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Lane detection for autonomous vehicles using image processing

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Title

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Abstract

This study proposes a performance analysis of conditions that affect the ability of conventional image processing for lane detection used by motor vehicles. Conditions where image processing performance can be analysed are road surface change, faded lane markings, bad light and other non-lane road markings. Performance analysis is conducted to establish how badly the conditions affect the image processing ability and if possible, what condition has the biggest impact on conventional image processing performance.

Keywords

Image processing, computer vision, Canny edge detector, Hough transformation, lane detection algorithm, thresholding

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Introduction

Autonomous vehicles are today no longer merely depicted in Sci-fi movies, [1]they are present-day solutions and provide promise for safer and error free road transport for the future. This study sets out to explore how effective the current standards for lane detection using image processing are and ways to improve them. The paper explores current solutions for lane detection using image processing [2] and investigates problems that this technology when sensors are used to detect vehicle surroundings enabling vehicle controllers to make decisions with the information.

The idea of autonomous vehicles is an old concept and introduced since 1939 [3] and today's biggest challenge is the safety. Science in the automotive industry encourages unique and fascinating projects every day, thus creating high-tech products that are truly driving change.

Road accidents have become one of the most common causes of death globally reasons such as reckless driving and lack of high road standards. In the world, over 1.3 million are killed by road accidents every year according to the IRTAD (International Traffic Safety Data and Analysis Group (IRTAD) [4]. Surveys also clearly indicate that the number of road accidents are severely high in poor countries compared to developed countries. With the help of autonomous vehicles and ADAS, we can minimize the number fatalities to a better scale taking advantage of various technical features such as adaptive cruise control (ACC), lane detection, lane keeping assistance and driver monitoring awareness. Digital image processing which is a subset of computer vision (CV) techniques has gained popularity among researchers for detecting lanes due to the availability of onboard visual sensors [5]

In this research paper we are going to review a conventional feature-based method to detect lanes which is Canny Edge Detector together with Hough Transformation [6].

Problem area

Autonomous vehicles and ADAS systems are the biggest recent technologies to impact, change and develop the motor vehicle industry. The giant global motor vehicle industry affects the lives of billions of people making it a big part of our lives one way or the other. The exact area of focus in this report is to look at factors that decrease the ability of in car image processing for lane detection.

Keywords and associated articles

The keywords that have been used are quite novel in creation because they are simply the words that define the process that we investigate. Of course, when used to search google not all search results that were found were of use to our goal. We selected our sources based on the quality of the information that they provided. That quality being clearly comparable to known and established science.

Keyword	Source database	Hits
Image processing	Google Scholar	6.73 million
Canny Edge Detector	Google	1.82 million
Hough Transformation	Diva	3 student theses
Lane detection algorithm	Google scholar	440
Computer vision	Google	1.6 billion

Research Question and Hypothesis

This study aims to answer the following questions:

R1: How to detect road lanes using image processing?

R2: What is the threshold for being able to optimally detect the lanes?

Hypothesis: Conventional lane detection by image processing is affected by various visual information.

Why this RQ?

There are approximately 1.446 billion cars in the world [7]. And conclusively it is one of the most influential inventions ever. The fact that cars are seen everywhere in the world and make travel more viable to most people in the world, therefore it is of great interest. With technology enhancing and redefining how motor vehicles work as computer scientists we are now strongly connected with the motor vehicle industry. As well as positives that motor vehicles have brought to mankind there are also negatives. We are encouraged by the new advances but also very curious to see how solid and reliable that technology is.

Variables

The process values in image processing or the image processing method should reduce the impact of the non-controllable variables, non-controllable variables such as absent lane markings, poor lighting, and other non-lane road markings. Accurate lane detection as a dependent variable depends on the independent variable of the image processing process and its processes.

The challenges

There are always some limitations and challenges when it comes to real life implementation of all technologies [7.1].

