NEW CONCEPT OF PROFILE BASED PAVEMENT MEASUREMENT SYSTEM

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ABSTRACT

The current paper is the continuation of the research work, of which initial results has already been published at the 2005 ASPRS annual meeting. The system is dedicated to derive certain parameters that enable classifying roads based on their condition. Applying vertically projected laser marker points and stereophotogrammetric method, the digital road surface model can be obtained. Moreover, mono images enable crack detection, which is important indicator of pavement aging and damage.

In the recent system the measuring method has been completely redefined. Instead of using a camera pair, the images are captured by a single frame camera. For the road classification the International Roughness Index (IRI) has to be derived, which shows the roughness of the pavement. A continuous laser line is projected onto the road and images are captured applying oblique camera.

The accumulated vertical movements of the image points of the projected line are the inputs for IRI calculations, therefore these movements are extracted by the image processing module. The oblique camera position and the vertical laser beam assure optimal positioning accuracy as well as have increased mechanical and numerical stability during the measurements. Similarly to the previous system, the best imaging reliability is guaranteed by time-to-time calibrations.

This paper discusses the initial investigations, tests and the concept proof of the method.

INTRODUCTION

Our department (Department of Photogrammetry and Geoinformatics, Budapest University of Technology and Economics) has developed an image based road surface detection system in 2004-2005. This first version composed by a control computer, two digital cameras, a navigation unit with GPS/INS, laser projector array and a photogrammetric and image processing unit. Recently, the industrial tests are running at the Municipal Public Service Company in Budapest.

Most of the shortcomings turned out during the tests, and it has been decided to develop a second version (V2) based on the initial experimental results. The major emphasis has been put on simplifying the system: a single camera is used (no trigger and matching is needed anymore) with a laser line projector (much easier calibration). The basic concept of measuring the heights of the surface points has been also changed: now it's possible to measure all the points along the projected line (i.e. in one cross-section of the road) and the method of computing the heights is also simpler.

Description about the initial results has been already published at ASPRS, in Baltimore, 2005. A brief description of the previous system design is needed to explain the motivation of V2.

The first version uses stereo imagery for the accurate road surface generation. The exterior orientation parameters are provided by an integrated GPS/INS system. The system components are depicted in Fig 1.

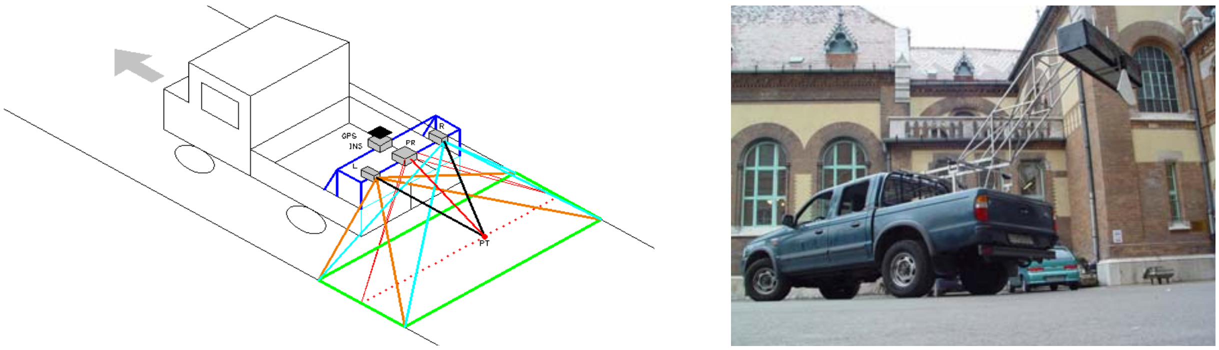

Figure 1. The system components (mobile platform, cameras, projector, GPS/INS) and the measuring concept (markers as dotted line on the pavement).

The basic concept is the following: 21 well visible points are projected onto the road surface by separate laser diodes. Both the synchronized cameras acquire images about the road with the projected points at max. 15 fps. Then the marker points are identified and matched in all image pairs. The image coordinates are corrected by the previously defined distortion parameters and the 3D model coordinates are computed by spatial intersection.

Even from this brief description it clearly seems how many error sources should be considered during the computation: camera synchronization, exterior orientation for both cameras, laser projector calibration etc. This complicated procedure motivated the development of a significantly simplified and therefore completely redesigned system, which is discussed in details in the following.

V2 – BASIC CONCEPT

The idea behind the second version is measuring height in a single image by profile detection. If a straight line is projected on a smooth surface and an image is taken from oblique camera position, the line appears straight on the image (Fig. 2).

