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Semi-automatic inspection tool of pavement condition from three-dimensional profile scans

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Abstract

In the present work the preliminary study on qualitative and quantitative assessment of the road surface condition is presented. The work is motivated by a very actual and important problem of visual inspection of the road network. In general the road managers are obliged to perform a regular, periodic maintenance road testing, also the road constructors and civil engineers in the recent design framework – 'design-build-maintain' are interested in seasonal inspections of their constructions. Therefore the semi- or full-automatic visual testing methods of the road surface condition are under a constant development and in the center of interest of many research groups. Herein the main attention is focus on the automatic quantification of a road surface damage type from the three-dimensional cloud points. The stereo vision system, its intrinsic and extrinsic parameters as well as the correspondence-reconstruction problems are here assumed theoretically, since the practical design of the full methodology is still under the development in the ongoing national project.

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1. Introduction

Many researchers, civil and structural engineers devote their work to develop reliable systems for the monitoring of pavement condition. As the problem has been studied for over two decades, the three approaches seems to dominate in the recent years [1], namely (a) a two-dimensional image processing, (b) a three-dimensional laser scanning and (c) the combination of the two previous techniques. While detection procedures are utilized a different distress type can be monitored [2], e.g. a pothole, a rutting, a macro/micro texture, a shoving, a raveling or a cracking.

Nowadays, the assessment of the road surface using image processing only is considered to be the least reliable method [1], [3], since it's vulnerable to potential artifacts in detection results, such as tire marks, oil spills, shadows and pavement repairs. However, many research groups published interesting papers based on the two-dimensional

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approach, for example [4] shows how to detect potholes in asphalt pavement, basing on pothole shadow, approximated by an ellipse. The achieved accuracy basing on 120 tested pavement images (with different shapes and sizes of potholes) is about 86%. Another instance is presented in the paper [5], where authors describe two different approaches for detecting pavement cracks, namely: edge detection and fuzzy set theory. Presented algorithms are capable to classify four types of cracks: longitudinal, transverse, block and alligator (fatigue) cracking. The comprehensive description of fully automatic road distress assessment given in [6], shows the process based on the line scans and image processing tools. The research introduces detection parameters, which should be correctly adapted for particular type of a pavement in order to reduce false detections which might appear due to bad parameter setting. The similar strategy of setup parameters is also adapted here, more details will be presented in the forthcoming section.

Parallel to the two-dimensional image processing, the methods based on the three-dimensional scans were constantly developed, where the measurement database is usually collected by a laser scanner. For more details in 3D data acquisition technologies used in pavement surveys, the reader is referred to the review article of Mathavan et al. [2]. The instance of the three-dimensional approach is proposed in [7], where a real-time 3D scanning system for tracking the rutting and shoving is presented, the scanned data are preprocessed to create transverse, discrete profile lines. Surface distortions, then, are characterized by computed second-order derivatives of each line. Alternatively, in the work of Sun et al. [3] pavement crack detection is computed from sparse linear representation. It is assumed that the pavement profile signal can be decomposed into a number of components, namely: (a) crack, (b) a main signal, (c) a bump, (d) a rut, (e) a pothole and (e) a noise. In attached example main profile is reconstructed very well, however computations are time consuming. Therefore the implementation of the three-dimensional approach gives good results, however still its performance has to be improved.

Combined methods, both two-dimensional and three-dimensional techniques, are merged together in order to obtain a high detection accuracy. Though the concept is known for almost two decades [8], [9], only recently it turned out to be a current trend in the developing of the pavement condition evaluation tools [4]. In the recent works the several strategies in the road surface inspection are introduced. One of the example is the research initiated in 1997 [8] and continued in 2012 [10], where advance and complete laser crack measurement system (LCMS) was demonstrated. The LCMS uses two-dimensional images called intensity data and a three-dimensional point cloud called range data to merge them into the 3D profiles. The algorithm is able to automatically extract not only pavement defects such as longitudinal, transverse and alligator cracks, but also ruts and raveling. Moreover, the system performance was verified on over 9000 km of road network, what resulted in 95% compliance with the manual classification. Another example of mixed approach of pavement crack detection can be found in the paper [1]. Authors report higher detection accuracy, due to the fusion of the 2D gray-scale image and the 3D laser scanning methods. On the contrary, despite many advantages, the mixed approach requires more instrumentation, merging the two different measurement fields (the color intensity and the 3D point cloud) and more advanced algorithms to handle a complex data.

In this communication a slightly different approach is proposed, namely a stepwise global search of surface distress of any type, its further classification and final quantification. The starting point in the proposed procedure is a 3D representation of a road surface. Details on the remaining parts of a full system, namely: (a) acquisition, (b) stereo vision setup and (c) correspondence-reconstruction procedures are omitted here for brevity. The detection procedure bases on smoothen lines (both in longitudinal and transversal directions) and their first-order derivatives.

2. Methodology

2.1. Acquisition and simplification of database

In general a stereo vision refers to the ability to infer information on the 3D structure and distance of a scene from a series of images taken from different viewpoints. In the herein presented design and methodology the two cameras at fixed position and distance from the observed surface are utilized together with a linear scanning system. Both provide a mutually complementary measurement data which after an algorithmic preprocessing allows to perform proper and precise projection to a 3D cloud of points. Since all optical, photometric and geometric parameters as well as intrinsic (e.g. focal length, frame and pixels coordinate, geometric distortion) and extrinsic (e.g. cameras positions