- Invisible lane markings due to aging
- Various road texture
- Not always bounded by lines such as curbs and guard rails
- Lane markings covered due to shadows of trees, bridges and other cars one the road etc.
- Interference from other road signs in urban roads
- Lighting conditions

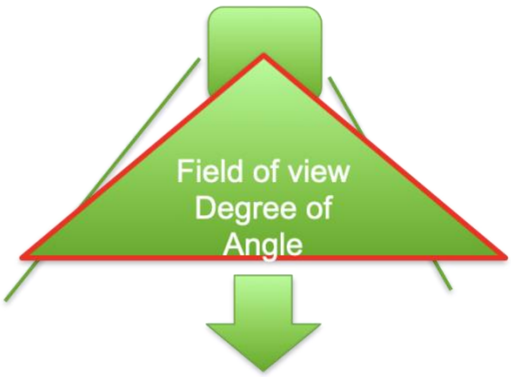
Experiment design / Implementation

The experimental design option for this paper follows modelling and simulation and uses the observations from that in a case study approach. Modelling and simulation, makes it possible to observe the results of image processing for lane detection used by motor vehicles. A novel approach of obtaining results of lane detection from image frames and video of road lanes uses key parameters as values to allow representation of a real physical model and situation. The mathematical processes of the Canny edge detection and Hough transformation methods model the phenomenon of vision that can recognise lanes in a road. These processes are pieced together using mathematical concepts such as the Gaussian function. The Gaussian function is used in the Gabor filter to quantify light and image which is considered amongst scientists to be like the human visual system. Overall, these mathematical models are intertwined in a pipeline to simulate the process of human vision detecting road lanes. The additional case study design approach of this paper is to explore 'how' and 'what' results occur using descriptive and explanatory knowledge in an in-depth way concerning image processing for road lane detection.

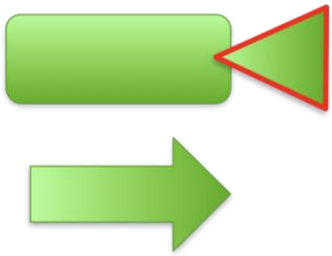
A simulation of real-life experience, a camera view is displayed below, showing front view and side view

1st person camera view from the car, with mounted camera sensor.

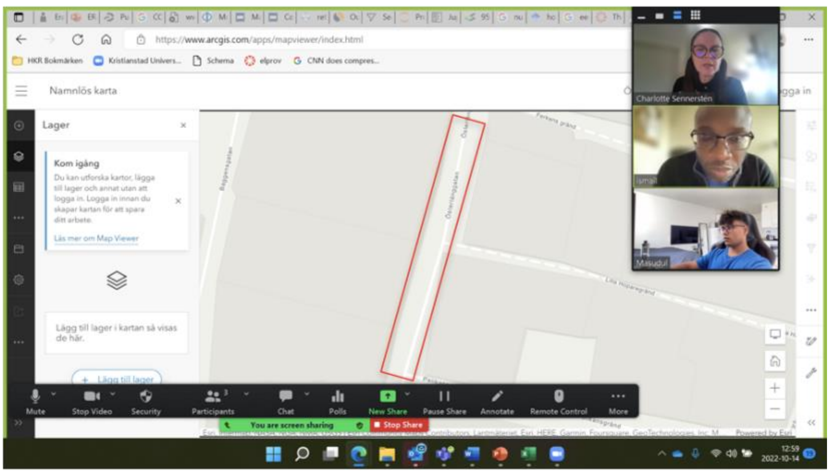
Frontview



Sideview



Top Down View(s)



Lane Detection Technique

Canny edge detection with Hough line transformation [8] [9] runs in several steps. Conventional edge detection method for image processing involves mathematical calculation. The Canny edge detection algorithm stages are given below [10].

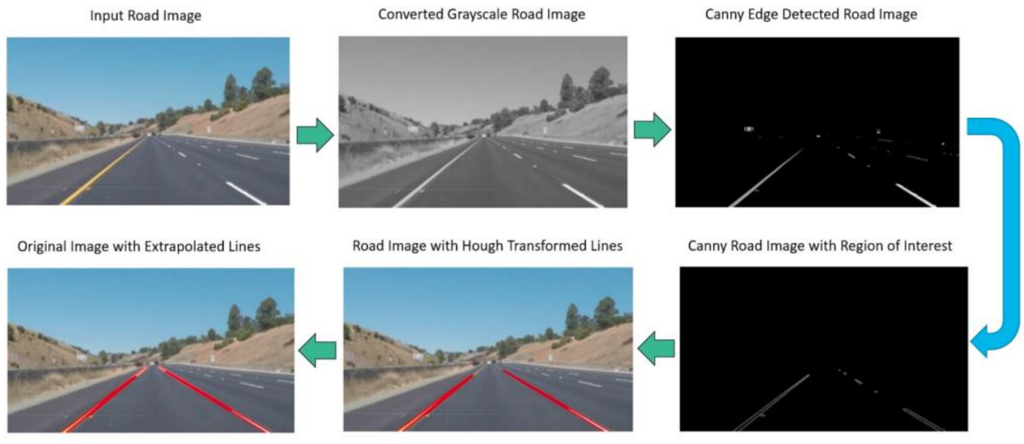
Smoothing: Blurring of the image to remove noise.