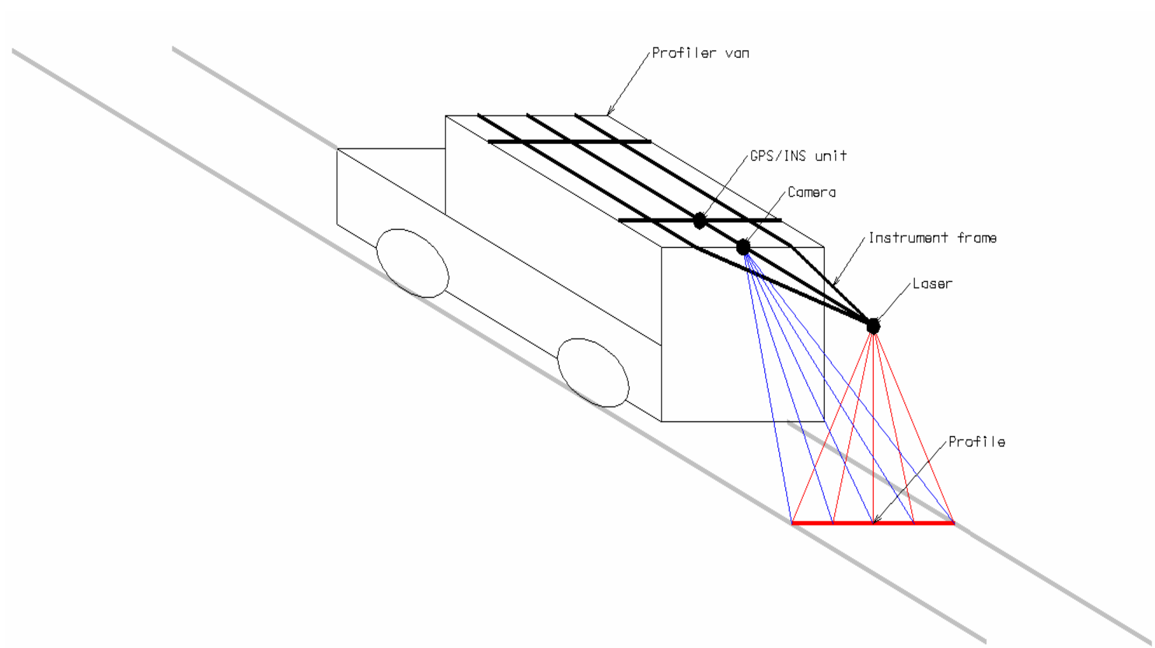

Figure 2. The concept of the second version.

In case of height change (an object or pothole, for example), the image of the line seems straight only from top view, but it's broken from any oblique view point.

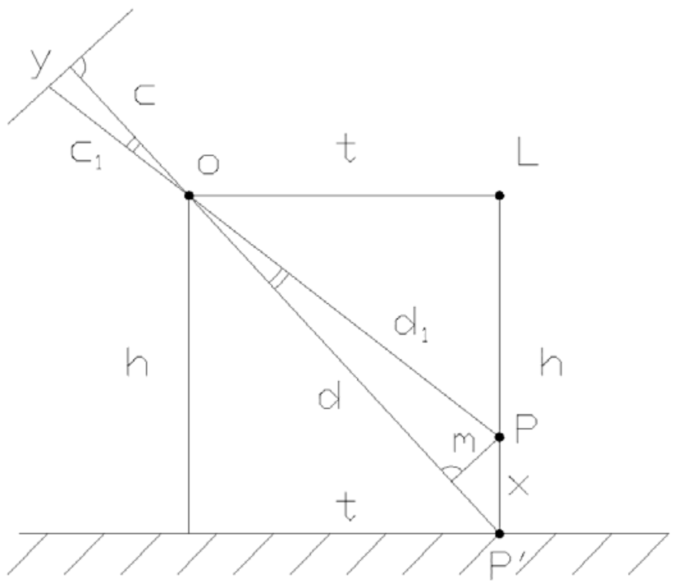

Figure 3. The basic concept of measuring height (*x*) in a single image taken from oblique viewpoint.

Based on the ycc_1 and mdd_1 similar triangles clear correspondence can be defined between *y* and *x*, which is a quadratic equation. Without going into the details, the main equation can be solved for *x*:

$$\frac{\sqrt{t^2 + (h-x)^2} \cdot y}{\sqrt{c^2 + y^2}} = x \cdot \sin\left(\arctan\left(\frac{t}{h}\right)\right)$$

The result is a function in the following form:

$$x = f(h, t, c, y)$$

During the calibration, the camera focal length is considered as constant. So the only inputs of calibration are the *h* and *t* values.

