

SPR RESEARCH PROGRAM

SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE

27-38: Modernizing Tunnel Inspection with Reality Capture Data

PROBLEM SUMMARY

There is no established standard for consistently determining overall tunnel conditions. ODOT has had success with UAS (unmanned aircraft system) for bridge inspections, utilizing raw video and infra-red imagery to assist inspectors. Currently ODOT inspects in-person and determines overall tunnel conditions qualitatively (good, fair, or poor), aggregating element condition information as a workaround. A routine inspection procedure typically requires lane closure for hours, sometimes taking several nights for a thorough and detailed inspection. And yet, the assessment and reporting procedures can still be inconsistent due to subjective judgement, large workload, and hand drawing. The lack of consistent and precise reference also makes it difficult to conduct any comparative assessment between different epochs. While leveraging lidar, photogrammetry, and other reality capture techniques can potentially improve the consistency, accuracy, and efficiency in tunnel inspection, new methodologies are needed to overcome challenges for georeferencing in GNSS-denied areas (e.g., tunnels), as well as make the reality capture data (e.g., georeferenced images and 3D point clouds) workable for inspectors. Modernized inspection will help ODOT become more effective and efficient in maintaining tunnels managed across the state.

ODOT OBJECTIVES

To improve the consistency of current tunnel inspection, the following key objectives need to be achieved:

- Establish a detailed baseline database for the tunnels that ODOT maintains. This baseline database will serve as a reference for future data processing and analysis.
- Develop a workflow to constrain ODOT's mobile lidar data collection in GNSS-denied areas.
- Develop an automated methodology along with prototype tools for reality capture-based tunnel inspection. The prototype tools implementing the proposed methodology will aid ODOT's current practice in tunnel inspection.

BENEFITS

Benefits of remote sensing techniques for tunnel inspection include reduced field time for inspectors in a hazardous work zone and reduced need for traffic control which has cost benefits. Most importantly, improved consistency between tunnel inspections through improved mapping will provide more informed decision making when it comes to keeping the tunnels functional and safe while reducing the cost. Note that the methodology developed in this work could also be extended to monitoring wildlife tunnels.

SCHEDULE, BUDGET AND AGENCY SUPPORT

Estimated Project Length: 42 months

Estimated Project Budget: \$498,000

ODOT Support: Susan Ortiz (State Geotechnical Engineer), Mike Nichols (State Surveyor).

FOR MORE INFORMATION

For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at:

<https://www.oregon.gov/odot/Programs/ResearchDocuments/27-38.pdf>

SPR RESEARCH PROGRAM

SECOND-STAGE PROBLEM STATEMENT

FY 2027

PROBLEM NUMBER AND TITLE

27-38: Modernizing Tunnel Inspection with Reality Capture Data

RESEARCH PROBLEM STATEMENT

There is no established standard for consistently determining overall tunnel conditions. ODOT has had success with UAS (unmanned aircraft system) for bridge inspections, utilizing raw video and infra-red imagery to assist inspectors. Currently ODOT inspects in-person and determines overall tunnel conditions qualitatively (good, fair, or poor), aggregating element condition information as a workaround. A routine inspection procedure typically requires lane closure for hours, sometimes taking several nights for a thorough and detailed inspection (Figure 1). And yet, the assessment and reporting procedures can still be inconsistent due to subjective judgement, large workload, and hand drawing. The lack of consistent and precise reference also makes it difficult to conduct any comparative assessment between different epochs. While leveraging lidar, photogrammetry, and other reality capture techniques can potentially improve the consistency, accuracy, and efficiency in tunnel inspection, new methodologies need to be developed to overcome challenges for georeferencing in GNSS-denied areas (e.g., tunnels), as well as make the reality capture data (e.g., georeferenced images and 3D point clouds) workable for tunnel inspectors. Such modernized tunnel inspection will also help ODOT become more effective and efficient in maintaining tunnels managed across the state.

RESEARCH OBJECTIVES

To improve the consistency of ODOT's current practice in tunnel inspection, the following key objectives need to be achieved:

- Establish a detailed baseline database for the tunnels that ODOT maintains. This baseline database will serve as a reference for future data processing and analysis. The data will include not only the interior of a tunnel, but also the surrounding areas such that the final



Figure 1: Arch Cape tunnel inspection, both lanes closed



Figure 2: Note the erosion impacts (red) and landslide (yellow) presenting instability risks for the Arch Cape tunnel.

data package is able to support more comprehensive analysis, which is especially valuable for tunnels that are subject to landslide, coastal erosion, and other geohazards (ex. Arch Cape, Figure 2).

- Develop a workflow to constrain ODOT's mobile lidar data collection in GNSS-denied areas. ODOT collects mobile lidar data on regular basis, which provides great recurring detailed 3D coverage of the tunnels to be inspected. However, because a mobile lidar system is heavily reliant on accurate GNSS positioning, the GNSS-denied areas such as tunnels can be challenging to capture with the desired precision and accuracy. Thus, a new workflow needs to be developed to further constrain the mobile lidar data to align with the baseline database.
- Develop an automated methodology along with prototype tools for reality capture-based tunnel inspection. While 3D point clouds from reality capture technologies are powerful and can provide rich information, extensive training on both fundamental knowledge of geomatics and specialized software is often required. To break down this barrier for tunnel inspectors, a methodology needs to be developed to convert 3D reality capture data into a format that is easier for tunnel inspectors to utilize. Automated feature extraction will also help highlight certain features or damages to further improve the efficiency of tunnel inspection. The prototype tools implementing the proposed methodology will aid ODOT's current practice in tunnel inspection.

