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IQ INNOVATION QUARTERLY

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Reality Show

‘X-ray vision’ can see through metal — and see the future

PLUS: Add It Up
Discover how additive manufacturing will shape aerospace — and already has.

POINT WELL TAKEN
Boeing engineer Kennedy Woodard uses augmented reality glasses to see digital elements superimposed on real-world surroundings.

BOEING

THE VIEW

F-22 engineer Kennedy Woodard, formerly a manufacturing industrial engineer with Missile and Weapon Systems, dons an augmented reality headset at the Weapons Visualization Center in St. Charles, Missouri.

PHOTO: ERIC SHINDELBOWER/BOEING

REALITY SHOW

‘X-ray vision’ can see through metal — and see the future

Floating hands, holograms and headsets are increasingly becoming part of the aerospace process. Boeing teams in the United States and Canada have the future in their hands — and on their heads.

Boeing's virtual, augmented reality center:
Advanced capabilities enhance design, production, training and safety

BY JOSH ROTH, BOEING WRITER

At the Weapons Visualization Center in St. Charles, Missouri, engineers are designing tools, products, assembly stations, production lines and even factories in virtual reality (VR) and augmented reality (AR) environments.

Before the Build
See It 'Finished' First

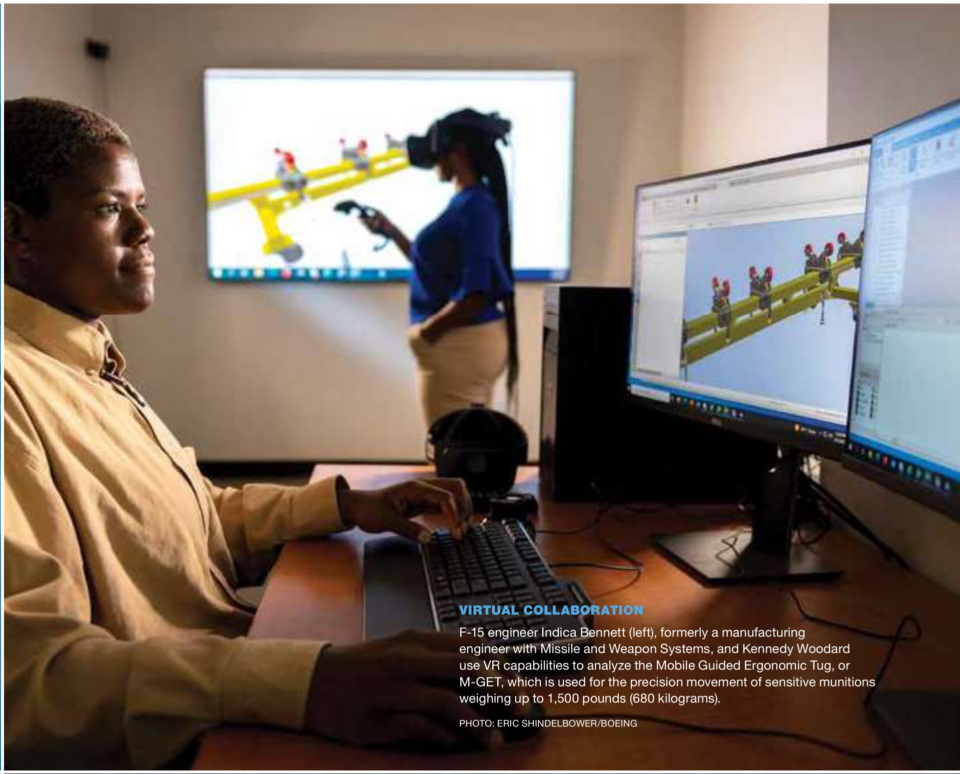
"VR and AR give us the ability to more closely view and scrutinize everything before we build it," said Scott Seddon, production engineer and virtual manufacturing specialist. "By placing our engineers into virtual environments, they're able to refine the function and accuracy of our designs and processes, eliminating risks and defects prior to 'bending metal.'"