Finding intensity gradient of the image: The edges should be marked where the gradient of the image has large magnitudes.

Non-maximum suppression: Only local maximum should be marked as edges.

Double thresholding: Potential edges are determined by thresholding.

Edge tracking by Hysteresis: Final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge.



Overall process that an input road image undergoes

Stepwise Implementation (Our Approach)

Image pre-processing means converting color image to grayscale format (RGB) and YCrCb (Y = luma, Cb = blue Cr = red) color space. First, the grayscale image captures white paints and the Cr channel of the YCrCb [11] image extracts the yellow paint on the road much better than the grayscale image. Which is much shaper. The Cr channel is especially useful to capture yellow markers on a grayish background such as bridges or concrete road sections. Therefore, to capture both suitable to capture yellow road mark on a grayscale background for accurate brightness modification. The purpose of capturing white and yellow colors from a road, the grayscale image is combined with the threshold [12] Cr channel to get a bright grayscale image.

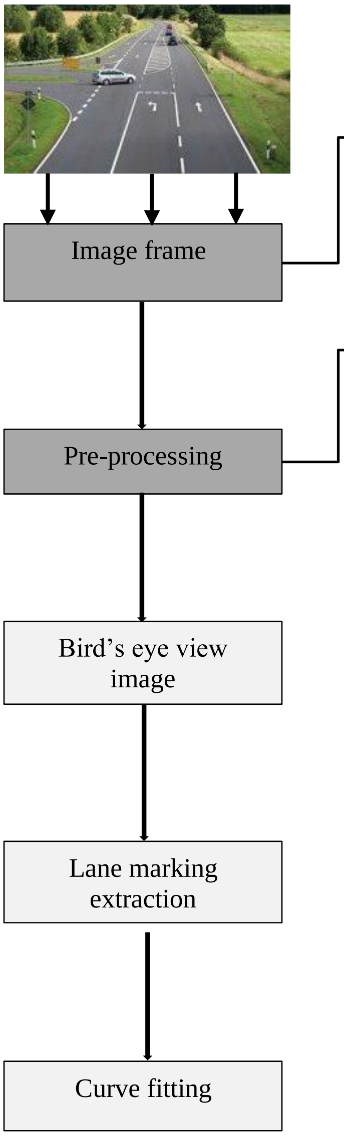


Image frame

Colour image (RBG) from camera (video stream/file)

Pre-processing

Converts colour image into grayscale image (extract white paints)

Converts RGB colour image into YcrCB colour space and separates the Cr channel (extract yellow paints)

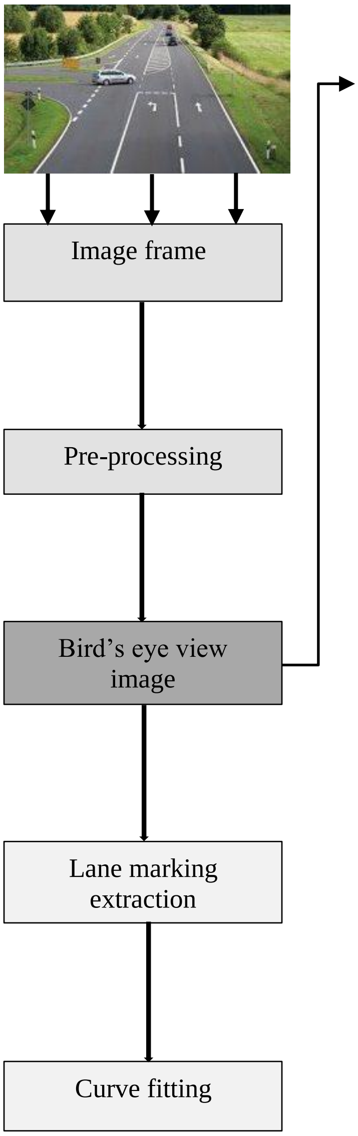
Combines grayscale and Cr channel image.

