DETERMINATION OF SKID RESISTANCE BY USING 3D SCANNING

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Summary: *The detailed progress to date of new measuring method for determining properties of pavement surface (macrotexture) is presented in this paper. The method is based on non-contact 3D scanning and subsequent evaluation of the scanned images. The measuring metric and the basic measuring plate were designed for this method. Now, it is supposed to solve data processing (point cloud filtration) and find a suitable statistical method for it. Application of approximation function using spline function by the method of least squares is presently tested.*

Keywords: *3D scanning, skid resistance, pavement surface, road safety, macrotexture*

1 Introduction

Generally, good skid resistance of pavement surfaces is one of the basic preconditions for safe roads. The skid resistance depends on a pavement surface texture. The texture is characterized by asperities present therein. These asperities occur with a scale ranging from micro level of roughness of the individual aggregate grains to irregularities spanning the length of several meters. Texture is classified at three levels: microtexture, macrotexture and megatexture. The type of pavement texture is determined by the extent of asperities which determine the level of friction performance and skid resistance.

The volumetric patch technique (ie. the sand patch test), 2D profiling methods and a determination of horizontal drainage belong among the oldest approaches for determining the properties of macrotexture. The first two of them are based on the ascertainment of the mean texture depth (*MTD*), the mean profile depth (*MPD*) or the estimated texture depth (*ETD*). The last method is a type of volumetric test that measures the water drainage rate through surface texture and interior voids. Generally, the range of texture depth is a basis for a current international classification scale of pavement skid resistance. This classification has 5 levels, from excellent to hazardous.

Most of texture measuring methods require road lane closures, but technical improvements in recent years make the measurement techniques faster and more reliable. Devices can be divided according to its mobility into mobile and stationary ones, according to its speed into fast and slow operating. The data collection process divides them into contact and contactless devices. The device is contact one if the sensor touches directly the measured surface. In respect to surface texture characteristics measuring, mainly profilometric devices are used. The majority of new devices are mock-ups or prototypes (Metris model Maker, Robotex, Texscan, P3 AT Autonomous Robot etc.). New data acquisition techniques include laser scanner that acquires three dimensional spatial data, as well as various 2D and 3D profiling methods with new calibration techniques. These methods lead mainly to determination of ETD.

2 Experimental work

This paper proposes a new measuring method for determining macrotexture properties. It is based on non-contact 3D scanning and subsequent evaluation of the scanned images [1]. The non-contact handy 3D scanner

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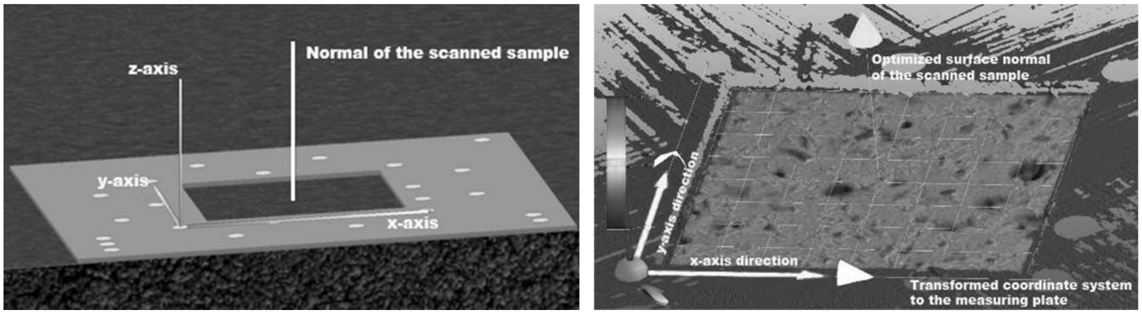

Figure 1: Coordinate system of the measuring plate and a normal of the pavement sample

ViuScan with resolution $0.10\,\mathrm{mm}$, accuracy more than $0.20\,\mathrm{mm}$ and scan speed 18000 frames per second is used for scanning. For the pavement surface measuring purposes, the basic measuring plate with an inner opening of approx. $100 \times 100\,\mathrm{mm}$ has been designed and made, which corresponds to the proposed basic scanned area and it is used for identification of measuring characteristics. The measuring plate determines the basic plane for all scanned samples. It has been experimentally verified that its position on the pavement should ensure parallelism with the terrain. The plane of template shall be the initial coordinate system for the purposes of virtual processing. An average deviation from the ideal plane of surface was $0.12\,\mathrm{mm}$, however, it is necessary to take into consideration that every surveyed point is unique and their heights cannot be completely identical. The maximum deviation from the transformed height was $0.197\,\mathrm{mm}$, therefore it was smaller than the set resolution of the measuring device.