Using the same technology, new employees can also train before ever stepping foot on an actual production line. Donning headsets and wands, employees learn processes, build skills and gain the muscle memory needed to perform tasks faster than previously possible.

"It can take people up to a couple of years to become proficient at all of the stations on a complex production line," said Kristi Shepard, production engineer and former mechanic. "By learning to do the work consistently well in a virtual setting first, we can drive down costs and defects significantly while improving safety and quality."

SCOTT SEDDON
Production engineer and virtual manufacturing specialist, Weapons Production Engineering
PHOTO: BOEING

KRISTI SHEPARD
Production engineer, Weapons Production Engineering
PHOTO: KRISTI SHEPARD



VIRTUAL COLLABORATION
F-15 engineer Indica Bennett (left), formerly a manufacturing engineer with Missile and Weapon Systems, and Kennedy Woodard use VR capabilities to analyze the Mobile Guided Ergonomic Tug, or M-GET, which is used for the precision movement of sensitive munitions weighing up to 1,500 pounds (680 kilograms).
PHOTO: ERIC SHINDELBOWER/BOEING

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>
> **SCOTT SEDDON, PRODUCTION ENGINEER AND VIRTUAL MANUFACTURING SPECIALIST, WEAPONS PRODUCTION ENGINEERING**

Additionally, engineers can use the same virtual training system to test design changes and possible improvements before implementation — the feedback they receive from operators is invaluable, helping to avoid rework and allowing for agile adjustments.

"Practical feedback from our mechanics is essential to make things easier and more efficient for them," Shepard said. "Part of the reason this training is so valuable is that it gives them an avenue to provide input, as they are the ones actually doing the work."

REAL-WORLD WORK

With virtual reality headsets, teammates can place a marker, like a red dot, to precisely investigate specific areas.

PHOTO: ERIC SHINDELBOWER/BOEING

What's the difference?
The FYI on XR, AR, VR, MR

EXTENDED REALITY (XR)

Production engineer Kristi Shepard calls XR "all encompassing" and said it is applied in the digital engineering world "to use digital applications to better the business." XR is the umbrella term that includes AR, VR and MR.

AUGMENTED REALITY (AR)

According to Shepard, AR overlays digital elements onto the already existing surroundings. Production engineer Scott Seddon added, "AR brings digital content into the real world with precise alignment, and the digital content is not the user's primary focus. The digital content is 'augmenting' something in the real world."

VIRTUAL REALITY (VR)

"This is computer-generated, lifelike images and sounds that simulate a user's physical presence in a virtual or imaginary environment," Seddon said. "VR immerses users in a fully artificial digital environment and often occludes the real world."

MIXED REALITY (MR)

"It's a mix between AR and VR, where there are digital elements in the headset laid over the real environment," said Shepard. Seddon also pointed out that the digital content is the user's focus. "It is not merely 'augmenting,' as the user is able to interact with virtual objects," he said.

"Practical feedback from our mechanics is essential to make things easier and more efficient for them. Part of the reason this training is so valuable is that it gives them an avenue to provide input, as they are the ones actually doing the work."

KRISTI SHEPARD,
PRODUCTION ENGINEER,
WEAPONS PRODUCTION ENGINEERING

Employee Benefits
Safety at the Center

Moreover, the center is beginning to use motion capture technology to analyze employee interaction with products during the build process.

"Things like posture, vision and reach analysis give us insight into the physical impact of different movements and lifting requirements so we can make adjustments that increase safety and well-being for our employees," Seddon said.

The technology was recently used to design a new manufacturing facility in St. Charles, which was completed last year to support increased production for the Harpoon missile program and the restart of the Standoff Land Attack Missile Expanded Response, or SLAM ER, production line.

"Because we were able to simulate production flow and move these products through the virtual facility layout during the design process, we were able to identify less-obvious issues like space and turning radius requirements, which would have been costly discoveries after the fact," Shepard said. "That insight early on allowed designers to avoid major redesigns and resulting scheduling delays."