This system can be considered much robust compared to the previous version, since it avoids stereo imagery. Moreover, in this concept every single points of the projected line can be evaluated and measured (note, that previously separated points have been projected); therefore it enables much higher resolution for the road surface model. The surface resolution depends on the camera cross-directional resolution. Initially only a single line is projected onto the surface, later, if higher measurement speed is needed, more lines can be projected simultaneously.

FIRST TESTS WITH V2: CONCEPT PROOF

In the first phase the image processing module has been developed. For the concept proof an industrial laser line projector and an industrial digital camera were used, the same equipments are intended to apply in the final version. The laser projector is a Lasiris laser diode (5mW, 660nm) with special optic for the structured light. The imaging unit is a TheImagingSource DFK 41F02 color camera with 1280 × 960 resolution and 7.5 fps image acquisition speed.

The laser projector was mounted vertically (perpendicularly to the surface); the projected line was captured by the camera from the oblique position of about 45 degrees (Fig 4).

Figure 4. The concept proof configuration.

Different objects were used for the tests: e.g. a floppy box, an RC car (Fig 5). In all cases the objects have been moved towards the camera, perpendicularly to the projected line.

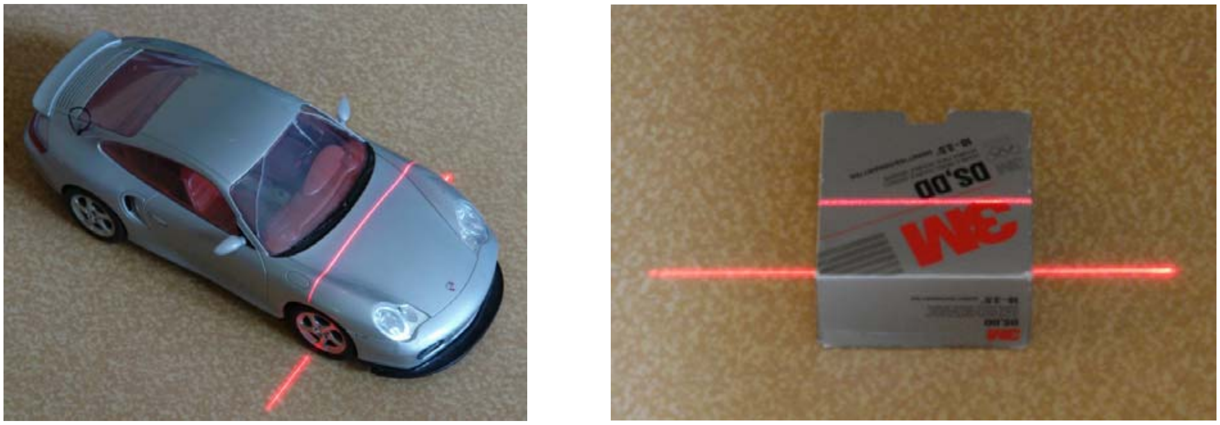

Figure 5. Test objects.

Sequences of camera images were the inputs of the overall object reconstruction procedure. In all images the red laser stripe was extracted by filtering and binary image morphology, and then the y image coordinates of the laserline were computed.

The accuracy of the reconstructed object depends on the capturing resolution (number of images per object) and the calibration parameters (camera height, object distance). In the following the computed cross sections and the reconstructed objects are shown (Fig 6-8).

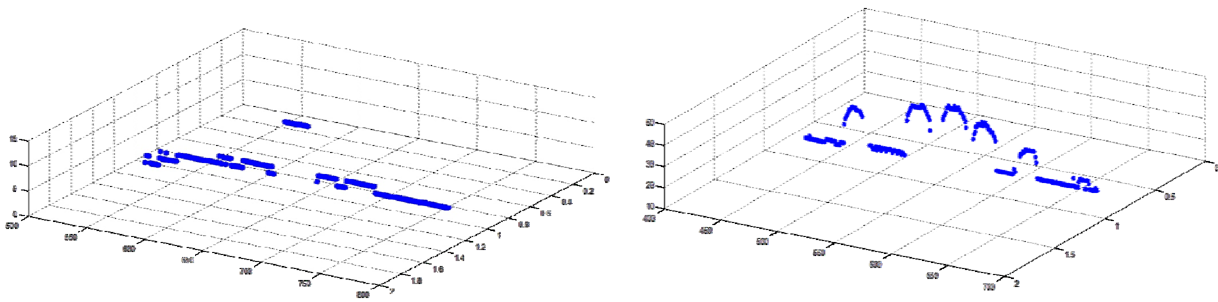

Figure 6. Computed cross sections of a tool and a hand.

