of the camera's interior parameters and the information of the processing are used to detect the distance of an object. The main idea of detecting the vehicle position is presented. The discussed technique was validated on road datasets and was shown a good rate of detecting distances.

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