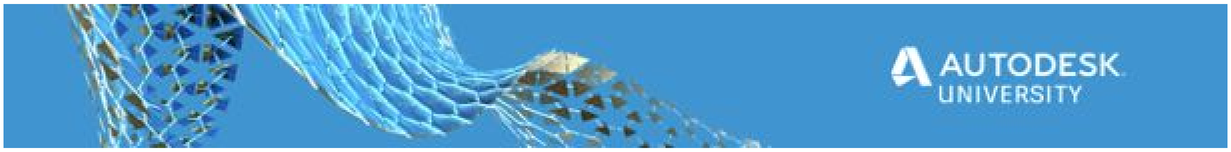

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Bridge Inspection with Aerial Robots: An End-to-End Automated Workflow

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Learning Objectives

- Learn how bridge inspection can be done automatically with drones.
- Review the Japanese government's initiative to transition to robotic inspection of infrastructure assets.
- Explore how automation can be introduced one step at a time for bridge inspection.
- Discover how inspection reports can be generated with a push of a button.

Description

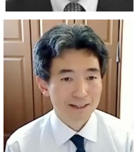
The aging of bridges and increased vehicular traffic have made it important that elevated highway structures receive timely and accurate inspections. Today's procedures for inspections require special equipment, disrupt traffic flow, and expose inspection personnel to safety hazards. The advent of drones that can carry cameras in close proximity to elevated structures as well as 360-degree cameras present an opportunity to conduct inspections quickly, safely, and effectively.

Towards this goal, this class presents an end-to-end system and workflow for visual and virtual bridge inspection. The system creates missions from reality capture using drones and 360-degree cameras; evaluates visual quality of data collection; generates 3D models; detects and localizes surface distresses in 3D; and generates reports complying with the requirements of highway agencies. We'll share lessons learned from deploying this system on 30 bridge inspection projects in the United States and Japan concerning procedures for documenting, communicating, and following up on bridge inspectors' recommendations.

Speakers

Dr. Mani Golparvar is the CTO and co-founder of Reconstruct, a Software-as-a-Service company that generates 3D reality models from drone, 360-degree camera and cell phone images and videos and integrates these reality models with building information models (BIM) and project scheduling to remotely monitor construction progress and operation of buildings and infrastructure assets. Dr. Golparvar is also Associate Professor of Civil Engineering, Computer Science, and Technology Entrepreneurship at University of Illinois at Urbana-Champaign.

Dr. Yasushi Nitta is the director for construction equipment and safety planning office at the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) in Japan.



Hirokuni Moirkawa is the director of an advanced technology research division at the Public Works Research Institute (PWRI) of the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) in Japan.

Dr. Yoshihiko Fukuchi is APAC infrastructure sales development executive at Autodesk. Dr. Fukuchi is responsible for business development in Asia Pacific matured countries, Japan, Korea, Australia and New Zealand. Dr. Fukuchi has been instrumental in the i-Construction initiative, led by the Japanese government to streamline and automate construction workflows.

Overview

The discovery of fractures in steel members of Kisogawa Ohashi Bridge and Honjo Ohashi Bridge in 2007, yet again raised alarms about the deterioration and fragile state of the infrastructure in Japan. By March 2019, deficient or functionally obsolete bridges constitute 9.6% of all the 700,000 road bridges in Japan. Japan's geography creates additional risks associated with natural disasters. Thus, evaluating as-is conditions of Japan's bridges and infrastructure assets is more important than many other places around the world.

Similarly, the collapse of a bridge in the state of Tennessee and a partial collapse of a railroad bridge in Chicago also in 2019 also raised a similar concern about the delicate state of infrastructure in the United States. Many years after the collapse of the I-35W bridge in Minneapolis, these incidents reminded Americans yet again that aging bridges and elevated highway structures are still at high risk to safety and security of transportation systems. A 2018 report demonstrates that 8.86% of the 612,408 bridges in the United States are still labelled as either structurally deficient or functionally obsolete. These bridges are not unsafe; however, a deficient bridge needs immediate attention, and an obsolete one does not meet current design standards.

Today's bridge inspection practices are expensive and can be disruptive to ongoing traffic. Onsite documentations are also time-consuming and assessments can be inconsistent. This means additional data collection may be necessary in many cases, while resource allocation is always challenging. The advent of agile aerial platforms with the ability to carry digital cameras, along with a greater awareness of the technology has created an cost-effective alternative to conduct bridge inspection in a quick, safe and effective manner. Application of aerial platforms resolves issues of access and traffic disruptions. Also, cloud-based analysis lowers the need for onsite engineer visits, reducing cost associated with inspection. As such, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in Japan launched an initiative in 2015 with the aim of leveraging advanced robots and artificial intelligence technologies to improve productivity in construction and infrastructure inspection tasks.

Because of the MLIT initiative as well as similar ones in the United States, a large body of solution has emerged which focuses on computer vision and visualization methods to process, analyze and share inspected drone data. These efforts have focused on improving one step in the process, rarely offering an insight or recommendation on how various techniques can be applied in an integrated manner to streamline the data collection, analytics, and reporting in an end-to-end fashion. While there are promising methods such as 3D reconstruction, image classification and object detection that can be applied to bridge inspection processes, yet their adaptability as part of an end-to-end system has not been investigated. Very limited work is done to create a roadmap for implementation and gradual transition of the whole industry.

