ANSLYSIS OF ROAD USING ON-BOARD CAMERA FOR DETECTION OF LANES AND TRAFFIC SIGNS PAINTED

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ABSTRACT

Lane tracking is an important topic in autonomous navigation because the navigableregion usually stands between the lanes, especially in urban environments. Severalapproaches have been proposed, but Hough transform seems to be the dominant amongall. A robust lane tracking method is also required for reducing the effect of the noiseand achieving the required processing time. This paper presents a method for detection andrecognition of road lane markings using an uncelebratedon boardcamera. Initially, lane boundaries are detected based on a linearparabolicmodel. Then, we build a simple model to representpixels related to the pavement, and explore this model to estimatepixels related to lane markings. In this paper,we present the plans of a driver-assistance system, which will becapable of lane and painted traffic sign detection by using a car'son-board camera and is integrated in a network which connectsdifferent users to enhance the efficiency of these detections. Thecurrent version is capable of lane and painted traffic sign detectionand is able to warn the driver about a possible lane departure onvideos captured in daylight, with medium quality road markings.Our system uses a lane detection method that is based on theHough transformation and contour detection for the paintedtraffic sign detection.

1. INTRODUCTION

For both driver assistance systems and autonomous driving, detection of lane markings plays a major role. As early as in the 80s, first approaches for autonomous driving used a camera to detect the lane markings and thereby the course of the road. Today, most upper class vehicles have a camera based system on board to detect lane markings and warn the driver when leaving the lane. Those approaches usually only detect boundary lines and ignore other road surface paintings. Recent systems for autonomous driving highly rely on accurate maps. These maps usually fulfil two tasks: Providing information for localization and providing static information for path planning. For localization, static landmarks are stored in the map and re-detected while driving. One approach is to compute generic feature descriptors for interesting points. With the position of the feature and the feature description itself, a relative pose between mapping pose and localization pose can be estimated (e.g. [1]). While this leads to good results, especially in urban areas, the necessary disk space for large maps must be considered.

Traffic safety is a major concern in present days, particularlyin underdeveloped and developing countries. According to theWorld Health Organization (WHO) [1], 90% of the deathsrelated to traffic accidents occur in low-income and middle-incomecountries, in a total of more than 1.2 million deathsper year and 50 million injuries every year.Brazil is considered as an emerging country, presentingvast natural resources and a strong potential for developmentand industrial production. As stated in the Brazilian NationalAgency of Land Transport [2], Brazil has approximately 1.7million kilometres of road network. A study from 2009 [3]reported that more than 33% of Brazilian roadways wereconsidered poor or very poor with respect to their overallcondition (signing, geometry and pavement) in 2007, and thatthe number of traffic-related accidents in 2006 was over 35,000in Brazil.

The annual road safety report [4] that was presented in2011 by the International Traffic Safety Data and Analysis

Group (IRTAD), shows that road deaths keep decreasing inmost IRTAD countries (mostly developed countries), carryingforward the significant reductions in the number of roaddeaths accomplished in 2008 and 2009. On the other hand, astudy by the Brazilian Confederation of Countries (CNM) [5]shows the high mortality rate due to traffic accident in Brazil.Death ended accident ratio in Brazil is 2.5 times more thanUnited States, and 3.7 times more than Europe with respectto population .

Since the past few years newcar models are getting equipped as a standard feature withseveral systems that process the images taken from on-boardcameras which are capable of warning the driver of lanedeparture, important traffic signs and so on by analysing thetraffic in front of the car. However, these systems are still verysimple, they have many errors and only the well-equipped carsmight benefit from their presence. Moreover, these systemsoften rely on data provided by the navigation system. Althoughmany of the new cars dispose of internet connection via the onboardcomputer, these systems do not take advantage of thisfeature, which would allow to connect with other car systems ascomponents of a network, in order to detect and recognize moreefficiently traffic signs, lanes, etc.

This would also aid the work of companies that maintainpublic roads and the ones that create and update maps fornavigation systems. The idea behind the internet of things (IoT)means physical items embedded with sensors and actuatorswhich enable these objects to collect and exchange data throughthe existing internet network. In our case the "things" refer to thecars that can collect useful data for other cars and for intelligenttransportation, smart cities, etc. In our paper we would like todiscuss the sketch of a system like this and to report about thefirst steps of its execution.

