Road Scene Image Analysis in Lane Departure Warning Systems

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Abstract

This paper will cover many aspects of image analysis including image pre-processing, image segmentation, and contextual analysis for road scene images acquired using a digital camera mounted to the rear-view mirror of different automobiles. In particular, road marker characteristics will be extracted including those for various white and yellow longitudinal lane markers. This lane marker information will serve to provide a position with respect to the lane for the vehicle as it travels down the road. If the vehicle should transition towards a position outside the lane boundary, the image processing system will have the potential to notify the vehicle operator that a lane departure is pending. This vehicular image processing system should be relatively invariant to illumination conditions and should be able to perform during a wide range of environmental conditions. This paper will also discuss many of the aspects required to implement the software in Matlab including flowcharts and partial code listings. Preliminary output results for the preliminary road scene image processing system will also be given.

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1. INTRODUCTION

1.1 Justification for road scene image processing systems

In the United States in the year 2000, there were approximately 6.4 million motor vehicle crashes reported to police [11]. In many of these crashes, the position of the vehicle with respect to its travel lane was an important characteristic of the situation. Although longitudinal lane pavement markings are intended to support the regulated movement of traffic within the roadway (thus reducing the likelihood of crashes), there are also many other important factors which must be considered in any traffic situation including (but not limited to) the number and type(s) of vehicle(s) involved, the vehicle(s) dynamic operating conditions, the absence or presence of an 'intended' lane transition, the type of transition (drifting, passing, intentional lane change, etc.), the physical setting, and environmental conditions. Two resources which may be referenced regarding analysis of vehicular crashes including those involving lane changes are given in [11] and [12]. It should be noted that lane change crashes sharing the characteristics of multiple vehicle, same direction, parallel path scenarios are not the only occurrences where longitudinal lane pavement markings may play a significant role in crash circumstances. Consider also crashes involving roadway departure or vehicles traveling in opposite directions (just to name two of the many others). Nonetheless, longitudinal lane markers (when present) serve to provide information including (but not limited to) boundary and guidance to be used by the motor vehicle operator on that roadway. The 2004 edition of *A Policy on Geometric Design of Highways and Streets* indicates that road-following and safe-path maintenance in response to road and traffic conditions are significant to performing vehicle guidance [26]. Thus, the ability of an individual vehicle operator to extract and interpret lane marker information is of paramount importance to the vehicle operator's efficient and safe usage of the roadway. However, situations (driver distraction, driver physical impairment, etc.) may arise which might potentially prevent the operator of a vehicle from using all of the available traffic control device resources (including lane markers). Under these circumstances, having a road scene image processing system in place as part of an overall vehicular safety system being used to minimize the potential consequences of 'missed lane markings' could potentially assist in reducing the frequency of crash occurrences, reducing crash severity, and thus helping to save lives. Additionally, a road scene image processing system might potentially provide travel lane guidance and roadway delineation where the absence or obscurement of a formal longitudinal lane marker has created some travel lane uncertainty. Note that *great care* must be taken when attempting to quantify and qualify important factors including (but not limted to) the position of a vehicle within its lane as well as when a vehicle has deviated from its lane, the intended or unintended maneuvers of a vehicle operator within the roadway, and the effectiveness in which a road scene image processing system both interprets road scene information and alerts vehicle operators to potentially dangerous situations.

There are many important factors which need to be considered governing the effectiveness of traffic control devices (including longitudinal lane pavement markers). The 2003 MUTCD lists five basic requirements as [10]:

1. Fulfill a need;
2. Command attention;
3. Convey a clear, simple meaning;
4. Command respect from the road users;
5. Give adequate time for proper response.