WORK TASKS, COST ESTIMATE AND DURATION

Task 1. Literature review: This task will result in a comprehensive literature review on topics such as current practice of tunnel inspection, examples of using remote sensing techniques to acquire data from tunnels, methodologies for feature extraction and modeling from reality capture data. This literature review can be conducted starting with the literature review published by the OSU Geomatics research team (Che, E., Jung, J., & Olsen, M. J. (2019). Object recognition, segmentation, and classification of mobile laser scanning point clouds: A state-of-the-art review. *Sensors*, 19(4), 810.) where it summarized the state of the art in using mobile lidar data for tunnel maintenance and monitoring.

Task 2. Research baseline tunnel database: The research team will work with ODOT personnel to gather existing datasets and collect detailed reality capture data at selected locations. Non-invasive targets or markers will be considered to help establish survey control to ensure more rigorous georeferencing process and QA/QC.

Task 3. Methodology to aid tunnel inspection: The research team will develop the methodology to convert the reality capture data (e.g., point cloud or mesh) into better format to aid tunnel inspection procedures. During this process, certain feature extraction and visualization enhancement will be considered to improve the workability of the data.

Task 4. Workflow for improving mobile lidar data quality: A new workflow will be developed and tested to demonstrate the feasibility of improving mobile lidar data quality in GNSS-denied areas such as tunnels.

Task 5. Case study for modernized tunnel inspection: The research team will work with ODOT tunnel inspectors to analyze selected tunnels using the proposed methodology and test its effectiveness to pave the way for future implementation.

Task 6. Workshop for tunnel inspectors: A workshop will be hosted for ODOT tunnel inspectors to cover the key findings of this research as well as fundamentals of reality capture to stay informed on the latest technological development.

Task 7. Reporting: A final report will be compiled to document the project in detail.

Key Deliverables: *Baseline tunnel database, tunnel inspection methodology with user-friendly data extraction, mobile lidar method update, case study results, workshop, final report.*

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Estimated Project Budget: \$498,000

EXPECTED ODOT IMPLEMENTATION ACTIONS

If successful the Engineering Automation section will work with Bridge Inspection and Geotechnical Engineering, Geology, and Hazmat Section to develop implementation plans. The Research team may serve an advisory role in plan development if needed.

POTENTIAL BENEFITS

Benefits of remote sensing techniques for tunnel inspection include reduced field time for inspectors in a hazardous work zone and reduced need for traffic control which has cost benefits. Most importantly, improved consistency between tunnel inspections through improved mapping will provide more informed decision making when it comes to keeping the tunnels functional and safe while reducing the cost. Note that the methodology developed in this work could also be extended to monitoring the conditions of underpass wildlife tunnels.

PEOPLE

ODOT champion(s): Susan Ortiz (State Geotechnical Engineer), Mike Nichols (State Surveyor)

Problem Statement Contributors: Ezra Che (OSU), Brian McNamara (Engineering Geologist, Rockfall and Landslides), Mike Goff (Senior Bridge Inspector), Mike Dyra (Region Bridge Inspector), Kira Glover-Cutter (Principal Research Analyst), Jon Lazarus (Research Coordinator)

STAFF REVIEW PAGE

LITERATURE CHECK

TRID&RIP

A review of TRID & RIP databases found no existing research that answers the research question

ODOT DECISION LENSES

Climate:

- *5d: Tunnels themselves are designed and built to provide a more direct and faster route that will reduce mileage and emission. Additionally, one potential outcome of this proposed research is to reduce the time that inspectors need to spend in the field while closing lanes or shutting down the entire tunnel, which will reduce detour or idling when tunnel inspections take place.*
- *5e: Some of the tunnels that this proposed research will focus on are subject to frequent climate events and ongoing natural hazards. For example, the tunnel at Arch Cape is impacted by both coastal erosion and landslide, as well as other climate events such as sea-level change.*
- *The methodology developed in this work can be extended to monitoring the conditions of underpass wildlife tunnels.*

Equity:

- *Although equity is not the primary focus of this proposed research, keeping tunnels safe and sound while minimizing the disruption of traffic due to inspection work can maximize their functionality in the transportation systems to advance equity for all.*

Safety:

- *Leveraging remote sensing techniques can potentially reduce the time that tunnel inspectors have to spend in the work zone, which in turn can improve the safety for transportation workers.*
- *The mobile lidar system that ODOT operates is a state-of-the-art remote sensing system. Leveraging such systems can significantly reduce the need for traffic control and work on the roadside and hence improve safety for transportation workers and users.*
- *More consistent tunnel inspection procedures and reporting can result in more informed decision making when it comes to keeping the tunnels functional and safe while reducing the cost.*

TECHNOLOGY & DATA ASSESSMENT

No Identified T&D output

At the end of this project, the implementing unit(s) within ODOT will need to coordinate the adoption of new technology or data in order to realize the full potential of this research.

CROSS-AGENCY IMPACTS

- List ODOT partners or impacted units. Geo, Bridge Inspection Program, Engineering Automation
- Identify any issues of concern raised by an ODOT partners. Note expected mitigation that addresses these concerns.