Application of Digital Photogrammetry to Quantification of Road Surface Distresses

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Abstract: Amongst the salient aspects in treating road surface failure, proper diagnosis and correct timing are considered as the forefront in road maintenance. It is important to obtain the assessment systematically and subsequently performing the appropriate treatment in time. This is because such actions will prolong the actual service life of the road and optimize both financial and human resources. Conventionally, road surface conditions are assessed manually for various types of road surface failure. Current technology is to utilize an infra-red image processing technique to automate the evaluation process. The earlier approach is laborious and time consuming thus limits the frequency of the assessment. The later, on the other hand, is expensive in terms of instrumentation and expertise, thus, limits the frequency of the assessment. This paper describes the application of close-range photogrammetric and digital image processing techniques to obtain the required raw data for future assessment of any given road surface. The potential capability and reliability of a workstation-based digital photogrammety system for quantifying road surface delamination was demonstrated and assessed. Surface measurement is represented by ortho-image, overlay contour wit ortho-image, as well as digital elevation model of the delamination area. Preliminary results on delamination indicate that the extent of the road surface distress can be quantified swiftly and accurately when compared to the conventional method.

Keywords: Pavement Distress, DPW, Stereovision, Photogrammetry.

1. INTRODUCTION

As reported by (Abdul Hameed & Hj. Hasim, 1993), large sum of money has been spent to maintain road pavements in serviceable conditions. In order to economise on the maintenance cost, extensive research has been carried out by the Public Works Institute Malaysia (IKRAM) to understand the pavement behaviour under Malaysia climatic conditions. Therefore, quantification of road surface distresses is necessary for monitoring pavement performance. Different types of surfaces under differing conditions (load and volume of truck traffic, construction practices, weather conditions, etc.) will perform in a unique fashion (Hintz et al., 1989). One of the important factors which define pavement performance is delamination. Pavement delamination refers to the loss of a discrete and large (minimum 0.01 m^2) area of the wearing course. Usually there is a clear delineation of the wearing course and the layer below (JKR, 1992).

For many years photogrammetric procedures have significantly contributed to the non-physical contact measuring objects. Furthermore, the introduction of digital image processing techniques has seen the applications of photogrammety in various fields. Since 1990 digital photogramtry has made a rapid development, such as the development of Digital Photogrammetry Workstation (DPW) (Zhang and Zhang, 2002).

This paper describes an approach for digital photogrammetry system to collect three-dimensional data from stereo digital image pair. The images were captured with a non-metric digital camera.

2. CURRENT PAVEMENT INSPECTION METHODS

Currently, pavement distress data are usually collected by raters walking or travelling along the highway watching for distresses area, and measure to record some parameters of pavement conditions. Therefore, conventional visual and manual pavement distress analysis approaches are tedious, time consuming, labour intensive, and almost lead to inconsistencies in distress detail over space and across evaluation. To improve the execution of this data collection process and the quality of the data collected, there are several research groups working to develop a more efficient method of obtaining pavement distress data (Fukuhara et al., 1990; Ritchie, 1991). The general approach desired is to capture pavement images using video cameras mounted on a moving vehicle and then use a computer to recognize and quantify the pavement distresses from these video images. The other evaluation approach is using laser sensors which collect information related to the profile of the pavement such as rutting and depth of cracks.

Advancement in stereo digital machine vision technology creates an opportunity to overcome some problems associated with the manual methods. It can provide a low-cost, near real time geometrical imaging through digital photogrammetry without physically touching the surface being measured. Moreover, DPW is user-friendly, and less tedious.

3. CLOSE-RANGE PHOTOGRAMMERTY APPROACH

The workflow for generation of ortho-image, overlay contour with ortho-image, as well as digital elevation model is made up of four steps: Camera calibration, control field placement, stereo image capture, and stereo image processing.

3.1 Camera Calibration

In this work, a commonly available non-metric Charge-Couple-Device (CCD) digital camera of the type Canon IXUS 330 was used. Digital camera enables automation of the image measuring process and near real-time output. The camera was calibrated using a target plate that consists of 36 retro-reflective points as shown in Figure 1. The calibrated focal length and offset principal point are 5.34mm and (-0.0702mm, -0.0269mm) respectively.