2. LITERATURE REVIEW

Yu et al. also use Hough Transform to detect the lane boundaries.This work additionally considers the pavements at the sidewayds. Since the pavementboundaries are another means of continuous lines, the paper has put special attentionon them. The HT is used to detect lane boundaries with a parabolic model. Roadpavement types, lane structures and weather conditions have carefully been investigated.The 3-D Hough space is decomposed into two sub-domains. A 2-D domain ofparameters shared by all the edge types, and a 1-D domain of remaining distinctive parameters. This study uses the Canny edge detector to get two images: a binaryimage denoting the edges and a gradient image denoting the ratio of vertical and horizontalgradients. They have applied the HT several times from a low resolution tothe desired resolution images. They call this method multiresolution HT, and theyhave proven it to reduce the computational cost of classical HT while preserving theaccuracy.

McCall and Trivedi have designed a system (called VioLET) using steerablefilters for robust and accurate lane detection. Steerable filters are especiallyuseful for detecting circular freeter markings, segmented-line markings, and solid-linemarkings. They are insensitive to varying lighting and road conditions, hence providingrobustness to complex shadowing, lighting changes from overpasses and tunnels, androad-surface variations. By computing only three separable convolutions, a wide varietyof lane markings can be detected. This study also has an improved curvature detectionmethodology. They have incorporated the road visual cues (lane markings and lanetexture) with the vehicle-state information. The work is one of the most comprehensiveones in the lane detection scope. It contains a detailed literature survey and comparisonof the previous researches.

Wang et al. have proposed an algorithm based on B-Snake. Thealgorithm is able to discover a wider range of lanes, especially the curved ones. B-Snakeis basically a B-Splines implementation, therefore it can form any arbitrary shape by aset of control points. The system aims to find both sides of lane markings similarly. This is achieved by detecting the mid-line of the lane, followed by calculating theperspective parallel lines. The initial position of the B-snake is decided by an algorithmcalled Canny/Hough Estimation of Vanishing Points (CHEVP). The control points aredetected by a minimum energy method.

Snakes, or active contours, are curves defined within an image which canmove under the influence of internal forces from the curve itself and external forcesfrom the image data. This study introduces a novel B-spline lane model with dualexternal forces. This has two advantages: First, the computation time is reduced sincetwo deformation problems is reduced into one; Second, the B-snake model will be morerobust against shadows, noise, and other lighting variations. The overall system istested against 50 pre-captured road images with different road conditions. The systemis observed to be robust against noise, shadows, and lighting variations. The approachhas also yielded good results for both the marked and the unmarked roads, and thedashed and the solid paint line roads.

Another study from Kreucher et al. uses the LOIS Lane DetectionAlgorithm to track the lanes. The system emits warning messages if a lane crossingis detected. The vehicle's location with respect to the lane markings is detected byLOIS, which uses a deformable template approach. This approach has a parametricset of shapes that describes all possible ways the object can appear in the image. Alikelihood function is used to measure how well a particular detected object matchesthe given image. Previous articles on LOIS focus solely on lane detection where thevehicle is located around the centre of two lanes. This paper's contribution is using aKalmanfilter to predict the future values of vehicle's location considering the previouslyobserved ones. The location is measured in terms of offset values with respect to theright and left lane markings detected by LOIS.