Moving forward, the center is looking at developing manufacturing digital twins to support entire product life cycles — including design and production processes, shop floor activities, logistics, and tool and workstation use. By modeling entire process flows and facility layouts, the team hopes to analyze complete production systems and harness the power of predictive analytics.

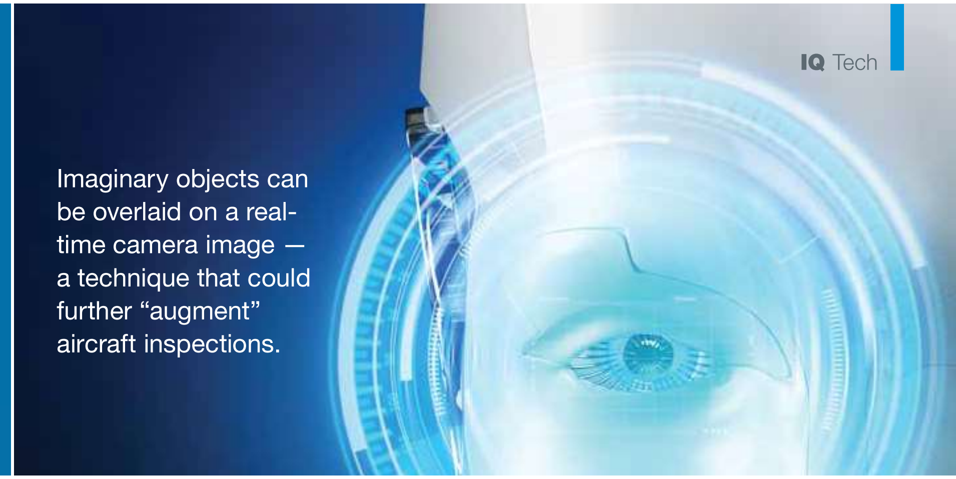
The center's underlying value is found in the seamless integration and collaboration of operations, production and engineering experts through shared virtual environments.

"We're really just scratching the surface of what's possible, and we're eager to find new opportunities to apply these capabilities," Seddon said. "The sky is the limit on what can be done in here."

A vision in Vancouver:
AR for inspection and maintenance

BY JACK HSU, BOEING VANCOUVER

Augmented reality (AR) for aerospace production happens in a constant, controlled environment. But maintenance and inspection happen in dynamic settings, inside different hangars, sometimes outdoors in changing weather conditions and lighting, with different liveries on aircraft. These are the challenges a team in Vancouver, Canada, is approaching.



> Imaginary objects can be overlaid on a real-time camera image — a technique that could further “augment” aircraft inspections.

Imagine if an aircraft mechanic had something like X-ray vision. Circling with a digital device in hand, a mechanic could “see” under an aircraft’s skin on a real-time camera image. As the camera moves, it reveals previously identified defects or damage as the operator records newly discovered issues.