In this talk, we present a series of methods and their integration in form of an end-to-end system and workflow for visual and virtual bridge inspection. We will specifically present workflows to create reality capture missions (for drones and 360-degree cameras) to collect inspection data; generate image-based 3D reconstruction of the elevated structures; perform visual and virtual inspection to detect and document surface distresses such as cracks, spellings, etc. in 3D; and render inspection reports in compliance with the requirements of highway agencies. We also share best practices and insight from deploying this system on bridge inspection projects in Japan and the United States focusing on documenting, communicating, and following up on bridge inspection recommendations. The presented workflow and system are now part of the Japanese national guideline for robotic inspection of infrastructure assets.

Visual & Virtual – a new approach to infrastructure inspection

Our workflow supports multi-modal capture using images and videos taken with drones, 360-degree cameras as well as cell phones. These images and videos can be taken in a structured form to guarantee accuracy and completeness of the capture. To facilitate this process, the following links provide reality capture guidelines in English and Japanese:

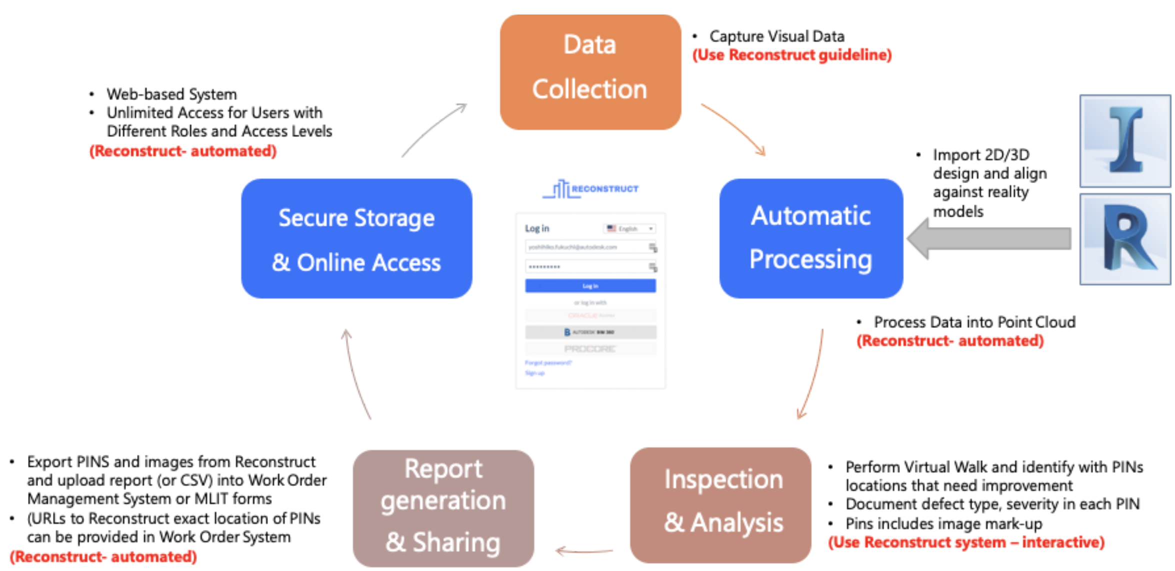
English: [Using Reconstruct for 3D Mapping (Creating a historical Record of your project](#)

Japanese: [Reconstruct を使って行う3Dマッピング（プロジェクトの履歴を作成](#)

Once these images and videos are uploaded into Reconstruct data manager, Reconstruct cloud-based engine automatically transforms them into 3D point cloud models, 3D meshes, and 2D orthophotos. The engine has the ability to process unlimited amounts of data and can stitch together images and videos captured from a variety of sources. These reality models are visualized and shared with web-based 3D and 2D viewers. Users can import as-is or as-designed 3D CAD models, Building Information Models (BIM) and 2D drawings from Autodesk REVIT, Navisworks, InfraWorks, Civil 3D and BIM360 into Reconstruct data manager and overlay these as-is design against reality to form “what is there” vs. “what should be there” views. When needed, laser scanning point cloud data can also be brought into the same system to have one integrated environment for all visual assets of a project. These reality models (with or without as-designed models/drawings) will be used to perform visual and virtual inspection in 3D.