3. LANE DETECTION AND TRACKING

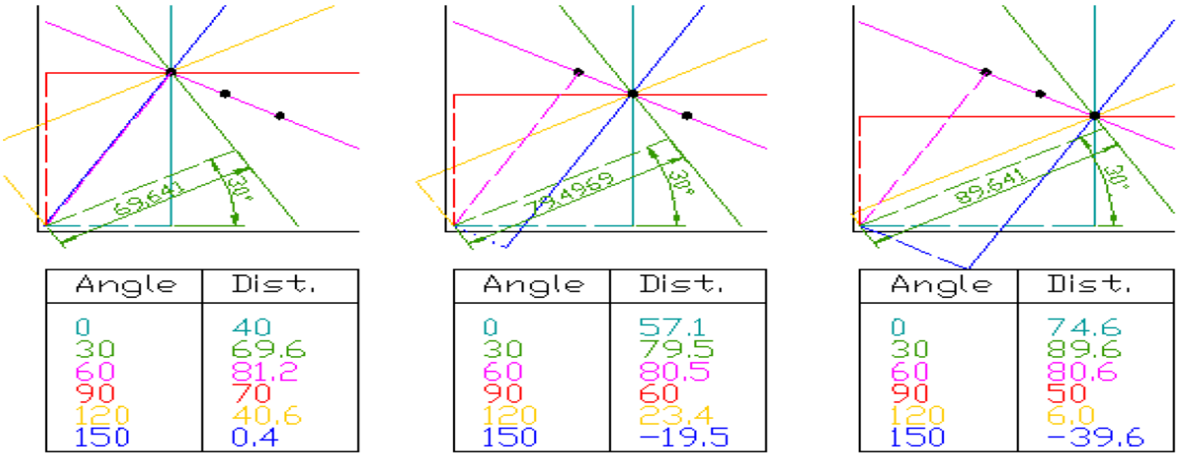
3.1. Methodology

3.1.1. Hough Transform Overview

Hough Transform (HT) [7] is a technique to detect arbitrary shapes in images,given a parameterized description of the shape in question. Hough transform can detectimperfect instances of the searched shapes. Besides, HT is tolerant of gaps, and imagenoise has minor effect on the output.The simplest form of the HT is the line transform, where lines are the targetelements sought by the transform. Representing a line in polar form (Equation 3.1)specifies its normal passing through (x, y) drawn from the origin to (r, θ) in polarspace. These are represented by the dashed lines in Figure 3.1.

$$xCos\theta + ySin\theta = r \quad (3.1)$$

For each point in the (X, Y) plane and on the line, the values of r and θareconstant. Therefore for a given point in the (X, Y) plane we can calculate the linespassing through the point in terms of r and θ. Passing a range of lines at varyingangles $[0, 2\pi]$ and varying θ accordingly it is then possible to calculate the value for r.By taking a set of lines through a point and calculating the r and θ values for thelines at that point a Hough space can be created (Figure 3.1). Distributing the resultsof these calculations to "bins" and incrementing their value or "vote" for every resultthat is placed in them, an accumulation array can be built. The greater the vote valuesof the bin, the higher the probability that it is a point on the line.



Angle	Dist.
0	40
30	69.6
60	81.2
90	70
120	40.6
150	0.4

Angle	Dist.
0	57.1
30	79.5
60	80.5
90	60
120	23.4
150	−19.5

Angle	Dist.
0	74.6
30	89.6
60	80.6
90	50
120	6.0
150	−39.6

Figure 3.1. Liner Hough transforms.

3.1.2. Detection: Multiresolution Hough Transform (MHT)

The classical HT approach processes the entire vision data in order to detect thelines. This scenario has two main drawbacks. First, the occluded lines (i.e. another carpassing through the line) become noisy since the transformed relative intensity of theline decreases. Second, the relative intensity of the lines also decreases at the curvesin the road.

The proposed solution divides the road image into partitions, where the sizes ofthe partitions are inversely proportional to the distance of the partition to the vehicle.After the image is partitioned, several reprocessing steps are required before applyingthe Hough transform. These reprocessing steps should be fast because the Houghtransform is already computationally expensive for real time applications. Since edgedetection techniques are also usually computationally expensive for real time applications, each partition is converted to binary images via applying a thresholdfilter after a color remapping process.

Tracking: HMM

HMM is an alternative to Kalmanfilter and particle filtering. It is a statisticalmodel in which the system being modelled is assumed to be a Markov process withunobserved states. As shown in Figure 3.2, the system consists of predefined sets ofstates and observations. A state transition probability matrix defines the probabilitiesof transition between states. An emission probability matrix defines the probability ofencountering each observation for each state. System also defines the start probabilitiesof each state. The ultimate aim of an HMM is to estimate the next observation relyingon the current observation, without access to the state information.

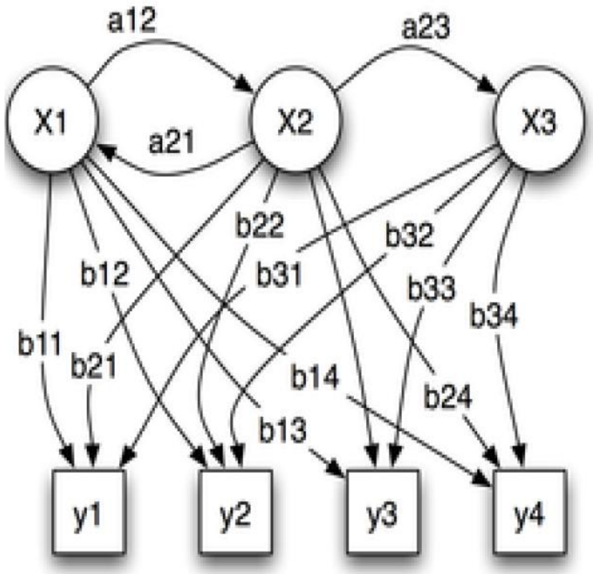


Figure 3.2. Hidden Markov Model. (x: states, y: possible observations, a: statetransition probabilities, b: emission probabilities)

