

Designs of Automated Pavement Surface Distress Survey System

Wang Hua^{*}, Hou Xiangshen^{**}, Wang Qi^{*}, Ma Songlin^{**}

^{}Department of Automatic Measurement and Control, Harbin Institute of Technology, Harbin 150001, China*

*^{**}School of Transport Communication Science and Engineering, Harbin Institute of Technology, Harbin 150001, China.*

ABSTRACT: This paper describes a novel design of survey system to collect pavement surface distress. The system includes four modules. They are artificial illumination module, image acquisition module, sync control module, data storage and analysis module. The system can carry out crack surveys at a nominal speed of 72km/h with full coverage of pavement surface. Crack recognition is performed offline. The prototype has been tested in laboratory conditions and completed a survey of about 15,000km real road at normal running speed (72km/h) between the year of 2003 and 2004.

KEY WORDS: Pavement surface distress, survey system, image processing

1. Introduction

At a time when speed of communication and mobility are important factors, the detection of pavement distress on highway pavements requires special attention from the transportation authorities in China and other countries. For the inspection of the surface distress of highway pavements, the most widely used method to conduct such surveys is based on human observation. The surveyors traverse the roads, stop and measure the pavement distresses when they are found. This approach is extremely labor-intensive, very costly, subjective, time-consuming, prone to errors, and dangerous. Successful automation of surface distress survey can reduce the overall cost of performing distress surveys and provide more objective and standardized results for rehabilitation management.

In recent years, technological innovations in computer hardware and digital image acquisition techniques have provided opportunities to explore new approaches to automating distress survey in a cost-effective way. Some researchers (Kelvin,2000; Guralnick,1993; Toshihiko,1990)have paid a great deal of attention to developing automated pavement distress detection and recognition system. This paper presents a novel automated pavement surface distress survey (APSDS) system capable of collecting and analyzing pavement cracks with

high-resolution digital images.

2. Design and Implementation of APSDS

Figure 1 illustrates the framework of the APSDS. The APSDS comprises of four modules. They are artificial illumination module, image acquisition module, sync control module, data storage and analysis module. A dual-computer architecture in data storage and analysis module is used for image acquisition, artificial lights and data controlling and processing.

2.1 Artificial Illumination Module

As the survey vehicle can travel at highway speed and the distress, such as cracks, can be very small, it is difficult to obtain a faithful replication of the pavement surface as pavement surface moves extremely fast relative to the CCD cameras. Similar to a photographic filming of any action, proper artificial illumination of the pavement surface is required. In the APSDS, four strobe lights provide a controlled illumination source for the acquisition of pavement images, as demonstrated in Figure 2. Those strobe lights are mounted behind the survey vehicle and used to illuminate a rectangle area of the highway pavement surface. The rectangle area is 3.75m transversely and 1m longitudinally. In order to minimize the disturb of day lighting variations, strobe intensity is set to about twenty times that of the direct sunlight, up to 2×10^6 lx. The high intensity can increase the contrast between the crack and pavement surface and also remove any unwanted shadowing, such as shadowing of trees, clouds and the survey vehicle itself that can occur when natural lighting is used. Another advantage of the high intensity is to increase the CCD cameras shutter speed and reduce motion blur.

2.2 Image Acquisition Module

The APSDS uses three CCD cameras to obtain the images of pavement surface. The cameras are mounted behind the survey vehicle directly above and orthogonal to the strobe illuminated pavement surface. They are mounted 2.4m above the pavement as shown in Figure 2. Each of the three CCD cameras is high resolution with 1280×1024 pixels and covers an area of 1.25m transversely and 1m longitudinally. Those cameras provide digital images at a

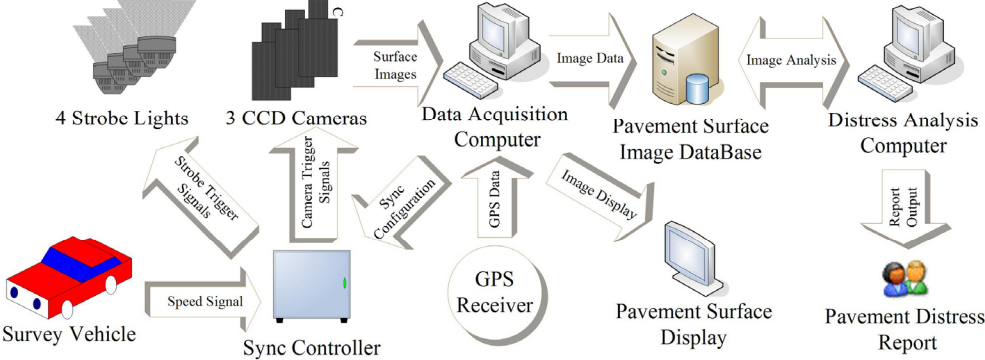


Figure 1: The Framework of the Automated Pavement Surface Distress Survey (APSDS) System