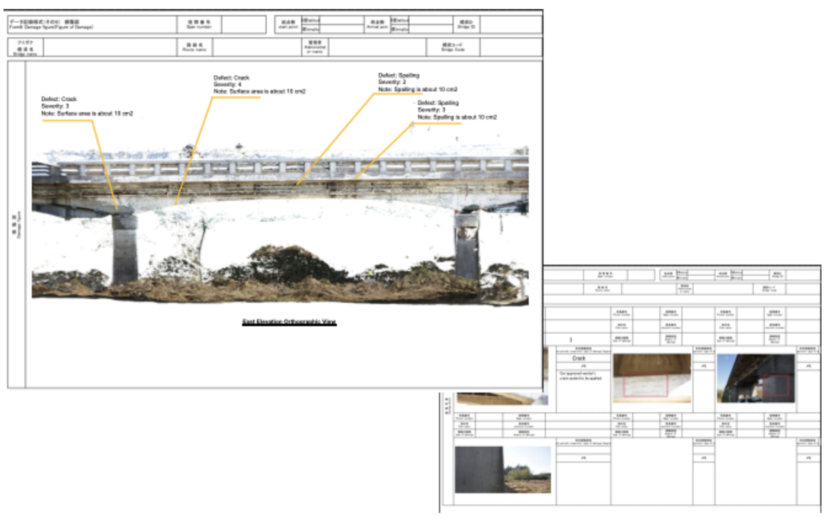
Any 3D location on the infrastructure asset (e.g., box girder of a bridge; below the deck, columns, etc.) can be measured directly from the pictures. The accuracy of a 3D measurement depends both on the accuracy of the reconstructed model and the ability of the user to select the right points on that model. The most common method to perform 3D measurements from photographs is to use photogrammetry to estimate 3D points and then fit a surface to those points to create an orthophoto or mesh. The problem is that the surface is simplified to fill holes and improve visualization. While the texture on the mesh gives the impression of detail, the geometry of the mesh is typically oversimplified and can be inaccurate.

In the proposed workflow, both the original images and the reconstructed points are used directly to perform measurement. Our recent user study shows that measurement using images overlaid on 3D point clouds with Reconstruct viewer provides the best combination of precision and user experience, improving the accuracy by a factor of 4 vs. using point clouds alone and a factor of 2 vs. using a mesh. ([Maximize measurement accuracy with images overlaid on point clouds](#))

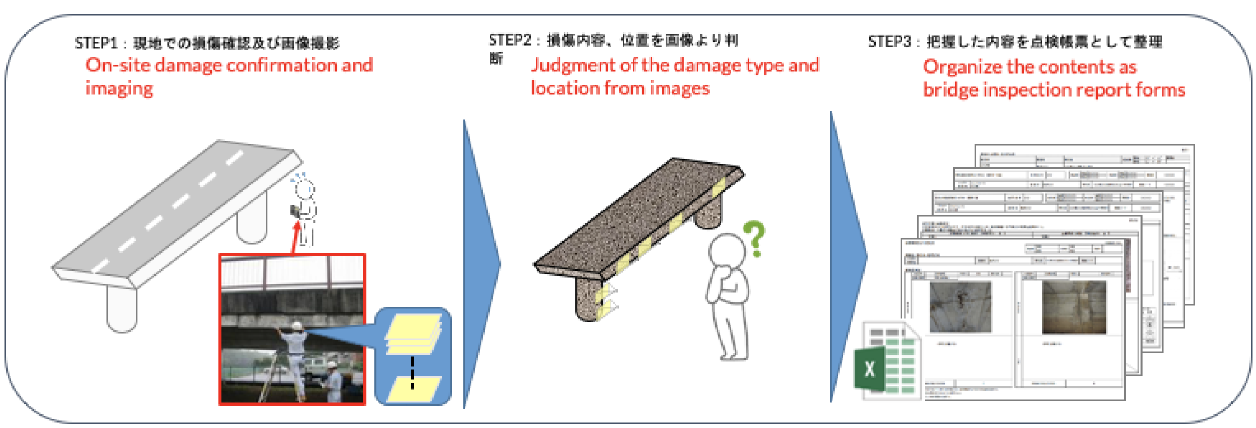


Annotations can be created to simulate how markups are done in the field over an infrastructure asset. These annotations, measurements, together with additional files such as field instructions in forms of .PDF, .DOC, .XLS, can be uploaded and pinned against any 3D location. Customized forms can be created to document user information, pin location, and enter specific information related to inspection (e.g., type of detected defect and severity which in the case of Japanese MLIT includes 26 different types of defects at five grades of severity). These documentations will preserve their location in space and time, allowing future 3D reconstructions to be overlaid against previously captured data. Users can review progression of defects over project timeline. This allows any documented defects to be compared against previous documentations without necessarily requiring images to be taken from the same location.

Once the inspection is completed using 3D and 2D viewers, the user can create specific views to generate orthophotos from any desired view, while being able to render and print a summary of defects in form of drawing callouts (see the snapshot below). Other required forms can be automatically generated to include most relevant pictures of each defect and inspection data. With this new workflow, all projects can use the same inspection template and generate reports that are consistent with the requirements of the agency reviewing them (in this case, Japanese MLIT).



When desired, each pinned defect information can be transformed into a work order and form a project schedule for addressing retrofit needs. The following figure offers a summary of the workflow.



A quick video describing the use case of visual and virtual inspection of infrastructure assets is offered in the following link: https://vimeo.com/427798041 (japanese language with English subtitles). This workflow -described in the recorded presentation video- offers substantial time and cost savings associated with a standard inspection workflow; it improves productivity in the inspection process and takes away subjectivity of current processes. The inspection data is also stored security in the cloud allowing inspectors to easily and quickly access previously recorded inspection logs.