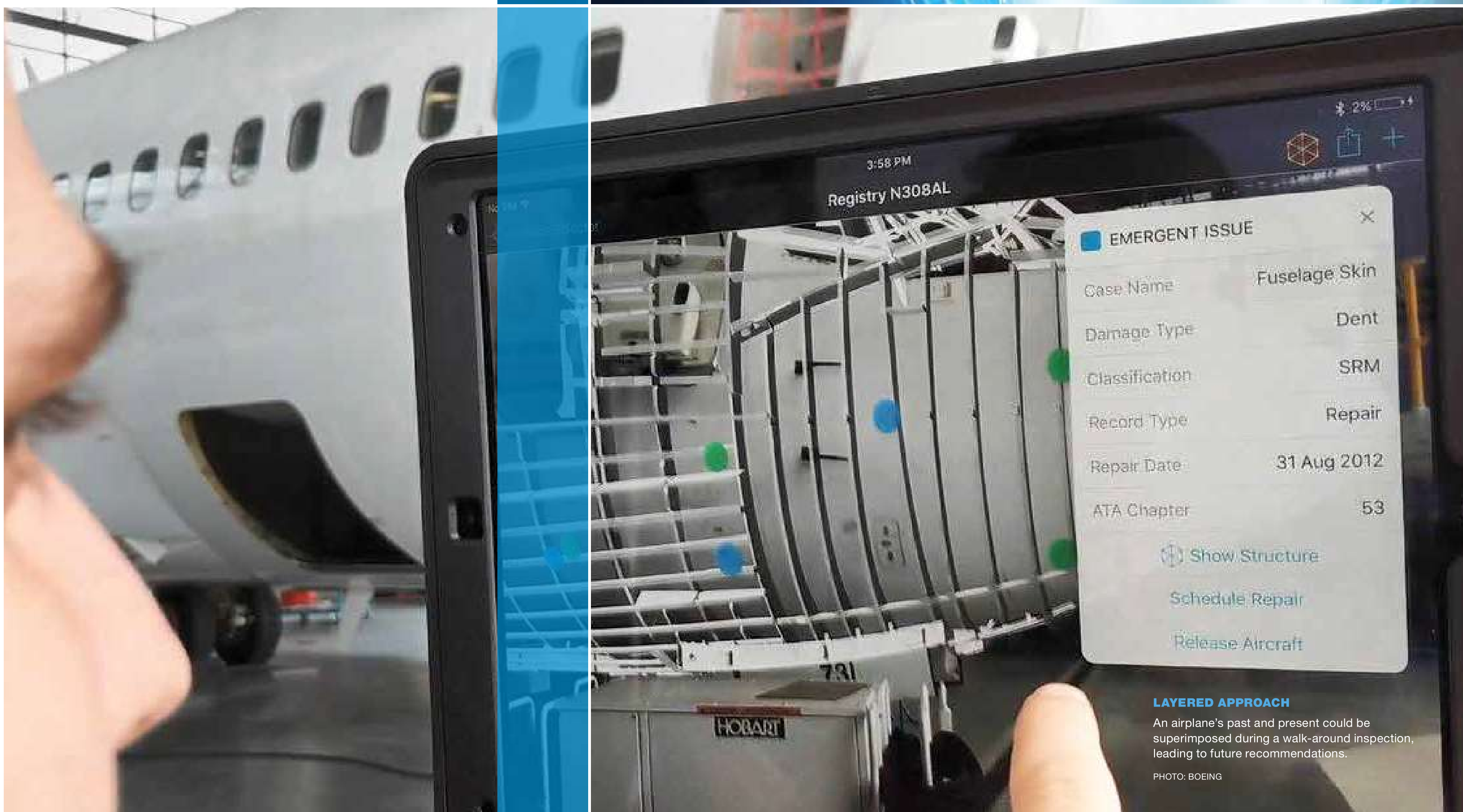
This approach may be the future of aircraft inspection.

The Boeing Vancouver team is inventing a process where repair indicators can be recorded and displayed directly on the surface of an aircraft when viewed through an AR digital device. Imaginary objects can be overlaid on a real-time camera image — a technique that could further “augment” aircraft inspections, with benefits to both quality and efficiency.

Aircraft Inspection
Augmenting Efficiency and Quality

A typical aircraft inspection involves maintenance technicians and engineers walking around an aircraft, recording new defects or damage with a pencil in a notebook. This constant and critical operation must also cross-check defects that have already been recorded to avoid replication.