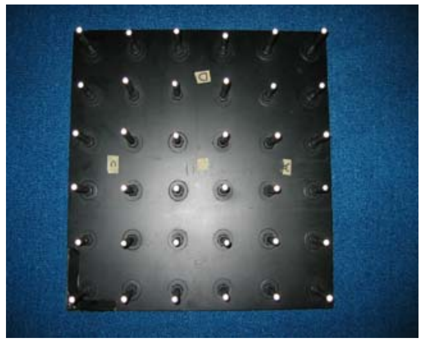

Figure 1: Target plate used in camera calibration.

3.2 Control Field Placement

A control frame must be created throughout the area of interest, including all area that will capture in each photographic frame. Relative and absolute orientations of the stereo images were obtained using proprietary DPW software known as VirtuoZo. The software requires at least three control points on the mapped scene. To facilitate the task in generating stereo model, 16 control points distributed across a wide range of x, y, and z values were installed throughout a steel frame (see Figure 3).

3.3 Stereo Image Capture

At least two images must be collected to produce a digital elevation model (DEM). Each stereo pair must overlap at least 60 percent as shown in Figure 2.

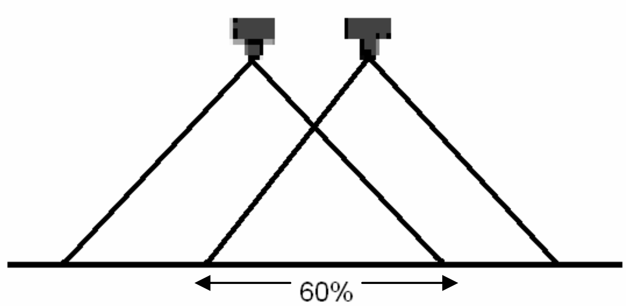

Figure 2: 60% stereo overlap image concept.

A single stereo image (two overlap images) was captured for selected samples of delamination (disintegration distress) section of Jalan Gangsa 2 in Taman Sri Puteri, Skudai. Figure 3 show the image captured.

Figure 3a: Left image of delamination

Figure 3b: Right image of delamination

3.4 Stereo Image Processing

Stereo Image processing was carried out using the VirtuoZo system (version 3.2) running on a computer workstation. The methodology for workstation-based digital photogrammetric processing can be summarised as follows:

a) *Relative Orientation*.
Perform relative orientation: the images are displayed simultaneously to allow generates common points identifiable on the stereo overlap for each image. This will relate the overlapping portions of both image to be merged together to provide a 3D stereo image.
b) *Absolute Orientation*.
Absolute orientation is the final orientation process to be carried out to tie the 3D stereo image into the real world coordinates system.
c) *Image Matching*.
Points were automatically matched across the entire surface during this process. In other words, points on the images are paired automatically using projective transformative properties.
d) *Create DEM & Ortho-image*.
DEM is derived in this stage from the points matched in the preceding image matching stage. Ortho-image (photo map) was created automatically in a matter of seconds in the system, as well as the contour map.

4. GRAPHICAL REPRESENTATION OF DELAMINATION AREA

The extracted surface measurements can be visualised by representing them graphically. The severity of delamination was analysed according to the DEM data. The three-dimensional surface of the delamination is shown in Figure 4: the X-axis coordinates are positive in the direction of traffic movement; the Y-axis coordinates represent the measurements crossing the road; and the Z-axis coordinates area positive upward. Figure 5 shows the two-dimensional ortho-image extracted from stereo vision. Figure 6 shows the overlay contour with ortho-image of the delamination area.

