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Automatic image acquisition with knowledge-based approach for multi-directional determination of skid resistance of pavements

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ABSTRACT

Evaluation of pavement skid resistance (SR), as a crucial index for assessing the degree of pavement safety, is essential for pavement management. Considering the difficulties involved in estimation of an overall index of extent and direction of SR, a new method is proposed in the present work for estimation of the SR using an automated image-based system. The images were first captured by an automated image acquisition system (IAS) and then an image processing expert system and a knowledge-based decision support system (DSS) were designed. The central part of the system proposed in the current work runs based on Wavelet Transform (WT), which consists of distinct modules including pre-processing, feature extraction, approximate indexes in three different directions (horizontal, vertical, and diagonal), and the overall index. The method was verified on a database of pavement images collected in dry and wet conditions. A comparison of the obtained results with those of British pendulum tester (BPT) indicates the validity and high speed of the proposed method.

1. Introduction

Road surfaces shall provide an adequate level of friction during wet weather for fulfilling road safety [1–9].The friction level, which occurs at the contact surface of the rotating wheel and road surface, is controlled by the relative vertical (wheel load) and horizontal (friction) forces between the wheel and road surface [5,7].

In addition, friction force developed between the vehicle's tire and pavement surface keeps the vehicle on the road and allows it to maneuver [4,7,8,10,11,12]. The skid resistance (SR) is the friction force developed from the vehicle's tire and pavement surface interaction, preventing tire sliding [3,5,7,11,13,14].

The SR of a pavement surface is related to two important surface characteristics: microtexture and macrotexture. Macrotexture is the coarse irregularities (wavelengths between 0.5 mm and 50 mm), while microtexture is the fine asperities (wavelengths below 0.5 mm) of a road surface [3,5,6,7,8,11,15,16,17,18]. The SR is influenced by microtexture at low sliding speeds and by macrotexture at high sliding speeds [7,12,16].

The SR, which has an important effect on pavement safety, is in turn affected by time [5,8,9]. Due to the abrasion of traffic flow, SR increases in the early life of a pavement and then decreases for the remaining life of pavement [5,8]. Thus, SR should be monitored continuously.

There are several approaches for SR measurement; some directly measure the friction of pavement surface and some other measure the texture of the pavement surface that is indirectly related to the SR. Direct methods consist of field tests, high-speed and laboratory tests, and low speed approaches. At high-speed approaches, there are four types of SR measurement methods. All these methods involve applying a trailer or a wheel connected to a car and then measuring the friction force at the interface of the sliding locked wheel and wet pavement surface [2,8,11].

The locked wheel is the friction force measurement at 100% slip situation. In addition, sideway force is the friction force measurement of a rotating wheel with a 20° yaw angle to the direction of motion [2,7,8,11]. Fixed slip is the friction force measurement of the constantly slipping wheel, whereas variable slip is the friction force measurement at any desired slip [2,8,11].

Laboratory tests are typically carried out using two testers including British pendulum tester (BPT) and Dynamic Friction Tester (DFT). In these tests, the pavement surface friction is measured by determining the loss in kinetic energy of a sliding pendulum or rotating disc when in touch with the roadway surface and converted to a frictional force. The DFT enjoys the additional advantage of being able to measure the speed dependency of the pavement friction by measuring friction at various speeds [5,8,11].

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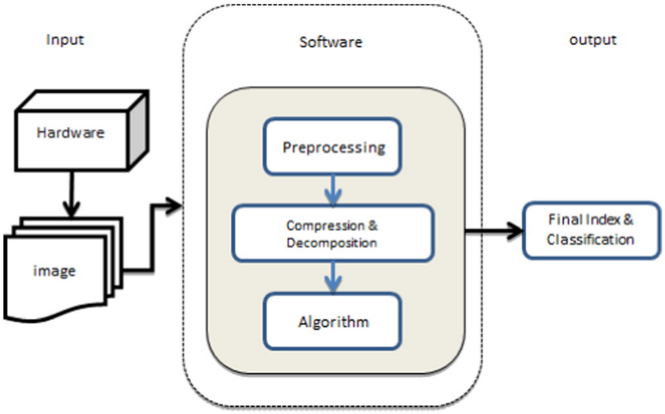

Fig. 1. Components of the proposed system.

