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Strategies for autonomous robots to inspect pavement distresses

Yuan-Hsu Tseng [a], Shih-Chung Kang [a,*], Jia-Ruey Chang [b], Cheng-Hao Lee [a]

[a] Dept. of Civil Engineering, National Taiwan University, Taipei City 10617, Taiwan
[b] Dept. of Civil Engineering and Environmental Informatics, Dept. of Leisure Management, Minghsin University of Science and Technology, Hsinchu City 30401, Taiwan

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ABSTRACT

The distress survey is an important task for pavement maintenance and rehabilitation (M&R) activities. As distress surveys require tremendous human resources, many investigators have begun to develop automatic inspection methods with the aim of increasing the efficiency and accuracy of inspections. After assessment of distress surveys on pavements using an autonomous robot (P3-AT), this research aims at developing motion strategies for executing distress surveys using robots under project-level practices. Three motion strategies were specifically developed: (1) Strategy I: random survey (R); (2) Strategy II: random survey with map recording (R + M); (3) Strategy III: random survey with map recording and vision guidance (R + M + V). To validate these three strategies, we developed a test field in a virtual environment. The test field included five distress types, including an alligator crack, a small patching, a pothole, a rectangular manhole and a circular manhole. We also developed a virtual robot to navigate the test field autonomously. The three survey strategies were then implemented by the virtual robot and their performances were compared with the current traffic-directional survey strategy.

1. Introduction

The distress survey is an important task in pavement maintenance and rehabilitation (M&R) activities [1]. Currently, pavement distresses are detected and recorded by manual inspection [2]. Previously, engineers have had to manually observe and record pavement distresses on paper, which is difficult to store and analyze. In recent years, engineers have used various instruments, such as PDAs (Personal Digital Assistants) with GPS (Global Positioning System), to record, digitalize, and localize pavement distresses. Nowadays, pavement engineers evaluate the type, coverage and severity of pavement distresses and then calculate Pavement Condition Index (PCI) following the ASTM specification to indicate the condition of a roadway [3]. The manual inspection approach, however, is still very costly, time-consuming and labor-intensive, and is often unable to be accepted in accordance with the current regulations and best practices.

To accelerate the distress survey process, previous researches in the past 30 years have developed automated inspection equipment [4–11]. During the 1970s, PASCO [12] started developing the first inspection vehicle possessing a distress survey function. Fugro Roadware, a Canada-based company, then developed Automatic Road Analyzer (ARAN). This inspection vehicle was equipped with a panoramic camera to collect pavement images and used the image processing software WiseCrax® [13] to detect cracks automatically in post-processing. Another inspection vehicle, Digital Highway Data Vehicle (DHDV) developed by WayLink Systems Corporation in the U.S., integrated a laser-scanner and was able to detect cracks in real time by processing the data collected from the laser scanners. A self-developed software tool, Automated Distress Analyzer (ADA), was developed to automate the entire process. Mandli's Pavement System [14] used a downward line scan camera to collect pavement data and used the customized software, Roadview Automated Distress Rating Software, to detect pavement distresses automatically. Apart from the industrial solutions, many academic researchers also developed inspection equipment by integrating sensors and software to achieve the goal of automatic distress surveys [15–18].

In view of pavement management practices [19], although the inspection vehicles significantly enhance the efficiency of distress surveys, they can only be used for surveying in network-level inspection (such as large areas and long-distances). In many project-level inspections (small areas, short-distances) such as QC/QA tests for manhole excavation and recovery, the vehicles are not applicable because of the expense and time limitations. Furthermore, in some cases, the vehicles cannot reach the survey area because of licenses or its big volume. To inspect in those cases, previous researchers have developed an autonomous robot for inspection [20]. Robots have greater mobility, are more convenient and have the ability to reduce the labor required, making them very suitable for small surveying tasks. Robots are autonomous, which means that they can operate without human control to conduct distress surveys. They can greatly reduce labor costs in inspection process, especially for routine distress surveys of specific areas. Moreover, robots also have

* Corresponding author.
E-mail addresses: windanthem@caece.net (Y.-H. Tseng), sckang@ntu.edu.tw (S.-C. Kang), jrchang@must.edu.tw (J.-R. Chang), piggyhoward@caece.net (C.-H. Lee).

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