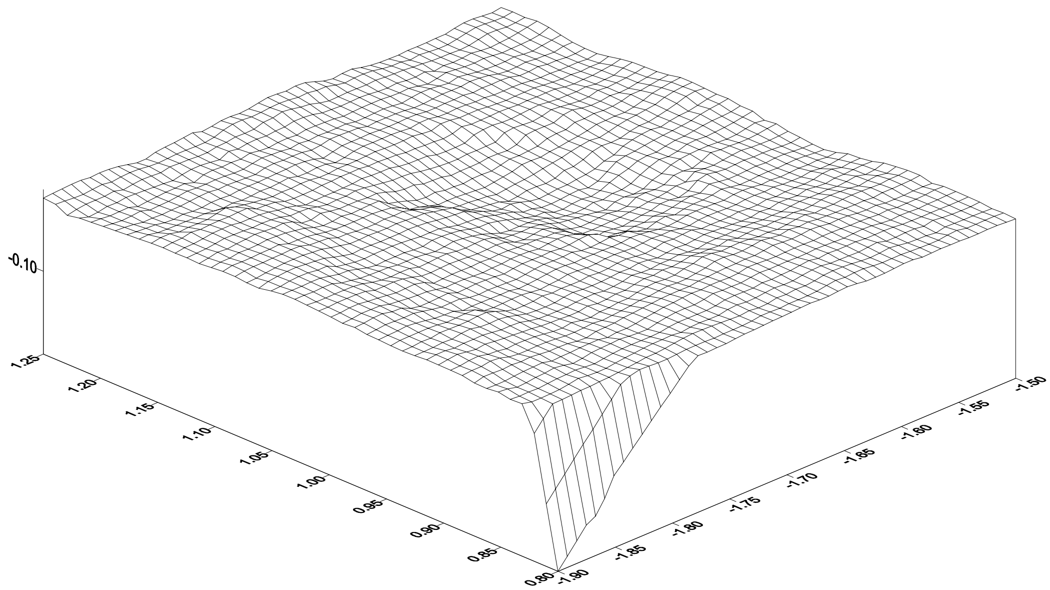

Figure 4: DEM of delamination

Figure 5: Ortho-image of delamination.

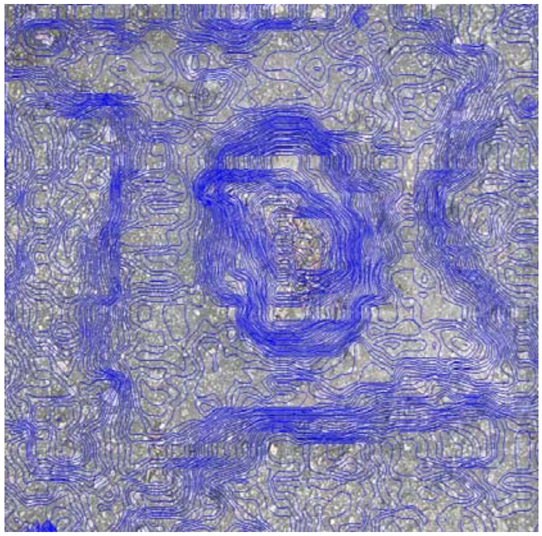

Figure 6: Contour overlap of delamination

5. QUANTIFICATION OF DELAMINATION

In this study, the delamination is quantified based on the affected area according to JKR standards shown in Table 1. Three-dimensional coordinates are extracted for the delamination distress by DPW system. At this stage, negative surface area which is approximately to the affected area of delamination was calculated about 0.28 m^2. It can therefore be considered that the delamination as moderate.

Table 1: Severity Level of Delamination

	Severity Level
Peeling of the top layer has started but has not progressed significantly. Surface area peeled off is less than 0.1 m^2	**Low**
Surface area peeled off is between 0.1 m^2 to 2.5 m^2. Several crocodile cracks in and around the peeled area.	**Moderate**
A group of more than two moderate delaminations along a short stretch of road.	**High**

6. CONCLUSIONS

In the presented paper, an approach for semi automated quantification of pavement distress (delamination) using a stereo image has been introduced.

Quantification of pavement distress using stereo photogrammetry approach is seen as an alternative method that can be employed in the field. It is anticipated that the quantifying pavement distress will be effectively and conveniently done without physically touching the surface, thus reducing the disruption of traffic movement. The time saving factor is also important, as well as non-laborious.

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