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**Transportation Infrastructure Precast Innovation Center**

**(TRANS-IPIC)**

**University Transportation Center (UTC)**

Continuous & Low-cost Inspection of Precast Concrete Bridges using Connected Automated Vehicles (CAVs)

UB-24-RP-01

Quarterly Progress Report

For the performance period ending 03/31/2025

**Submitted by:**

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**Collaborators / Partners:**

None

**Submitted to:**

TRANS-IPIC UTC

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**TRANS-IPIC Quarterly Progress Report (Section 1 – 7, 5 pages max.):**

**Project Description:**

1. Research Plan - Statement of Problem

This project aims to develop a continuous, low-cost data collection system for bridges with precast components prone to reflective cracking. Early damage detection is crucial for durability, but existing inspection methods are costly, especially when performed continuously. Leveraging existing vehicles on the roads, we propose using vehicle-to-everything (V2X) technologies, where bridges request connected vehicles with standard forward-facing cameras to inspect critical areas. Connected automated vehicles (CAVs) will execute cooperative motion to maximize inspection efficiency. Aggregated data from continuous traffic and inspection results will detect early signs of damage, enabling proactive maintenance. To deliver such a system, a couple of problems need to be tackled: 1) how to design a robust crack-detection algorithm that can work with standard forward-facing cameras with limited focus on the road surface; 2) how to effectively communicate detection requests and results using CV2X communication; 3) how to coordinate the motion of the CAVs to maximize the detection results.

1. Research Plan - Summary of Project Activities (Tasks)

This project has two main objectives with six sub-tasks.

Objective 1: Develop a cooperative inspection system of road surface cracking between infrastructure and CAVs on the test track on the UB campus.

Task 1.1: Develop a vision-based road cracking inspection algorithm using a vehicle forward-facing camera.

Task 1.2: Update the V2X protocol to enable information sharing between vehicles and infrastructure

Task 1.3: Design cooperative vehicle motion planning control algorithms with V2X information to maximize crack inspection efficiency

Objective 2: Implement and demonstrate the developed cooperative inspection system on a precast concrete bridge in NYS

Task 2.1: Identify ideal precast concrete bridge sites in NYS near the UB Campus

Task 2.2: Deploy and fine-tune the cooperative inspection system at the identified sites

Task 2.3: Deliver a demonstration of the developed system at a pilot site

**Project Progress:**

1. Progress for each research task

Objective 1 [40% completed]:

Task 1.1 [40%] This quarter, the research team started developing vision-based road cracking inspection algorithms. Specifically, the team started calibrating two state-of-the-art concrete crack detection models, DeepCrack [1] and LECSFormer [2], to work with a vehicle's forward-facing camera. The team conducted a preliminary performance analysis and identified some limitations.

Task 1.2 [20% completed] This quarter, the research have started quantifying the bandwidth available from CV2X SAE J2735 standard and customized messages. A couple of candidate messages to be repurposed are Roadside Safety Messages and Probe Vehicle Data, which are being analyzed and tested.

Task 1.3 [40% completed] This quarter, the research team has also started implementing the CV2X-based vehicle motion control on the Lincoln Connected Automated Vehicle Platform at UB [3].

Objective 2 [10% completed]

Task 2.1 [80% completed] with the help from the NYS DOT team. We have identified a few precast bridge candidates near the UB campus. We have acquired historical inspection results, paid an on-site visit to inspect the site, collected initial road surface image data, and evaluated the feasibility for demonstration.

Task 2.2 [0% completed] (Not started)

Task 2.3 [0% completed] (Not started)

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1. Percent of research projects completed

25% of the total project completed through the end of this quarter

1. Expected progress for next quarter

In the next quarter, the research team will continue working towards achieving the first objective. We will collect more data, improve the model design, optimize the inference pipeline (Task 1.1), and keep optimizing it together with CV2X message customization that supports detection results transmission (Task 1.2). We also seek to finalize the vehicle control implementation (Task 1.3). We are also expected to finalize the precast bridge candidates with NYS DOT.

1. Educational outreach and workforce development

The research team actively participated in all TRANS-IPIC Monthly Webinars. The team also plans to present their preliminary research findings at the TRANS-IPIC workshop on April 22-23, 2025.

1. Technology Transfer

None

**Research Contribution:**

1. Papers that include TRANS-IPIC UTC in the acknowledgments section:

None

1. Presentations and Posters of TRANS-IPIC funded research:

The research team plans to present their preliminary findings at the TRANS-IPIC workshop on April 22-23, 2025.

1. Please list any other events or activities that highlight the work of TRANS-IPIC occurring at your university (please include any pictures or figures you may have). Similarly, please list any references to TRANS-IPIC in the news or interviews from your research.

None

**Appendix 1**: Research Activities, leadership, and awards (cumulative, since the start of the project)

1. Number of transportation related classes developed or modified as a result of TRANS-IPIC funding.

* No. Graduate = 1: MAE 502 Vehicle Control Systems.

**References:**

[1] Liu, Y., et al. "DeepCrack: A deep hierarchical feature learning architecture for crack segmentation," in Neurocomputing, vol. 338, pp. 139–153, 2019, doi: 10.1016/j.neucom.2019.01.036

[2] J. Chen, N. Zhao, R. Zhang, L. Chen, K. Huang and Z. Qiu, "Refined Crack Detection via LECSFormer for Autonomous Road Inspection Vehicles," in IEEE Transactions on Intelligent Vehicles, vol. 8, no. 3, pp. 2049-2061, March 2023, doi: 10.1109/TIV.2022.3204583.

[3] S. Beregi, S. S. Avedisov, C. R. He, D. Takács, and G. Orosz. Connectivity-based delay-tolerant control of automated vehicles: theory and experiments. IEEE Transactions on Intelligent Vehicles, 8(1): 275-289, 2023