For lane tracking, HMM is used to represent the relation between the currentframe and its successor.

4. DETECTION OF TRAFFIC SIGNS PAINTED ON ROAD

The traffic signs placed on the side of the road usually havea matching sign painted on the surface of the road. Alongsidethe lane detection, another main purpose of this software is todetect the painted road signs. The detection of road signs isperformed by analysing their shape. Currently, the software iscapable of detecting any circular (prohibitory) or triangular(warning) signs.

A. Changing the Original Perspective

Since the road signs we want to detect are painted on thesurface of the road, it seems like a good idea to switch to thebird's-eye view, which was already mentioned at lane detection.The advantages of this are the same as those at lane detection:
removing perspective effect and excluding unnecessary factors.Because we are detecting shapes, another benefit of this view isthat it allows to analyze the shapes in their original form, ratherthan a distorted, unclear figure. Thus, we can search for actualshapes like circles, triangles, etc. when detecting road signs. Inorder to reduce the time and space complexity of the algorithmwe are using the previously created bird's-eye view, which wasused at the lane detection. Painted road signs are situated withinthe borders of a lane, so a view that works for lane detection willsurely work for traffic sign detection, too.

B. Finding Shapes

Just like lane recognition, traffic sign detection needs somereprocessing before detecting sign shapes. The used method isvery similar to lane detection. First, we convert the bird's-eyeview image to grayscale. Then, just like at lane detection, a welleffectuated thresholding will allow us to highlight painted road signs.

(a) (b)

Fig. 4. Detection of different shapes. (a) Circular, prohibitory sign (No overtaking). (b) Triangular, warning sign (Pedestrian crossing)

Thresholding is a good idea at this detection too, becausethe previously mentioned Vienna Convention on Road Signsand Signals allows the use of just two colours for traffic signbackground: white or yellow. The thresholding used in ouralgorithm is currently set to perform on white colored laneborders and painted traffic signs with white background.Adaptive thresholding in painted traffic sign detection isessential because of the road deterioration, which leads toimperfect, seamed shapes that are harder to detect. This type ofthresholding of the image is done with the same method. We have setthe size of the neighbourhood matrix in concordance with the sizeof traffic signs on the road.

The resulting image of the adaptive thresholding allows usto detect shapes. For shape detecting we extracted the objects'contours and approximated them by polygons. This method ispresented flawlessly in the work of Salhi, Minaoui and Fakir. A contour can be explained simply as a curve joining allthe continuous points (along the boundary), having same coloror intensity. The contours are useful tools for shape analysis andobject detection and recognition. Detecting contours is based onthe algorithm of border following (also known as boundarytracing) [18]. After contour detection, the next step is sortingout those contours which are not likely to be circular ortriangular shapes. This sorting is done with the help of the lengthof the contour and the area that it covers. Thus, objects that aretoo small or too big to be traffic signs are discarded.In order to make the detection even more precise, anothercriteria is assigned which is the number of edges on the contour.

CONCLUSIONS

This paper presented a real-time algorithm to detect andidentify different types of lane marking using an on-boardvehicular camera in a fully automatic manner. In the proposedapproach, a simple statistical model is used to represent pixelsrelated to the pavement, which is then used to extract lanemarkings. In conclusion, we have taken the first steps in creating asystem that is capable of detecting lanes and warning a possiblelane departure, detect traffic signs and thus helping the driverby giving fast and precise information. In the near future wewould like to integrate traffic sign recognition, and pedestriancrossing detection.

However, the supreme objective of thisproject is to take advantage of the power of internet in cars,which has a big potential. Our plan to achieve this is to createan intelligent system that communicates through a device thatis capable of connecting to the internet (e.g. car's on-board computer) and to give and receive feedback to and from otherusers through a map-based database.

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