University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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M.Tech (Nirma University, 2015)
B.Tech (Nirma University, 2013)

"Surface and Subsurface Damage Quantification using Multi-Device Robotics-based Sensor System and other Non-Destructive Testing Techniques"

Department of Civil Engineering

Friday September 6, 2019
10:00 A.M.
Engineering Computer Science Building
Room 468

Supervisory Committee:
Dr. Rishi Gupta, Department of Civil Engineering, University of Victoria (Supervisor)
Dr. Cristina Zanotti, Department of Civil Engineering, UVic (Member)
Dr. Caterina Valeo, Department of Mechanical Engineering, UVic (Outside Member)

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Dr. Danu Stinson, Department of Psychology, UVic

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Abstract

Aging infrastructure such as bridges, water mains, roads, dams, electrical transmission lines, etc. is at a major risk in terms of potential failure for any country around the world. 33% of the Canadian municipal infrastructure and the entire American infrastructure have been given a D+ condition rating by the Canadian municipalities and the American society of civil engineers. This includes some of the structural elements of infrastructures that pose a significant risk. In the U.S., almost 4 in 10 bridges are 50 years or older. Hence, there is an urgent need for frequent and effective inspection to ensure the safety of people. Visual inspection is a commonly used technique to detect and identify surface defects in bridge structures as it has been considered the most feasible method for decades. However, this currently used methodology is inadequate and unreliable as it is highly dependent on subjective human judgment. This labor-intensive approach for inspection requires huge investment in terms of an arrangement of temporary scaffoldings/permanent platforms, ladders, snooper trucks, and sometimes helicopters. This approach typically warrants traffic closures and hence becomes time-consuming and managerial intensive. Owing to these issues, infrastructure owners pay a very high price and spend hours inspecting structures. To address these issues associated with visual inspection, the completed research suggests three innovative methods; 1) Combined use of Fuzzy logic and Image Processing Algorithm to quantify surface defects, 2) Unmanned Aerial Vehicle (UAV)-assisted American Association of State Highway and Transportation Officials (AASHTO) guideline-based damage assessment technique, and 3) Multi-device robotics-based sensor data acquisition system for mapping and assessing defects in civil structures. In the first method, fuzzy logic-based decision-making tool along with the image processing algorithm is developed. Using this tool, damage indices for civil structural elements can be determined. In the second method, to expedite the visual condition assessment procedure, a UAV-assisted AASHTO guideline-based condition rating system is suggested. It utilizes a combination of a UAV system, an image processing tool, and a bridge element inspection guideline

published by AASHTO to inspect bridges. In the third newly invented patentpending method, a combination of multiple sensors is proposed to be integrated into a UAV system. These sensors include two optical cameras, an infrared camera, an acoustic assembly, and two laser sensors. The sensors are integrated such that the data collected could be overlaid to detect and quantify damage more accurately and reliably. To detect and quantify subsurface defects such as voids and delamination using a UAV system, another patent-pending UAV-based acoustic method is developed. It is a novel inspection apparatus that comprises of an acoustic signal generator coupled to a UAV. The acoustic signal generator includes a hammer to produce an acoustic signal in a structure using a UAV. An outcome of this innovative research is the development of a model to refine multiple commercially available NDT techniques' data to detect and quantify subsurface defects. To achieve this, a total of nine 1800 mm × 460 mm reinforced concrete slabs with varying thicknesses of 100 mm, 150 mm and 200 mm are prepared. These slabs are designed to have artificially simulated defects like voids, debonding, honeycombing, and corrosion. To determine the performance of five NDT techniques, more than 300 data points are considered for each test. The experimental research shows that utilizing multiple techniques on a single structure to evaluate the defects, significantly lowers error and increases accuracy compared to that from a standalone test. To visualize the NDT data, two-dimensional NDT data maps are developed. This work presents an innovative method to interpret NDT data correctly as it compares the individual data points of slabs with no defects to slabs with simulated damage. For the refinement of NDT data, significance factor and logical sequential determination factor are proposed.