resolution of 1mm^2 of pavement surface per pixel. As demonstrated in Figure 2, the total covered areas of pavement surface is 3.75m transversely and 1m longitudinally. In other words, the width of the traffic lane is complete coverage.

To avoid disruption to traffic, the APSDS can carry out crack surveys at a nominal speed of 72km/h or 20m/s . In order to cover 100% of the pavement surface when surveying the highway pavement, three CCD cameras are triggered simultaneously every 1m of forward travel. Each camera can capture digital image of pavement surface with 20 frames per second. In order to capture clean images of pavement surface with camera, the exposure time should be as short as possible. However, the shorter exposure time requires higher illumination intensity to obtain the needed images. As the smallest crack under consideration is less than 1mm , the cameras or survey vehicle must not move 1mm distance during the exposure time to shoot one frame in order to avoid blurring of the image. Therefore, the available maximum exposure time per frame is calculated as $50\mu\text{s}$. The APSDS sets the high shutter speed of the cameras up to $1/100,000$ second, or $10\mu\text{s}$. Shutter speeds $10\mu\text{s}$ should be obtained providing 0.2mm of blurring at 72km/h . So there is no effect on image quality.

2.3 Sync Control Module

In the APSDS system, Sync Control Module has two tasks. One is to synchronize the strobe lights to the CCD cameras exposure window. The other is to dynamically adjust to acquisition rate of the cameras with the speed known and coverage fixed. Sync Controller monitors the variable speed signal of survey vehicle. Based on the known speed, Sync Controller generates both camera trigger signals and strobe trigger signals as survey vehicle travels a constant distance set by Data Computer. In order to release the most of strobe light in the exposure window of the CCD cameras, tight synchronization between the strobe lights and CCD cameras is required.

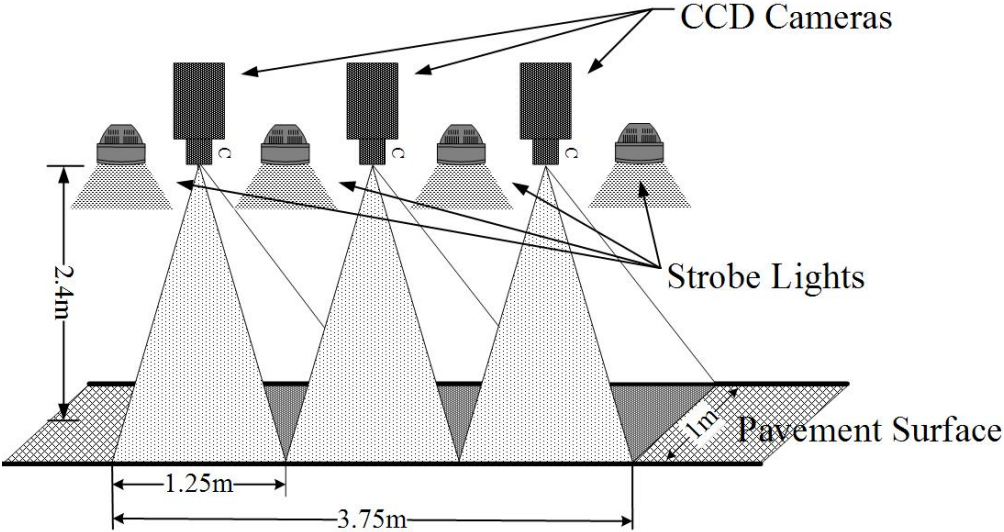


Figure 2: The three CCD cameras and four strobe lights geometry

2.4 Data Storage and Analysis Module

A dual-computer architecture is developed to store data and analyze pavement distress. As shown in Figure 1, two computers, called Data Acquisition Computer and Distress Analysis Computer respectively, are included in the dual-computer architecture. Data Acquisition Computer with a Pentium 4 processor at 2.4-GHz is used for data acquisition of pavement surface images from three CCD cameras. Data Acquisition Computer can also config the Sync Controller to decide the coverage rate of pavement surface. The image capture rate can be configed by the Data Acquisition Computer at maximum 20 frames per second.