To measure the texture of the pavement surface, two groups of contact and non-contact methods are mostly conducted. OutFlow Meter Test (OFT) and Sand Patch Test (SPT) are the most popular contact methods that measure the macrotexture of the pavement surface. The OFT is a clear perpendicular cylinder that stays on a rubber ring placed on the roadway. Then, the water is permitted to flow into the pavement, and the required time for passing between two marked levels in the clear perpendicular cylinder is recorded. This time, which is reported as the outflow time, is related to the pavement surface ability of drainage [1,2,6,8,11,12,19,20].

In addition, the Sand Patch Test is a volumetric method for macrotexture measurement, through which a known volume of sand spreads into the pavement surface and the resulting circular area is measured. Eventually, by dividing the initial volume by the area, Mean Texture Depth (MTD) is calculated via this test [1,2,8,11].

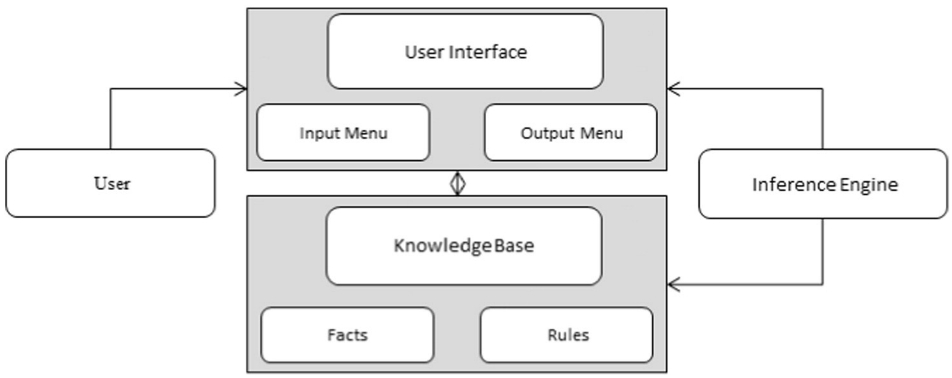

Fig. 2. An expert system's components [25].

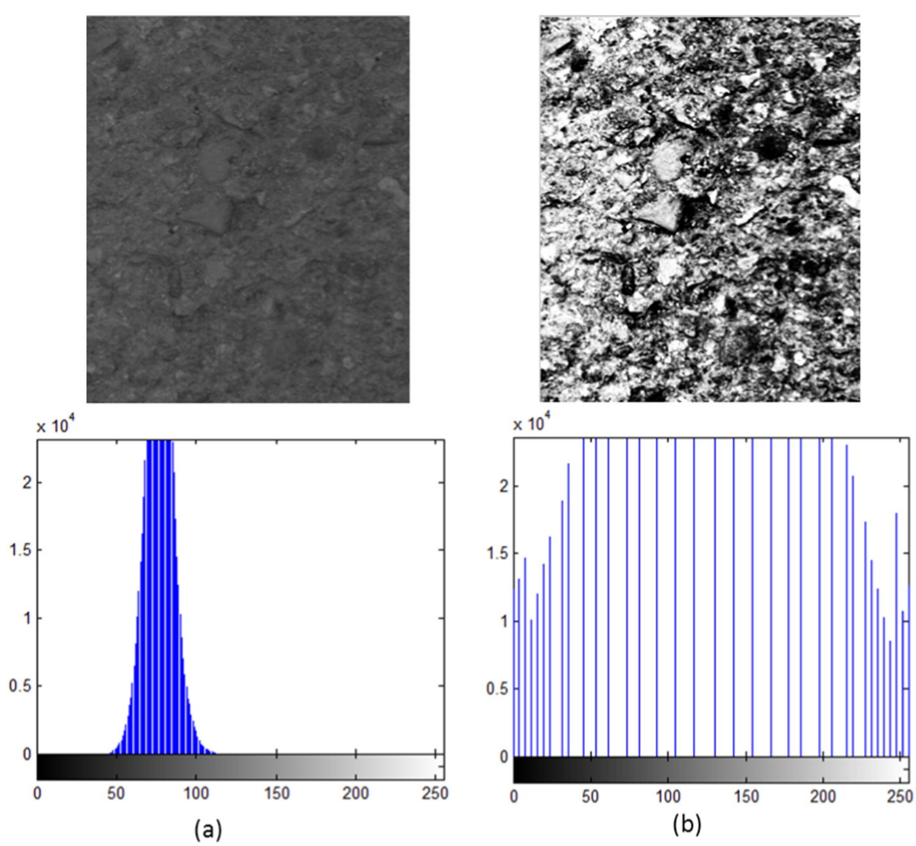

Fig. 3. (a) The original histogram of a pavement image, (b) the histogram after equalization.

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