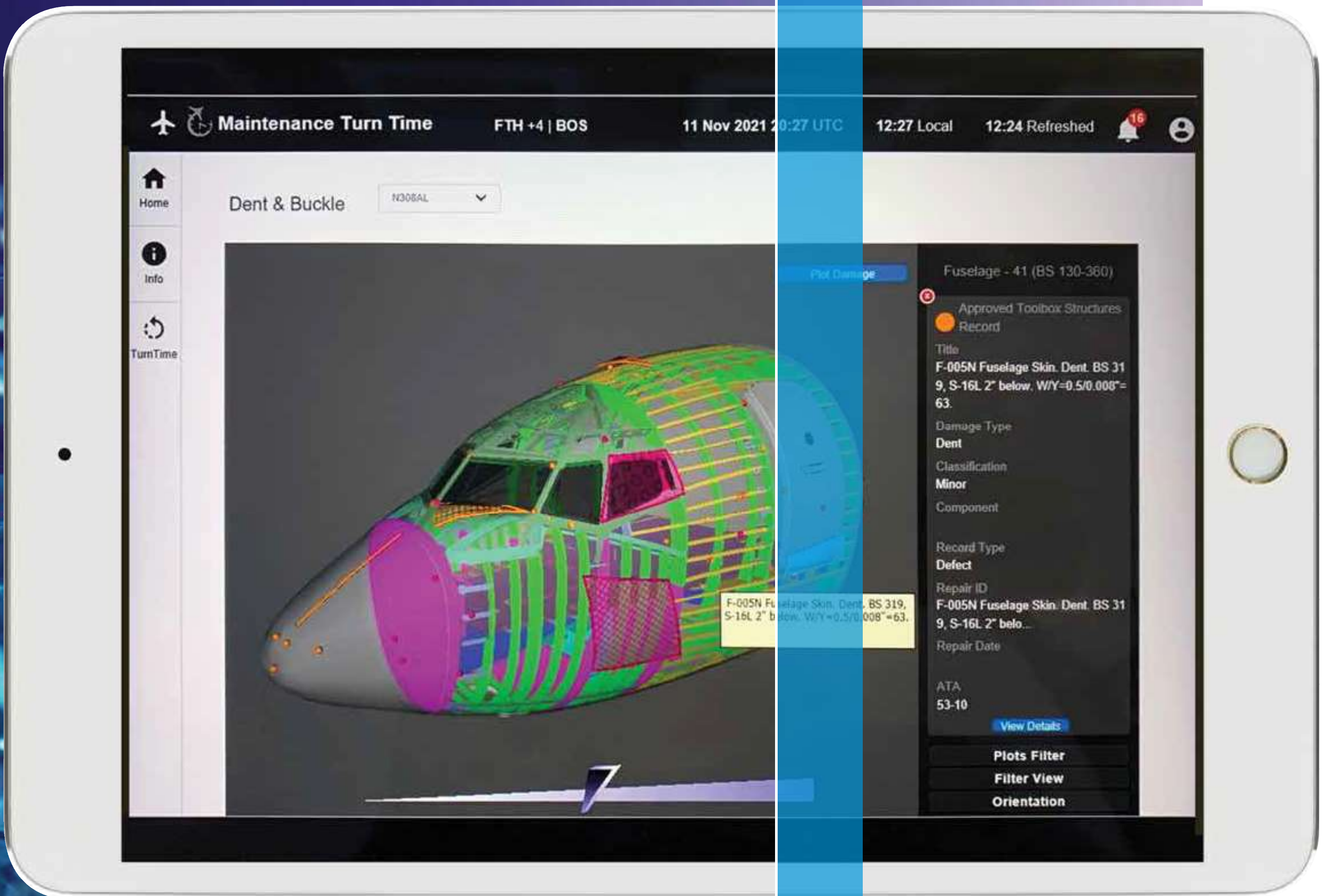
Locations are often described in language like “3 inches from the fifth left side window.” Depending on the size of the structure, the inspection often takes hours, even days.



LAYERED APPROACH

An airplane’s past and present could be superimposed during a walk-around inspection, leading to future recommendations.

PHOTO: BOEING



PENCILS DOWN

Operators can replace literal notebooks with virtual ones that can gather all inspection information in one place and precisely pinpoint issues.

PHOTO: STEPHANIE TOWNEND/BOEING

But what if you could simply hold up a digital device and see locations of all previous damage and repairs highlighted in 3D — and, with the touch of a screen, note newly discovered issues? Damage/repair indicators could appear as dots projected directly on the surface of the aircraft itself. The virtual dots would "augment" reality and dramatically increase efficiency.

