Oregon Department of Transportation

Stage 1 Research Problem Statement

Number*: 25-88*

Proposed Title: Structural Health Monitoring and Repair Planning Through Motion Simulation and Imaging

1. Concisely describe the **transportation issue** (including problems, improvements, or untested solutions) that Oregon needs to research.

Historical structures, such as bridges along the Oregon coast, are experiencing increased effects due to climate change in addition to normal wear. Visible material loss and wear from unexpected motion are becoming more pronounced. With modern imaging technology that uses robot cameras and unmanned aerial devices, it has become feasible to access hard-to-see areas on these structures and has broadened the scope of structural health monitoring. However, imaging mainly shows the consequences of the wear and seldom reveals the causes; e.g., a crack can be captured in a camera image, but how the crack is created remains unknown. Filling the crack is a repair approach but it can at the same time jeopardize the overall health of the structure. Numerical modeling of the structures under various loading conditions can reveal weak regions in the 3D geometry. Comprehensive monitoring and repair planning can benefit from combing motion simulation and sensor measurement.

2. Document how this **transportation issue** is important to Oregon and will meet the [Oregon Research Advisory Committee Priorities]

Our goal is to avoid unexpected structural failures. Systematic monitoring can provide data for abnormal wear. ODOT has invested in unmanned aerial devices and LiDar technology to digitize some bridges and large structures of interest. These existing sensor measurements have also shown cracks and shifted pieces. In addition, the spatial data captured can be used along with solid mechanics modeling of these structures to comprehensively describe the use of these structures. The modeling can show the structures under loading and how some regions may tend to buckle or shear apart. Identifying weak regions and planning out long-term maintenance can be achieved by complementing field measurements and inspections with simulated motions.

Long-span and large structures are unique in their design and use. They pose many challenges to health monitoring and repair planning. Due to repeated use, change to the bases, ground tremor and climate change, these large structures are experiencing loading boundary conditions that need to be further analyzed. Computational modeling can be developed to produce simulated motions under different boundary conditions. After these simulations are corroborated with image sensor measurements, the knowledge learned from both simulation and measurement methods can help identifying and understanding the causes of the wear by viewing how the 3D structures move. With this understanding, repair planning can be more thorough in terms of regular maintenance specifications, seasonal reinforcement procedures or surgical repair tasks.

3. What **final product or information** needs to be produced to enable this research to be implemented?

The final product is a dictionary of causes for weak regions in a structure of interest to ODOT. This dictionary will contain texts, photo images, simulation results and visual analytics. Computational modeling can be complex and involves technical jargons. This project will have three stages that are aimed to demonstrate, validate and develop.

The demonstration stage is to present simulation results on elemental 3D structures to show the functionalities of the simulations and visual analytics of the calculated variables. Frequent meetings with research analysts and/or field engineers will be done so that the results are visualized and explained.

The validation stage is to focus on modeling a real-life structure with a reputable commercial package. Existing sensor measurements will be included in the validation of the simulations. The accuracy of the simulations heavily depends on the modeling of the materials used, the current geometries and the real-life boundary conditions. These parameters are sometimes not readily available. To compensate for the potential missing information, many scenarios will be created so that the contrast between the worst and the best possible options will be shown, e.g., steel materials with a range of strength from weak to strong will be simulated. Furthermore, as these models compute multivariate data, e.g. shear and normal stress are individual components of the stress and each has three directions in 3D, we will conduct comprehensive analysis and visualization to make the results interpretable to the analysts and engineers at ODOT.

The development stage is to develop a segmentation scheme for the structure in terms of load distribution, a ranking of the regions in terms of load bearing and a dictionary of text descriptions, frames of simulations and visual analytics for the use scenarios investigated. This dictionary will contain information that leads to possible causes of the wear and that aids the repair planning.

Lastly, the simulation results will be thoroughly documented for ODOT. Visual analytics will be customized so that the multivariate variables are studied correctly. All the models, data and software tools created will be delivered to ODOT.

4. (Optional) Are there any individuals in Oregon who will be instrumental to the success of implementing any solution that is identified by this research? If so, please list them below.

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Kira M. Glover-Cutter	Research Analyst and Coordinator	kira.m.glover-cutter@odot.oregon.gov	971-701-0051

5. Other comments:
NA

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