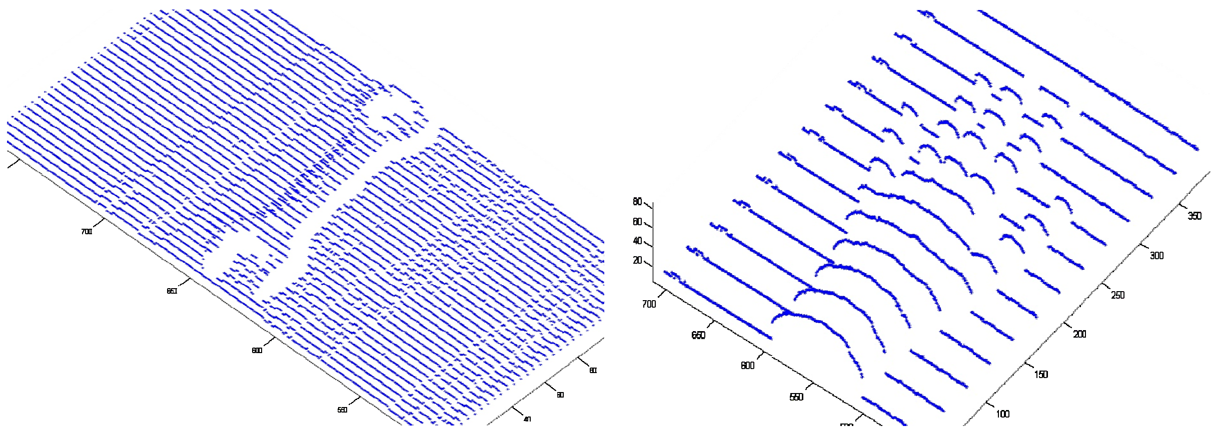

Figure 7: Sequence of cross sections

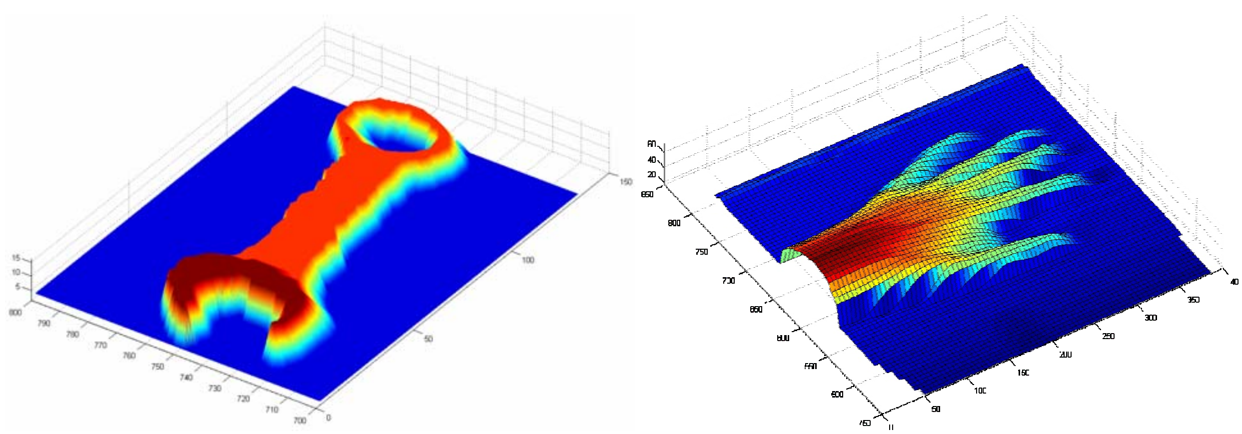

Figure 8. Reconstructed object (linear and cubic interpolation applied).

As it can be seen in Fig 8, the detected objects are nicely reconstructed. The accuracy of the height measurement ensures adequate solution for road condition detection, since the final purpose is measuring the height differences on the road surface and deriving the IRI number for dedicated road segments. Based on the IRI values, the transportation authorities classify the roads, schedule the road construction works, reconsider the speed limits etc.

CONCLUSIONS

The investigations and tests described in this paper proved that the proposed detection method assures robust solution for road surface generation. Applying a single imaging unit simplifies the georeferencing and avoids the complicated calculation and calibration of two cameras which have to be synchronized. Using line projection instead of laser point array enables measuring all point heights along the profile, therefore the surface model resolution depends only on the horizontal resolution of the camera. This concept also has further potential in development, e.g. applying multiple projected lines in order to allow higher measurement speed, and also leaves open the possibility of using the camera images for additional purposes, such as crack detection, which is a critical issue regarding road condition detection.

The next step in development is creating the engineering prototype of the road detection system; the camera, the laser projector, the control unit, and the navigation system are to be mounted on a vehicle and the next tests are to be carried out in the environment of the final system, i.e. on the roads.

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