# Research Project Highlight

# Autonomous Drone or Inspection-driven Exploration of Structures

*TSRP Topic:M6 - Instrumentation, data collection, use of AI and ML*

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**Start-End Dates:**
8/1/2021-8/1/2022

**Abstract**
The transportation network, particularly bridges, needs an inspection and damage assessment technology able to function at scale. Unlike fixed cameras, the mobility of drones makes them the ideal platform to perform inspection tasks at large scale. To improve the efficiency of inspection and reduce the complexity of manual input, the drones should be able to perform the inspection tasks autonomously. This will also allow the deployment of drone swarms to the field. To this end, a drone inspection system will be developed to be used in the immediate aftermath of an earthquake. The swarm will be built to face a structure of unknown shape and be able to learn its new shape and damage by exploration. It will explore and reconstruct a three-dimensional (3D) model of a given area, and detect and label its damage autonomously. We combine a deep learning (DL) model and the photogrammetric technique to overcome the limitations of 2D object detection and annotate the damage in the 3D reconstruction of the bridge (Figure 1).

To validate the drone inspection system at scale prior to an actual field test, AirSim, an open-source simulator built in Unreal Engine, will be used to test and verify the algorithms. Unreal Engine is a sophisticated game engine with powerful visual rendering capability used to simulate the real-world environment. This enables the implementation of image processing in the simulation, which is one of the core elements in the autonomous drone inspection system. The inspected structure is the Jefferson City Community Church, which was damaged during a tornado (Figures 2 and 3). A monocular visual simultaneous localization and mapping (vSLAM) algorithm will be implemented for the drone to localize itself in real-time and map the environment. A DL model will be embedded for the drone to

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detect the structure damages. Once the damage is detected, an online path planner will plan a safe path for the drone to fly closer to capture high-resolution images. This system is expected to provide insight into how autonomous robotics can benefit the civil engineering community.

**Deliverables**

A PEER report and one conference or journal paper describing the autonomous drone system and simulation environment; Imaging, lidar, and IMU data collected by drone from the structures being inspected; An autonomous inspection-driven drone-based system for exploring the structure with open-source code.

**Research Impact**

Transportation infrastructure constitutes vital links in modern society. Therefore, rapid post-disaster response is essential for community and regional resilience. This project aims to develop a rapid drone-based sensing and computing system that incorporates cognitive remote sensing, autonomous 3D-mapping and damage inspection, path planning, data-driven integrated damage assessment from first-principles. The platform will explore the environment with the purpose of finding the damage and collecting high-quality images, which enhances worker safety and improves post-earthquake safety inspection efficiency. The scientific and technological innovation from this project takes us a step closer to the life-cycle digital twin desired for civil structures. The research team aims to build a prototype platform validated in simulation for practical use. If successful, the prototype system can be adapted for use in many other transportation structures and critical infrastructure systems, and be usable for urban-scale post-disaster reconnaissance, thereby facilitating community resilience at a larger scale.

**Project Images**

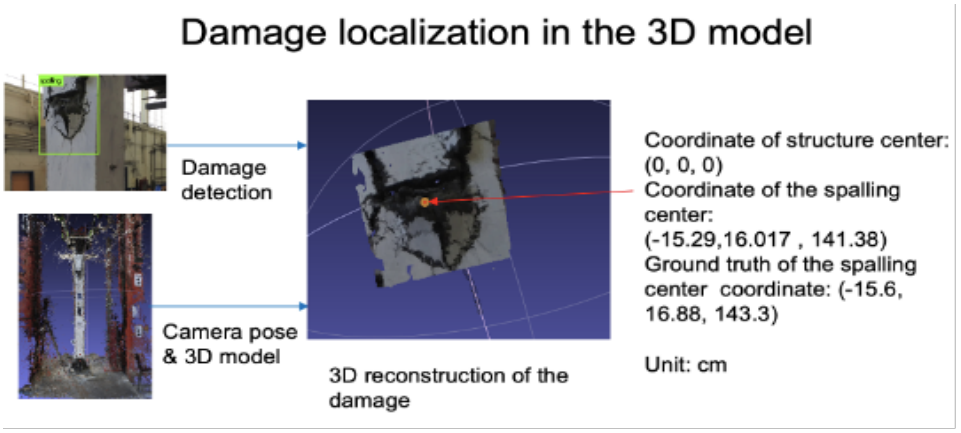


Figure 1. Damage localization in 3D model



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Figure 2. The Jefferson City Community Church after tornado, photo by DJI Mavics

Figure 3. The 3D reconstruction model of Jefferson City Community Church



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