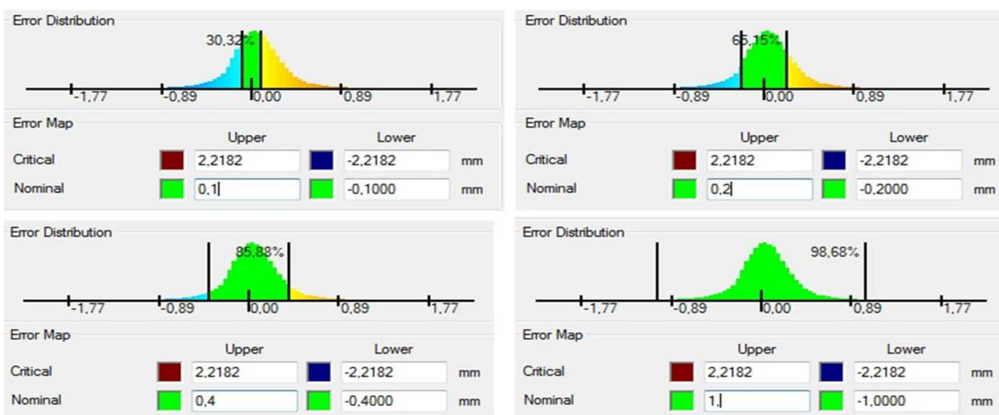

Figure 2: Basic analysis of the scanned pavement sample

The surface normal of a measuring plate draws near the optimized surface normal interlaced with the surveyed area (confirms the assumption of a coordinate system). To verify normal interlacing, in all samples of pavement scans a plane on the principle of a minimal bias was generated from all available selected surveyed areas (the principle of least squares), see the Fig 1. The compliance was accurate to four decimal places (all calculations and dimensions are based on dimensions of the samples surveyed in mm). Consequently, it is possible to use the coordinate system related to the measurement plate effectively, which was within experimental tracking calculated and designated as the new reference system. The analysis of Fig. 2 indicates the correct laying of the coordinate system plane; the resulting distribution does not only act symmetrically, but also indicates the scanned area of the pavement dimension (vertical projection) about $100\,\mathrm{cm}^2$.

A measuring methodology for scanning and pavement texture modelling has to take into account a limited possibility to scan the whole pavement area with such a high accuracy requirement. The optimal process seems to be scanning and processing of smaller areas and then generating the averaged (or interpolated) pavement terrain based on sample models. The designed metric of measurement is based on an area greater than $1\,\mathrm{m}^2$. This area is larger than the surface tested by a common volume patch technique in combination with a pendulum. The inspected area is divided into scanning individual zones. Each zone consists of surface parts of area $0.01\,\mathrm{m}^2$, while the area is defined by the designed reference measuring template. The focus of the default zone must be done by a geodetic spatial focus so that it is possible to continue retrospectively with already analyzed areas when repeated measurements are required. A measuring methodology for scanning is showed in detail on the symposium poster or in literature [1].

The potential threat for this type of measuring, as for all laser scanners, is the presence of too sunshine and a poor scan of reflected rays from the pavement surface. For processing it is necessary to use a powerful workstation, since in operation in the terrain, it will always be necessary to carry out measurements as quickly as possible, ie. point filtering, noise removal and mathematical compensation as follows.

In further processing, the samples are subjected to a surface and volume analysis in the parametric environment of CA modelers. A point cloud is generated from the imported data of measured sample. Than the visible errors are checked, cancelled and repaired. After that step, the sample borders for analysis (masking) are determined. Before export and visualization of a pavement surface, the surface and volume analysis of sample have to be done.