A global spatial reference information is provided, which includes the distance traveled and the geographic coordinates in perfect registration with the surface distress data. A Global Positioning System (GPS) receiver card provides the geographic coordinates of the vehicle. The Data Acquisition Computer combines the images captured from three CCD cameras into one image and stores the image into Pavement Surface Image DataBase together with the location information. The image of pavement surface and the location information are presented on the screen in the survey vehicle.

The Distress Analysis Computer is a dual-CPU computer with two Pentium 4 processors at 2.4-GHz per CPU. The Distress Analysis Computer is used to analyze the distress of the pavement. The image of pavement surface stored in Pavement Surface Image DataBase is sent to the Distress Analysis Computer and the Distress Analysis Computer processes the image by using mathematical algorithms developed by Wang (Wang,2004). Image processing algorithms, implemented in Microsoft Visual C++, identify cracks in the mages stored on avement Surface Image DataBase and the analysis result is saved into Pavement Surface Image DataBase. The computer analyzes the data and checks the number of cracks, length, and existence of branches. The report summarises for every 100 metres of pavement surface and also includes the pavement location during image acquisition. The report is generated with the cracking type, cracking severity to the surveyor.

3. Discussion and Conclusion

Although the similar prototype systems have been designed by other researchers in recent years, the system in this paper shows new advantages over previous ones.

A. Superintensive artificial illumination. Some of others' systems applied natural light in there designs, but the shadows caused by natural light become troublesome in further processing. Meanwhile, the variations of natural light make it difficult to ensure the quality of pavement images. Other systems though applied artificial illumination, their purpose is to enhance the shadows formed in distress (Klassen,1993). This kind of artificial illumination is just several times that of direct sunlight. The intensity of artificial illumination in the author's system is up to 2×10^6 lx so that the intensity of natural light is less than 5% of that of artificial illumination to ensure the quality of the pavement images.

B. Flexible dual-computer structure. In order to increase the efficiency of image collection and image processing, some researchers proposed parallel processing and dual-CPU structure. In current systems, image collection is definite. In addition, the working

process is complex. In spite of the minor increase of the cost, the author's system adopts dual-computer structure. This structure makes it flexible to improve the algorithm and update the hardware and leaves other parts intact.

C. High resolution of image. As is well known that the higher resolution of pavement images is, the smaller cracks could be found. However, this causes some problems, such as the increase of storage capacity and processing time. According to Klassen (Klassen,1984), crack less than 1/8" (3.18mm) wide is evaluated as low severity levels. To take all into consideration, 1mm resolution is enough to meet the requirement of highway maintenance.

In this paper, a novel automated pavement surface distress survey (APSDS) system is presented. A prototype of the whole system has been built. The prototype has been tested in laboratory conditions and completed a survey of about 15,000km real road at normal running speed (72km/h) between the year of 2003 and 2004. Overall the performance of the system in this paper is already satisfactory for maintenance planning purposes. The current system still has some limitations. There remains work on increase of efficiency of image processing, as well as standardization of protocols for distresses.

REFERENCES

- Kelvin C.P. Wang, Member ASCE, 2000. *Designs and implementations of automated systems for pavement surface distress survey*, Journal of Infrastructure System, Vol .6, No. 1.,p:24-32.
- Guralnick, Sidney A. , Suen, Eric S. , Smith, Christian,1993. *Automating inspection of highway pavement surfaces*, Journal of Transportation Engineering, Vol.119, No.1,p:1-12.
- Toshihiko Fukuhara, Leiji Terada, Makoto Nagao, Atsushi Kasahara, and Shigeki Ichihashi. ,1990. *Automatic pavement-distress-survey system*, Journal of Transportation Engineering, Vol.116, No.3,p:280-286.
- Wang Hua,2004. *A study on detection of pavement cracks based on fractal theory*, Ph.D. Dissertation, Harbin Institute of Technology, (in Chinese).
- Klassen Gary, Swindall Bill,1993. *Automated crack detection system implementation in ARAN*, Proc Conf Digital Image Process Tech Appl Civ Eng,p:179-185.
- Bandyopadhyay, Sudipta S. ,1984.*Pavement distress identification and condition evaluation*. Civil Engineering for Practicing and Design Engineers, Vol. 3, No.1,p:19-44.