Original Image

Grayscale Image

Inverse Perspective Mapping (IPM)

In computer vision, a homography matrix H is defined as the mathematical relationship between two planes. The matrix H can be expressed as H = sMR and transformation matrix H selects 4 points from a source image and convert them into 4 points in a destination image. In perspective view, pre-processed images are mapped into top view and each pixel of source image to output image, where source and destination point are selected inside the ROI. From the equation below, x' corresponds new location of pixel after transformation and x indicates the pixel location of source image [13] .



Bird's eye view or inverse perspective mapping

Transforms the image from perspective to top view.

Transformation is done manually selecting four points in the perspective image (X) and four points in the destination image (X').

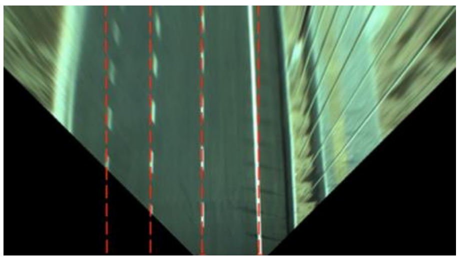
Transformation:

$$x' = H x$$

Using the H matrix, pre-processing the image is transformed to the bird's eye view image.

Original Image

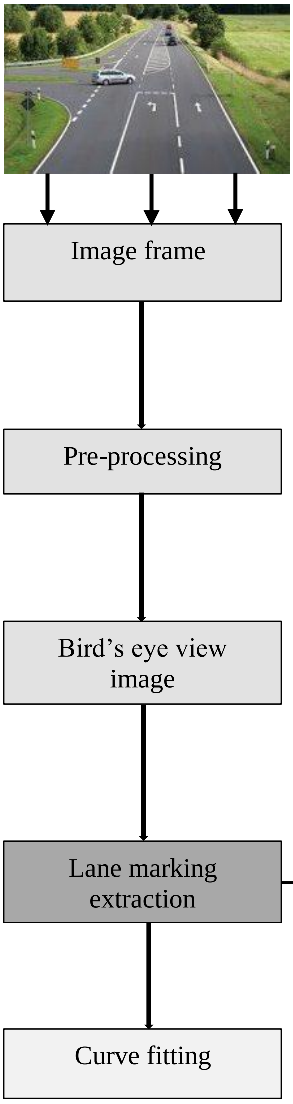
Grayscale Image



Bird's eye view transformation

Lane Marking Extraction

Gabor filter [14] is basically used to optimise the image quality and it's like the Gaussian modulated sinusoid. The given equations indicate 2D complex Gabor filter. Most lane detection methods use the thresholding [15] operation right after the image filtering. Gabor filter detailed steps and procedures are indicated here [16] .



Lane Marking Extraction

Gabor filtering

Gaussian filter with more parameters

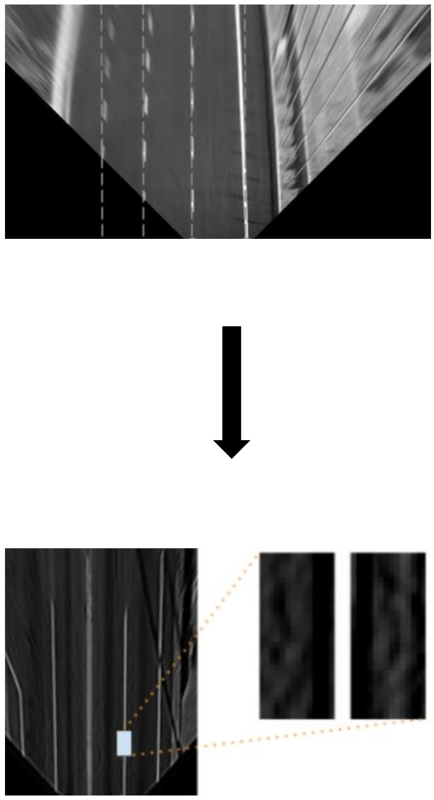
$$g_{\lambda,\theta,\varphi,\sigma,\gamma}(x,y) = e^{-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}} \cos\left(2\pi\frac{x'}{\lambda}+\varphi\right)$$

$$x' = x\cos\theta + y\sin\theta$$
$$y' = -x\sin\theta + y\cos\theta$$

Gabor filter kernel (size 7x3)

