PERSPECTIVE

Advancing Bridge Inspection and Asset Management Through Digital Twin Technology

by Monica Schultes

Digital twin technology shows huge promise for supplementing bridge inspection practices and monitoring the health of structures. A previous article (see the Summer 2021 issue of *ASPIRE*®) introduced the concept of a digital twin and explored how the technology might impact the bridge design and construction industry. This article focuses on using the new technology for bridge inspections and asset management.

Bridge Inspection Tools

Traditional hands-on visual inspections are labor intensive, require expensive equipment, present safety risks, and can be error prone. Agencies such as the Minnesota Department of Transportation (MnDOT) are turning to unmanned aerial vehicles (UAVs), also known as drones, to overcome such challenges.

"The Stone Arch Bridge in Minneapolis is a good example of how we have used UAVs for bridge inspection," says Kevin Western, state bridge engineer for MnDOT. "With the model developed from UAV footage, we can clearly identify cracks and missing mortar, and identify where repairs are needed. That helps the design team develop construction plans and allows us to easily communicate to the contractor," he adds.

With a grant from the Federal Highway Administration, MnDOT obtained drones for each of its eight districts. The agency is in the process of training employees how to use the UAVs to assist in inspections and provide information for inventory reports. MnDOT is still defining best practices to take that information and communicate it to evaluation and design teams.

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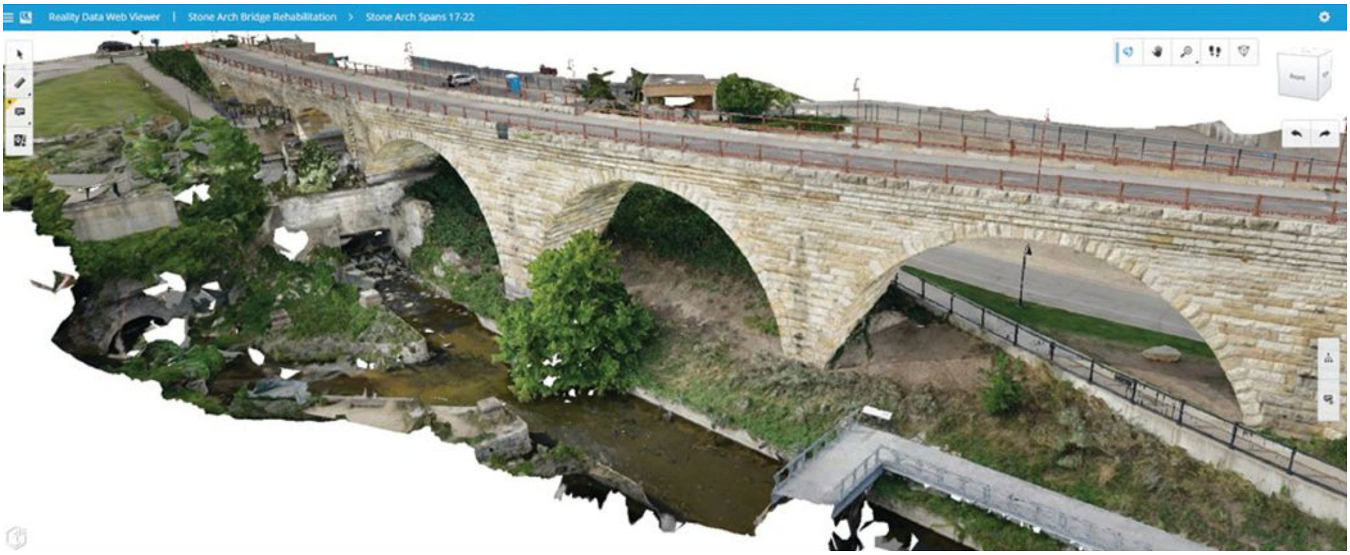
Simply taking drone footage is not enough. For example, an inspector failed to discover a crack in an Interstate 40 structure over the Mississippi River that prompted the span's closure. Western



The Minnesota Department of Transportation used unmanned aerial vehicles (drones) to capture photos, videos, and other data to produce a high-resolution "reality mesh" of the Stone Arch Bridge, as shown in this screenshot. These collected data are used to create a digital twin representation that can assist with inspection of the bridge, and the reality mesh can provide insights into structural changes over time. Photo: Minnesota Department of Transportation.