The filtering of the data cloud samples proves to be the most challenging problem. The software interface of 3D scanner - Vxelement enables a rough filtering of excessive scanned data in a graphical interface where the pavement surface must not be damaged by this process. The next phase of filtration is based on the work with raw data and a point cut off between designated limit levels. Generally, it is possible to remove these noises by parameterization of length set of edges and mainly by angle limitations. However, it is not generally possible to determine the correct boundary conditions because real surfaces may automatically be distorted and peaks which belong to the model may be omitted that means a real surface change. Rebuilding of surfaces from clouds of points is a standard method but the arrangement of boundary triangulation conditions may lead to degradation of the measured data. This problem will be solved in the ongoing research.

3 Ongoing research

At this phase of the research it is supposed to find a suitable statistical method for determining the estimated texture depth (*ETD*) from the raw data given by (x, y, z). In this case, an application of approximation function $f(x, y)$ in R^2 using a spline function $g(x, y)$ by the method of least squares seems to be suitable for approximating. The function $f(x, y)$ is defined on the area of points $O = \{x_i, y_i\}_{i=1}^{N}$, then the area of points $\mathcal{L} = \{x_j, y_j\}$, adjoining left side to the area O, the area of points $\aleph = \{x_k, y_k\}$, adjoining top to area O, are defined too. The function g is given by the equation:

$$g(x; y) = A + Bx + Cy + Dx^2 + E2xy + Fy^2 \quad (1)$$

The contemplated conditions for this case are minimum sum of squared deviations of $f(x_i, y_i) - g(x_i, y_i)$ for $[x_i, y_i] \in O$, the condition of continuity and smoothness of f and g on the left interface (ie. the continuity of f on $\mathcal{L}$ and g on points from O adjoining to $\mathcal{L}$), the continuity and smoothness of f and g on the top interface $\aleph$ ((ie. the continuity of f on η and g on points from O adjoining to $\aleph$). Application of this approximation is presently tested in various cases of continuity and smoothness conditions. The aim of testing is to find an optimal approximation of the real measured surface data without large degradation, so to avoid large distortion.

4 Conclusion

In this paper, surface texture measurements performed by the non-contact handy 3D scanner and the usage of the designed measuring template were presented. The measuring methodology was designed for areas of $1\,\mathrm{m}^2$ and tested on real pavement surface. The data processing becomes the most problematic part of research because of filtering error. For this reason the new statistical approach is proposed. This is based

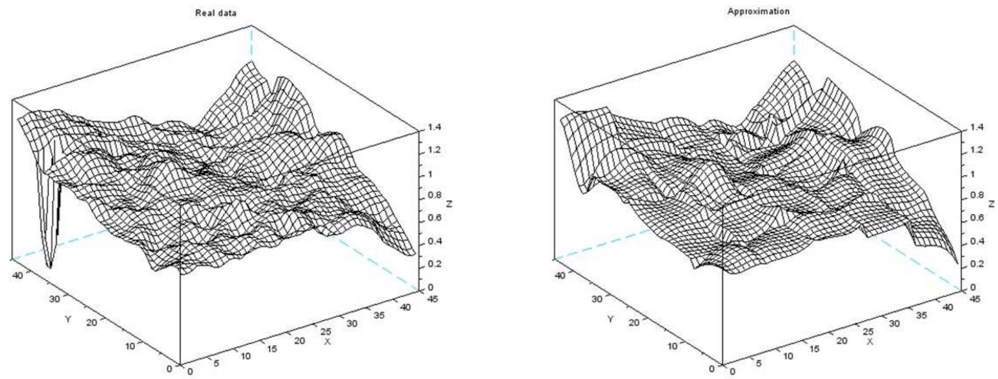

Figure 3: Example of approximation, left: measured data (rough filtered); right: approx. data [2, 3]

on approximation in R^2 by the spline function. Now it is tested with various compatibility and smoothness conditions. The goal of testing is to find the best way how to preserve real measured surface without large distortion. Rebuilding of surfaces using clouds of adjusted data allows more accurate decomposition of the surface into plane segments and makes the possibility of design the new classification. The new classification should be based on the measurements of the totally spanned area of the macrotexture surface. The last phases of research will be implementation of comparative measurements with a volumetric patch technique and comparison of the results, determining the extent of the surface areas for the each classification level.

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