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Research Notes

Geotechnical/ Structures

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Project Title: Human-centered Steel Bridge Inspection enabled by Augmented Reality and Artificial Intelligence

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Human-centered Steel Bridge Inspection enabled by Augmented Reality and Artificial Intelligence

AR-based bridge inspection tool that leverages Computer Vision (CV) and AI to support field detection, quantification, and documentation of various damage and deterioration for steel bridges.

WHAT IS THE NEED?

Fatigue cracks developed under repetitive traffic loads are a major threat to the structural integrity of steel bridges. Human visual inspection is currently the de facto approach for crack and corrosion detection. However, due to human limitations and the complexity of bridge structures, steel bridge inspections are time consuming, and labor intensive. Although non-destructive testing (NDT) techniques such as ultrasonic testing and acoustic emission have been used as supplemental methods to human visual inspection, they require complex testing equipment, and thus are not broadly used.

On the other hand, computer vision (CV) can perceive details beyond human capacity, and artificial intelligence (AI) such as deep learning has shown tremendous ability to conceptualize and generalize. By integrating CV and Augmented Reality (AR), a recent NCHRP Highway IDEA project (Li et al., 2022) completed by this research team successfully demonstrated how human-centered AR environment and automated CV algorithms can enable bridge inspectors to perform more accurate and efficient field inspections of steel bridges for fatigue cracks.

WHAT ARE WE DOING?

The scope of work includes three main tasks: the development and creation of CV and AI algorithms for steel fatigue crack and corrosion detection and quantification (Task 1), the comprehensive design and development of AR-based software to facilitate human-centered damage detection, visualization, documentation, tracking, and decision-making (Task 2), and extensive laboratory and field implementation,

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testing, and evaluation (Task 3).

Task 1: CV and AI algorithms for crack and corrosion inspection

Two types of algorithms will be included in the AR inspection tool. The first method is based on video analysis and will improve upon the NCHRP IDEA product in terms of accuracy and sensitivity. In addition, this research will also include image-based deep learning algorithms to enable classification, detection, and segmentation of cracks and corrosion, as illustrated in Figure 3 for the case of crack identification, using images taken by the AR headset, tablet, or UAV. Focus will be placed on minimizing the complexity of the deep learning model to reduce computation, with the goal of enabling real-time image processing and damage inference for practical inspections. With the two methods available, the inspector can first use the image-based deep learning method to identify and segment the regions where cracks and corrosion may exist, then apply the video-based algorithm to further examine the crack region for a refined result.

Task 2: AR-based software for human-center bridge inspection

This task will develop AR-based software environment and user interface to enable human-in-the-loop decision making during field inspections. A process will be developed to convert the damage detection result into holograms and deploy them to the 3D real-world environment with accurate anchorage onto the structural surface as illustrated in Figure 1. A cloud database will be created to store inspection results. This ability is the key to enabling documentation, allowing for comparisons and tracking of bridge damage in space and time. Build upon the user interface developed in the NCHRP Highway IDEA project, a more comprehensive virtual menu will be created to facilitate a smooth and user-friendly interface for human-centered bridge inspection. In addition, the software for AR headset will be adapted to enable AR-based inspection by using a tablet device. When a UAV is used to facilitate bridge inspection from a distance, the tablet device will receive the damage detection result for the inspector to facilitate human-centered documentation and decision making, as illustrated in Figure 2.

Task 3: Laboratory and field testing

The developed AR software and AI algorithms will undergo extensive testing in both the structural testing laboratory at the University of Kansas laboratory and on several bridges in the inventory of KDOT and other participating member states for validation.

WHAT IS OUR GOAL?

This project will deliver user-friendly AR software packages for participating member states empowered by AI algorithms for automated damage detection that can be readily adopted by bridge inspectors to perform AI and AR assisted bridge inspections using both AR headsets and tablet devices.

WHAT IS THE BENEFIT?

If the technology can also leverage Unmanned Aerial Vehicles (UAV) for remote image and video acquisition during inspections, enabling bridge inspections from a distance in a human-centered manner, without the need for a bridge inspector to be within arm's length of Non-Redundant Steel Tension Members (NSTM) to discover fatigue cracks, and federal regulation could be changed to permit this type of inspection; then there would be considerable savings in resources by eliminating the need for lane closures and personnel to operate and maintain a fleet of Under Bridge Inspection Trucks (UBIT).

Reducing the need for lane closures would reduce the potential for errant vehicular crashes and increases the safety for both bridge inspectors and the traveling public.

WHAT IS THE PROGRESS TO DATE?

TPF Solicitation 1597 was cleared in July 2024 and became TPF Study 5(535). The Kansas DOT facilitated the Kickoff meeting on 10/14/2024 and virtual meetings have been held quarterly to discuss on-going research. The Quarterly Reports have been posted on the Transportation Pool Funded (TPF) website. For Task 1, the research team has made progress in improving crack and corrosion segmentation through the combined use of tiling and ensemble learning. For Task 2, development of the AR infrastructure inspection tool has continued with ongoing refinement of features on the Magic Leap 2 platform.

IMAGES

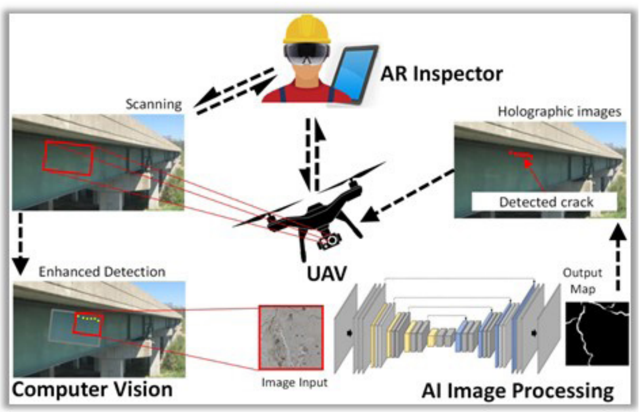

Image 1: Human-centered bridge inspection enabled by integrating AI, AR, and UAV

Image 2: Human-centered fatigue crack inspection tool developed under NCHRP IDEA 223

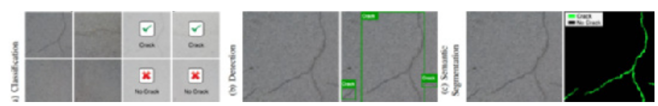

Image 3: Classification, detection, and segmentation of cracks using deep learning