One of the primary needs is to provide lane delineation assisting guidance of the vehicle traveling on the roadway. Thus, a longitudinal lane marker should be conspicuous, visible, understandable, and provide sufficient response time to safely maneuver the vehicle under a wide range of conditions including (but not limited to) driver state, vehicle speed (and other dynamic conditions), vehicle type, and environmental conditions (including weather and illumination). Two key aspects of any longitudinal lane pavement marker that must be considered are the markings luminance and the contrast of the marking with the substrate (road surface). A formal definition of luminance is the luminous flux emitted from a surface per unit solid angle per unit area, projected onto a plane normal to the direction of propagation [5]. However, luminance (in general terms) may be thought of as the amount of light reflected to the vehicle operator or road scene image processing system from the longitudinal lane marker. Contrast may be generally looked at as the difference between marking luminance and local substrate luminance and the greater the contrast between the two, the greater the potential for discernibility. Thus, the

materials used for both the road surface and the lane marker may play a very significant role in affecting lane delineation. Similarly, any materials used in roadway repair and maintenance may affect discernibility of longitudinal lane markers.

Lane markers may be composed of materials including paint, thermoplastic, and preformed tape (just to name a few). Each may include glass spheres or beads to increase retroreflective properties while also relying on the pigment to enhance the markers reflective characteristics. There are many different types of paints, thermoplastics, and preformed tapes and several sources which may be referenced for further information include [31], [32], and those listed in the related websites portion of the appendix under pavement preservation. Two compositions which may be used in roadway construction are bituminous concrete and Portland cement concrete. Bituminous concrete is a road surface composed from materials including (but not limited to) hot asphalt, hot mineral aggregate and refined tar while Portland cement concrete will typically be composed of materials including (but not limited to) Portland cement, sand, water and coarse aggregate. If simply considering the luminance characteristics of the two aforementioned road surfaces, it is apparent that a 'brighter' marker located on a 'darker' surface (or vice versa) would be more discernible than a 'brighter' marker located on a 'lighter' surface under comparable conditions. However, there are many other factors which may affect lane delineation including those listed in table X.

Table X. Some potential factors affecting lane delineation

	Some potential factors affecting lane delineation	Potential examples
1.	Illumination source	Natural generated from sunlight or skylight, artificially generated light from street lights or automotive headlights, ambient, etc.
2.	Illumination characteristics	Brightness, spectrum, illumination area, etc.
3.	Characteristics of the light wave or particle	Polarization, wavelength, frequency, phase, energy, etc.
4.	Direction of illumination	Front directed, back, etc.
5.	Angle of illumination and angle of observation	CIE 45/0 (0/45) geometry with CIE 2° standard observer, etc.
6.	Distance between vantage point and marker	Length, time, etc.
7.	Light interaction between marker and substrate	Specular reflection, diffuse reflection, retroreflection, transmission, absorption, scattering, etc.
8.	Spectral selectivity	Polarizers, IR filters, spectral transmittance vs. wavelength, etc.
9.	Environmental conditions	Temperature, surface moisture, humidity, fog, atmospheric transmittance, precipitation, etc.
10.	Human factors	Age, cognitive capability, physical status, human optics system, motor skills, color perception, tendency for vehicle position within lane, etc.
11.	Vision processing system factors	Optical characteristics, electrical/mechanical/sensor characteristics, algorithms, architectures, environment, vehicle characteristics, etc.
12.	Vehicular characteristics	Vehicle front end length, vehicle width, windshield glass transmittance, height of operator or vision system above road surface, the location and type of headlights, etc.
13.	Materials and properties of road substrate, repair or maintenance materials being used	Cement, sand, water, aggregate, refined tar, rubberized asphalt, asphaltic rubber, polymer-modified liquid asphalt, conductivity, reflectivity, luminance, etc.
14.	Materials and properties of longitudinal lane marker	Paint, thermoplastic, preformed tape, pigment, glass beads, reflectivity, refraction, luminance, etc.
15.	Marker pattern, dimensions, gap-to-segment ratios	Broken, normal, double, width, speed, and context dependent characteristics, etc.
16.	Road geometry	Vertical curves, horizontal curves, junction type, etc.
17.	Surface finish	Smooth, rough, grooved, etc.
18.	Road dirt and debris	Dust, dirt, automotive fluids, paper, etc.
19.	Illumination attenuation	Shading from roadside objects, other vehicles, etc.
20.	Discernibility	Legibility, interpretability, etc.
21.	Age, condition, performance,	Intended service life, durability, appearance and visibility, etc.
22.	Application process for marker	Paint striper, melting and forming, inlaid or overlaid, etc.