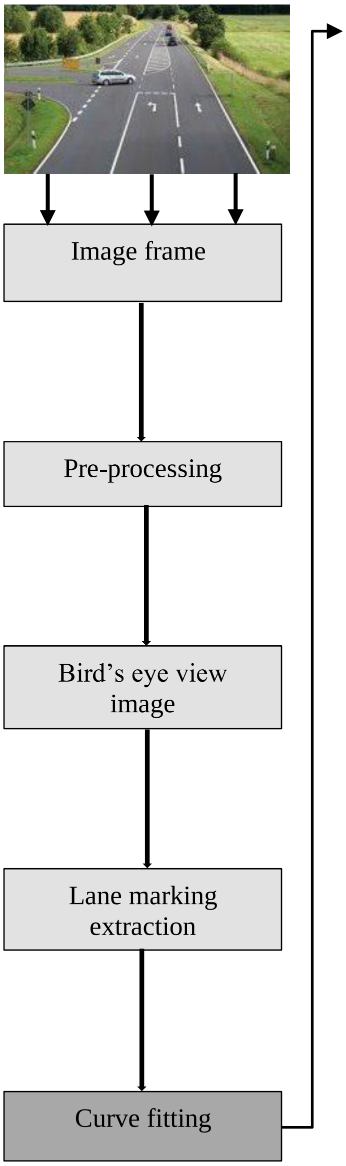
Filtering operation (2D convolution)

$f(x, y) = g(x, y) * I(x, y)$



Curve Fitting

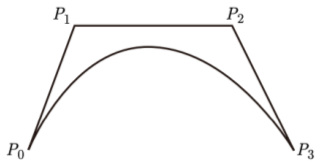
In our research paper, we only focus single lane detection, but it can the process can be used for multilane detection by expanding the ROI (region of interest). This is to remove parts of the image that are not of interest, meaning anything other than the lane segment that is directly in front of the vehicle. To fit the curve, ROI is vertically divided into double sections respectively right and left lanes borders and can be selected manually or finding the intersection point of Hough Transformation. We are considering third order Bezier Curve [17] to get an optimal result.



Curve fitting

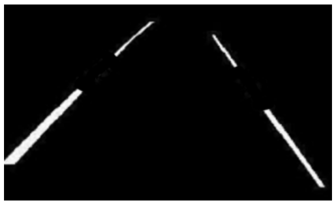
Third-order Bezier curve

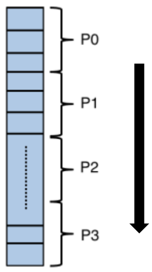
$$\mathbf{P}(\lambda) = (1-\lambda)^3\mathbf{P}_0 + 3\lambda(1-\lambda)^2\mathbf{P}_1 + 3\lambda^2(1-\lambda)\mathbf{P}_2 + \lambda^3\mathbf{P}_3$$

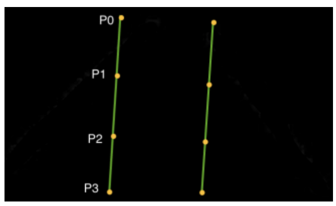


where P0-P3 are avg. control points estimated from the algorithm output

and $B_i^3(\lambda)(i = 0,1,2,3)$







Result

This is our outcome from our formulated Research question and hypothesis and how outcomes are met, and we describe this as an outcome from the variables we previously formulated. Our model/algorithm/NN/design may have to be changed and we will comment upon that here and discuss it in the next chapter Discussion.

Discussion

We will discuss our result and critically reflect upon our approach and what we can possibly improve later i.e., in a later study or for other people to take on.

Appendix

Week	**To do**	**Done**	**Comment**
Week 1	General information		
Week 2	Start of Thesis Course		
Week 3	Literature survey		Explore online resources and articles
Week 4	Literature survey		Read example thesis from different resources
Week 5	Start formulating the thesis		Actual writing starts, checking the topic with responsible teacher
Week 6	Model development and collecting data		ResearchGate, Diva, Google Scholar
Week 7	Evaluate and experiment and analysis		Experiment and discussion with teacher for real life simulation
Week 8	Final thesis submitted		First version
Week 9	Opposition feedback, update, and final version submission		Update the plan and submitted

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