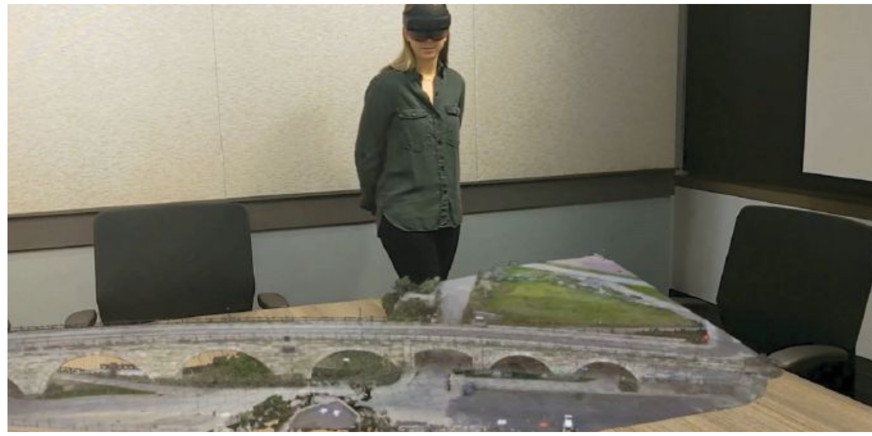
explains, "The footage was there, but no one was looking for or expecting a crack. We have to understand how to incorporate drone footage into the inspection process even before we start collecting and evaluating it."

Holistic View

While drones play an important role in capturing data, they are just one tool in the arsenal of an agency working to build and maintain digital twins. Another important tool is the right software. "Bentley Systems software combines data from surveys, photogrammetry, LiDAR [light detection and ranging], and sensors, as well as drone footage in the digital twin database," says Dan Vogen, vice president of road and rail asset management at Bentley Systems.

Because bridges have such a long life cycle (typically 75 to 100 years), it is important to track changes to the structures over time. A holistic view of the bridge is achieved by layering information from past inspections on top of current data to better understand what is happening on site.

"This is a great opportunity for agencies to use UAVs to complement and augment in-field inspections. The modern method of inspecting bridges uses drones and photogrammetry," says Vogen.



The software company Bentley Systems is adopting Microsoft HoloLens technology so that bridge inspectors can immerse themselves in the full-scale digital model of the bridge they are inspecting. The use of augmented reality aims to improve the connection between the bridge information model and actual field conditions. Photo: Bentley Systems.

The data from these inspections can be reviewed quickly and easily in the office by viewing a time-lapse comparison of changes and noting areas of concern and anything that needs to be reviewed in the field. Also, field crews can see all the inspector's notes right on the structure's digital twin, which is more visual, more accurate, and more efficient. All of this is geared toward saving costs, avoiding risks, and reducing time required for inspections.
Bridge inspection methods have remained stagnant for many years. Accessing and assessing an entire structure can involve snooper trucks, boats, or rappelling over the side of the structure. But a snooper truck is limited compared with the capability of a drone in hard-to-reach places. "We can fly a drone up under the deck, along the beams, and get the picture," says Vogen.

Geometric Accuracy

A camera-equipped drone on a repeatable flight path can capture a more accurate picture than an on-site inspector, who might focus on some things to the exclusion of others. The model is generated from thousands of pictures. It is geometrically accurate, says Vogen. The Federal Aviation Administration (FAA) recently relaxed restrictions for drone flight, making drone-based bridge

Software can piece together photos taken by an unmanned aerial vehicle to create a visually accurate and detailed model of the entire bridge in a process using photogrammetry technology. Using the three-dimensional model created by the software, different views of the "reality mesh" of the Stone Arch Bridge project were generated by the Minnesota Department of Transportation. Photo: Bentley Systems.

