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A line-based skid mark segmentation system using image-processing methods

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Abstract

We developed a line-based skid mark segmentation and measurement system to solve issues related to randomness from pavement texture and measurement subjectivity at car accident scenes. The system was designed to operate along the longer straight lines that exist in boundaries between skid marks and pavement at the scene of an accident. The operational system consists of two processes: preprocessing and feature extraction. Preprocessing steps include skid mark positioning, slope angle detection, and segmentation, whereas feature extraction involves detecting light striations, striation segmentation, and calculating the widths of striations from images. Experimental validation and objective measurements illustrate that this system saves operation time and cost while performing with accuracy similar to that of manual methods.

Keywords: Skid mark; Segmentation; Accident scene; Tire tread; Accident investigation

1. Introduction

Tire mark data provide important evidence in the investigation of car accidents. The types/patterns, length, and location of tire marks at the scene can be used to reconstruct drivers' behavior, collision points, vehicle heading, minimum speeds before collision, post-collision trajectories, etc. In addition, tire mark data can be used to identify the types of tires involved in a hit-and-run accident and thereby reduce the scope of the investigation.

A tire mark is a mark made on a road or other surface by a vehicle's tire. Its geometric patterns or outline features, such as distinctive striations (which appear as light and dark streaks), are greatly influenced by pavement texture. Road surfaces exhibit both macro- and micro-texture. The randomness of size, distribution, geometric configuration, and roughness of individual aggregated particles frequently result in a highly varied pavement surface when viewed through a microscope. Such an interwoven random texture of pavement means

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that the boundary between light and dark striations of a tire mark are difficult to distinguish with the human eye.

In practice, tire mark investigation requires that two policemen/investigators conduct the observation and measurement. One observes the tire mark from a distance and directs the other to mark the clear boundaries of the striations. This is a time consuming task that can require ~3–5 min for each clear mark, depending on the vehicle's braking condition and tire structure, the pavement texture, the inspector's vision and experience, and its accuracy is varied by the investigators. Detailed road examination usually is necessary only for fatal and other serious accidents; in such cases, the road at the scene of a traffic accident provides a site for supplementary data collection (second level of traffic-accident investigation) and for follow-up fact finding when required (third level of traffic-accident investigation). The best time to examine the road is at the scene of the accident or as soon thereafter as possible. If this is impossible, investigators have to rely on photographs (Baker and Fricke, 1986). Development of an image-processing system to extract tire mark features from photos and to conduct the tire tread matching task would greatly reduce the time and cost of tire identification and also ensure its accuracy. In addition, such a system would eliminate the time spent at the scene of an accident measuring tire mark striations, thereby restoring normal traffic flow quickly.

There are two types of tire marks: imprint and friction mark. Tire imprint retains the features of tire tread and can be used as an input to compare and match with tire tread (Wang, 2007). On the contrary, friction mark includes skid mark, yaw mark and tire scrubs which do not exactly mirror the texture of the tire tread that makes them. However, skid marks do possess an outline that is characteristic of a particular tire tread. A skid mark often has distinctive striations (streaks) that run parallel to its length. In contrast, yaw marks and tire scrubs look quite different from the tire tread that makes them (Wang, 2007). Because skid marks are mostly captured at accident scenes, herein we will focus on the problem of automatic skid mark segmentation. In the literature, many publications about accident investigation (Baker and Fricke, 1986; Martinez, 1994; Rivers, 1995, 2001; Van Kirk, 2001) have described in detail the causes of tire mark formation and their outline characteristics so that investigators/policemen can identify the types of marks manually. Many researchers have studied how to estimate a vehicle's speed using mark length or curvature (Goudie et al., 2000; Heinrichs et al., 2004; Neptune et al., 1995).

Few researchers have focused on automatic tire mark segmentation/identification and measurements. Bramble et al. (2001) defined such a forensic image analysis technique as a problem of image analysis/measurement (photogrammetry). In one study, Thali et al. (2000) matched tire tracks (imprint) on the victim head with the tire tread using 3D data model constructed by the Rollei Metric system. They used information about depth of the mark together with the normal 2D information to provide extra data for comparing and evaluating injuries and suspected injury-causing objects (tires) and to increase the discriminating power of the comparison. However, the cost of the 3D laser systems is ~US$70,000, which is the limiting factor for the acquisition of 3D traces and marks images (Bramble et al., 2001). In terms of the application, the method is appropriately used at serious traffic accident or crime scene due to its high cost (Buck et al., 2006). In addition, a skid mark on hard or soft surface (2D or 3D) is the product obtained from a tire tread (3D) projecting (i.e., sliding) on the surface. The only available matching elements are the outline features such as number of striations and their widths. The depth information of a skid mark is not helpful for matching with tire tread. Therefore, by nature skid mark analysis in 2D is much appropriate for tire tread matching.

Unlike standard object recognition applications, in the real environment skid marks are embedded in a complicated and irregular pavement texture and have to be detected in images that include this pavement texture (Wang, 2007). Unconstrained illumination conditions (although it can be compensated), the unknown position, orientation, size, and pattern of the skid mark, and the irregular pavement texture (background) are typical obstacles to recognizing objects in such images (Wang, 2007). In terms of practical application, an automatic skid mark identification system must have the following functions: skid mark localization, segmentation, feature extraction, and matching and tire identification (which can be used to identify which type of car tires produced the tire marks at an accident scene, particularly in the case of a hit-and-run accident). Wang (2003) proposed a distance-based matching model and used a similarity index to classify which skid mark belonged to which tire. For skid mark measurement, humans positioned and measured individual striation width using a pixel-reading program after the image was preprocessed. Because edges between light and dark striations (streaks) were judged by human eyes, this method was very time-consuming and the accuracy