ABSTRACT

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Thesis Title: **An improved automated and non-contact approach for characterising pavement surface texture**

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Pavement surface texture affects various engineering properties, for example, friction, noise generation, surface drainage, ride comfort, etc. In general, surface texture data is measured, and various indices derived from the data analysis are used as indicators of these engineering properties. In the present work, improvements are suggested to the existing surface texture measurement and analysis techniques.

The traditional surface texture measurement devices are generally manually operated, slow, contact-type and sometimes weakly repeatable. In recent times, developments in the fields of computer vision and visual metrology are being applied to the field of pavement engineering to develop measurement techniques that are automated, fast, non-contact, and repeatable.

In the present thesis, first, a review of such automated measurement techniques and their data analysis applied to pavement surface characterisation is presented. A classification of the measurement techniques based on the measurement principles is proposed. The work reported in this thesis has three main parts, and these are

discussed in the following:

- An extensively used automated measurement technique is active triangulation. Typically, laser-based scanners are used for active triangulation-based surface texture measurement. In the first part of the study, an active triangulation device (laser scanner) is designed and developed for pavement surface characterisation.

  The device is made in such a way that the triangulation geometry parameters, such as the baseline distance, the height, and the angles of the triangle are kept flexible and can be changed as per the requirement of the user. Such flexibility in changing these parameters allows the users to suitably customise the measurement parameters such as the measurement sensitivity.

  Off-the-shelf components are used in fabricating this device, making it easier to assemble and lowering its cost compared to the existing commercially available active triangulation devices.

  In such triangulation measurements, if a triangle gets broken (occlusion occurs) and a point gets missed, another triangle can be formed from an apex point of the existing triangle to attempt to re-measure the missed point. In the present design, multiple triangles can be formed by placing multiple illumination sources and detectors on the device.

- In the triangulation measurements, points may still get missed, even if the triangulation geometry is changed or multiple triangles are used. The points get missed as the surface profile obstructs the illumination rays, hindering the triangulation process. In the second part of the study, a new measurement approach is suggested, which makes measurements in a side-view configuration, where the illumination rays and surface profile are on perpendicular planes (unlike in the triangulation technique, where these lie in the same plane, that is, top-view). In the side-view configuration, the pavement profile does not obstruct the illumination rays, and measurements are made without missing any point.

In the second part of the study, a measurement device is designed and developed based on the side-view configuration. A side-view image of the pavement sample is obtained by perspective projection. The perspective projection does not generate the surface texture with its actual dimensions unlike the orthographic projection. Therefore, estimating the surface texture from a single side-view image may lead to errors. Thus, an approach is suggested such that the perspective-projection error is reduced in such a side-view configuration. An image contains an orthographic ray at the centre; the rest are perspective rays. It is proposed that the part of the image formed by the orthographic ray, or the rays close to it, should be used for measuring the surface texture of a point, and the rest of the image should be discarded. The closer a ray is to the orthographic ray, the less the error in surface texture estimation will be. Therefore, an image should be clicked for each point formed by the rays close to the orthographic ray. For each point, its image can be captured by moving the camera along the surface profile of the sample and capturing a unique image. The device is designed so the camera moves along the surface profile by a scanning mechanism. This camera movement is designed to take place in an automated manner. Whatever the shape of the profile is, the camera moves along it intelligently and captures the surface profile without any user input. The captured images can be analysed to obtain occlusion-free and perspective-error-free data.

- In the third part of the work, the designed active triangulation device (top-view) is used to measure the pavement surface texture data. The data analysis is carried out in the Fourier domain. Furthermore, Through Fourier transform output, the frequencies of the profile which are important for the given application can be selected and the rest can be filtered out. It is to be ensured that the texture data is equally spaced spatially before applying the Fourier transform. The measured active triangulation data is not equally spaced spatially and has certain points missing due to occlusion. An approach is proposed to convert this data to a uniformly spaced one. Subsequently, the Fourier transform is applied to this processed data of a few pavement core samples obtained from freshly constructed pavement surfaces. First, the frequencies which are important in influencing pavement surface characteristics are selected. It is argued that the influencing frequencies (in characterising the surface) should be selected from the Fourier spectrum by analysing the spectrum shape instead of the existing approaches, which divide the frequencies into fixed bands and select one such band. The spectrum shape is analysed (for frequency selection) by using information from the first and second moments of the spectrum. After selecting the influencing frequencies, an index is proposed which incorporates both the profile height information (from the amplitude values of the spectrum) and the rapidity of profile height change (from the frequency values of the spectrum). Most existing pavement indices consider only the profile height information, not how quickly the profile height changes. Subsequently, each pavement core sample is subjected to the British Pendulum Tester (BPT) and the obtained British Pendulum Number (BPN) is used to characterise the frictional properties of the pavement samples. The relationship between the proposed index and the measured British Pendulum Number values is presented.

Improvements to the existing pavement surface texture measurement and analysis techniques are suggested in this thesis. The active triangulation texture measurement device has a reconfigurable design, unlike the existing devices, which have not emphasized such a design. The side-view measurement device can provide occlusion-free surface texture data, which may not be possible with the existing measurement techniques. A more generalized and rational approach to frequency domain analysis of pavement surfaces is suggested by providing an approach to selecting important frequencies of the profile and suggesting an index based on the selected frequencies. These proposed texture measurement and analysis improvements can help advance the pavement surface characterisation practice.