Minnesota Department of Transportation (MnDOT) is one of many agencies employing drones as a way of innovating for a better outcome in its bridge inspection practices. MnDOT inspectors can conduct significant parts of the inspection while in the office. This reduces time in the field, making the overall inspection more efficient, safer, and more cost effective. Photo: Minnesota Department of Transportation.

inspection possible. "The FAA now allows the use of the drones without direct line of sight," explains Vogen. Meanwhile, the Federal Highway Administration currently allows the use of drone-based inspection as a supplement to, but not a substitute for, in-person inspections.

Bridge inspections have always been dangerous, but for many old-school engineers, nothing beats being there. Bentley is bridging the gap between staring at photos and being on site. The high-resolution drone photographs of the bridge are stitched into a "reality mesh" three-dimensional (3-D) model comprising hundreds of millions of polygons, explains Meg Davis, industry marketing director of road and bridge at Bentley Systems.

This mesh contains far more information than regular 3-D models, says Davis. "It has all the texture, all of the current conditions conveyed through the reality mesh."

The reality mesh can be viewed on a computer or tablet, or a cloud-connected HoloLens (augmented-reality headset) can be used to examine the bridge at a zoomed-out tabletop view or at a 1:1 scale; this lets engineers get up close and see every inch of the structure in high resolution. While this technology is not meant to replace in-person inspections, it has reduced the number of trips needed to inspect the bridge and has also allowed engineers to contribute from remote locations.

Looking Forward

MnDOT is already experiencing benefits in safety, tracking, and quality from drone bridge inspections, while also believing there will be long-term cost savings by using UAVs. "We are in the infancy of this technology. A bridge can last 75 to 100 years, so right now we are seeing only a snapshot over that lifetime," says Western.

MnDOT is also evaluating the use of sensors on bridges. "We have tried sensors on several projects and are still in the evaluation stage. There are challenges such as false positives and the longevity of the instrumentation, as well as understanding and interpreting the data," explains Western.

"How do we take the information and make better decisions going forward? That is the 'Holy Grail' for asset management. We are headed in the right direction here at MnDOT and are already seeing huge benefits. This increase in technology may ignite some excitement from young engineers and designers. Any way we can recruit young talent is a good thing," he says.

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A Different Perspective

Although digital twin technology shows great promise, there is still work to be done. Coming from a metrology (the science of measurement) perspective, David H. Parker, Parker Intellectual Property Enterprises LLC, challenges the industry to examine the instrumentation attached to structures. "Is the bridge industry gathering the right information?" he asks.

There are cases where we have relied on visual inspections to avoid disasters. But serendipity should not play a part in bridge monitoring. Digital twin technology is designed to remove some or all of this subjectivity.

"We shouldn't just throw sensors at a bridge and expect the data to illuminate what is happening in real life," says Parker. "I think there is a disconnect between bridge owners and researchers. The bottom line is determining if the bridge is safe. Engineers need to intuitively understand information flowing to them through the model and easily detect anomalies.

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"Does the bridge industry verify the actual movement of the bridge against their predictions? We need some degree of assurance that the model and the sensitivity of the data are correct."

In a follow-up article in the next issue of *ASPIRE*, Parker will expand on these topics and describe how to use high-accuracy dimensional metrology for monitoring structural health.

Conclusion

Just as office buildings use building management systems to regulate maintenance and operations, bridges are dynamic assets that demand close monitoring after they are built. Digital twins enable bridge owners to take advantage of the tremendous quantity of data obtained from remote inspections. This reduces time spent in the field, which makes the overall inspection quicker, safer, more efficient, and less costly. Bridge asset management based on visual inspections, which are subjective, time-consuming, expensive, prone to error, and sometimes dangerous, is changing for the better.