Research Problem Statement

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I. TITLE

[Provide a unique title that represents the research idea]

17-006 Estimation of tension forces in bridge cables and ropes using digital videos

II. PROBLEM

Federal law requires that States inspect every bridge (with a span larger than 20 ft) every two years. ODOT inspects bridges throughout the State, including those owned by the City of Portland and Multnomah County. Some of these bridges have lifting mechanisms that rely on cables or directly utilize suspension cables or stays to carry load. A question that often arises is what the tension forces in cables and ropes are for these bridges. While there is no direct way to measure the in-situ force in a cable, vibrations can be used to estimate the tension cable force (Graff 1991, Zui, Shinke et al. 1996). In order to do so, measurements have to be performed on each cable. Using conventional methods such as accelerometers along with portable data acquisition systems is time-consuming and labor intensive, resulting in less frequent or less comprehensive inspections. Furthermore, only one measurement per physical sensor can be collected.

The goal of this research is to evaluate the use of digital videos to capture the vibrations along the length of the cable without the need to physically attach a target or an instrument anywhere on the bridge. The proposed method could monitor a number of cables simultaneously with the possibility to take videos from unmanned air vehicles (UAV) will also be explored.

III. PROPOSED RESEARCH, DEVELOPMENT, OR TECHNICAL TRANSFER ACTIVITY

The research involves both theoretical and experimental work. The fundamental concept to monitor vibrating structures using Eulerian-based virtual visual sensors (VVS) from digital videos has been established by the PIs (Schumacher and Shariati 2013; Shariati and Schumacher 2015; Shariati and Schumacher 2015) but has not yet been evaluated for cables and ropes. One major objective is to evaluate this approach to capture a significant number of modes of a vibrating rope or cable. Different commercially-available cameras will be tested and compared. In order to determine the effect of boundary conditions on the vibrations and the associated tension forces, a set of laboratory experiments will be performed. These will serve to determine the uncertainly and noise in the measurement and the effect on the estimated tension forces. Following the laboratory development, field experiments will be conducted with the possibility of incorporating the digital camera with an unmanned aerial vehicle (UAV).

For all research activities, we will collaborate closely with ODOT personnel to make sure the product is of practical relevance and knowledge gained is transferred effectively.

IV. POTENTIAL BENEFITS

The research has the potential to change how tension forces in cables and ropes are currently estimated. Not only should the solution allow for much simpler and cost effective data collection, it will also be possible to capture the entire cable or significant portions of it. Additionally, multiple ropes can be captured in one video

session. This may allow for checking every cable during every inspection, and not just a few randomly selected cables as is currently done. Another benefit of a video-based approach is that one can select the measurement point after the data has been collected, which increases the chances to capture vibration points of interest. Finally, the possibility of taking videos from mid-air would make inspections safer for personnel and allow taking measurements without any traffic restrictions on the bridge. To conclude, the research has the potential to not only save cost, but also increase inspection fidelity while increasing the safety of bridge inspections.

V. IMPLEMENTATION

The final research product will consist of (1) guidelines on how to collect data, process and interpret them, and (2) a computer code that allows to perform these analyses.

VI. LIST OF REFERENCES *(optional)*

Graff, K. F. (1991). Wave Motion in Elastic Solids. New York, NY, Dover Publications, Inc.

Kim, S.-W., B.-G. Jeon, et al. (2013). "Vision-based monitoring system for evaluating cable tensile forces on a cable-stayed bridge." Structural Health Monitoring **12**(5-6): 440-456.

Schumacher, T. and A. Shariati (2013). "Monitoring of Structures and Mechanical Systems Using Virtual Visual Sensors for Video Analysis: Fundamental Concept and Proof of Feasibility." Sensors **13**(12): 16551-16564.

Shariati, A. and T. Schumacher (2015). "Eulerian-based virtual visual sensors to detect natural frequencies of structures." Journal of Civil Structural Health Monitoring **5**(4): 457-468.

Shariati, A. and T. Schumacher (2015). Oversampling in virtual visual sensors as a means to recover higher modes of vibration. Review of Progress in Quantitative Nondestructive Evaluation (QNDE). Boise, ID. **34:** 1717-1724.

Zui, H., T. Shinke, et al. (1996). "Practical Formulas for Estimation of Cable Tension by Vibration Method." ASCE Journal of Structural Engineering **122**(6): 651-656.

VII. CONTACT INFORMATION

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