The idea starts with a virtual 3D model (or digital twin) of the aircraft. Graphics software then places highly visible damage indicator dots (with locations coming from a previously recorded damage database) onto the surface of the model. The 3D model lines up with the actual image of the aircraft coming from the camera of the AR device.

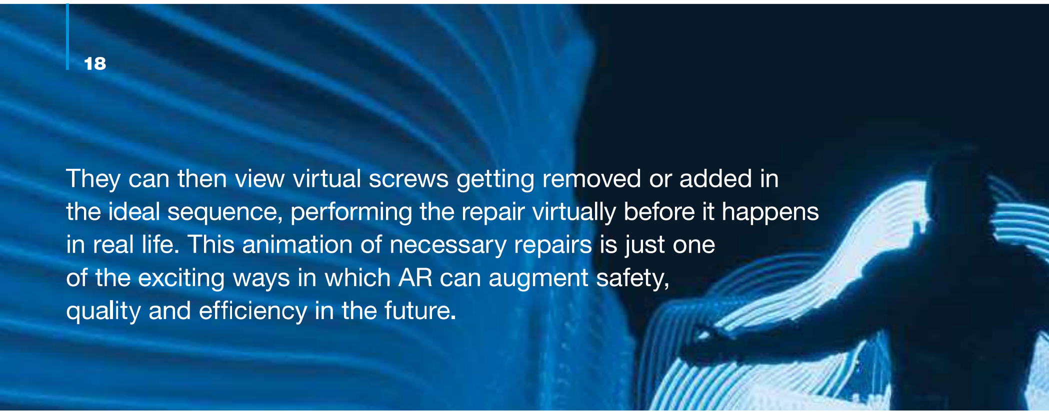
An operator could graphically remove the 3D model "mesh" of the aircraft but leave the indicator dots, which then gives the user the illusion the dots are actually painted on the surface of the plane. The dots would remain "anchored," indicating the location of damage, even as the mechanic and the device could move around the aircraft, adding new data.

Artificial Intelligence Needs a Human Touch

Placing damage markers on a 3D model of an aircraft is the easy part; the challenge turns out to be positioning the model over the actual aircraft image while moving around the plane.

It is critical that the 3D model and the real-world image align precisely to accurately record the position of new and existing damage. Current software is dependent on the working environment. In a relatively small indoor location such as an office, an app can easily track multiple feature points, such as furniture or window corners. But with a large airplane that has a shiny surface and is often sitting in a large open environment, the technology struggles.

The team came up with a solution to use artificial intelligence (AI) to train a machine learning algorithm. The trained algorithm, the team hoped, would be able to recognize the orientation and position of the aircraft based on the stream of images coming from the camera — an area of AI technology called "pose estimation."



They can then view virtual screws getting removed or added in the ideal sequence, performing the repair virtually before it happens in real life. This animation of necessary repairs is just one of the exciting ways in which AR can augment safety, quality and efficiency in the future.

This technique means a mechanic's manual intervention wouldn't be required to use special equipment or markers to orient the position of the device to the aircraft. The technician should, just by looking at the aircraft through the camera, be able to determine exact location. And once that is known, the virtual 3D model can be positioned in the appropriate spot.

Boeing partnered with Simon Fraser University (SFU), Unity and Canada's Digital Technology Supercluster to explore this solution on the Augmented Reality for Maintenance and Inspection project, started in 2020. SFU researchers Ali Mahdavi-Amiri, Anil Ufuk Batmaz, Johannes Merz, Wolfgang Stuerzlinger and Richard Zhang worked together to research and develop the pose estimation algorithm; Unity worked on software implementation for a holographic device and synthetic data generation; and the Digital Supercluster provided project funding.

Cloud Confusion
Seeking a Silver Lining

As with all machine learning algorithms, significant data is needed to train the pose estimation algorithm. Driven by the restrictions caused by the pandemic, the team found an aircraft that was still accessible, a Douglas DC-3 in the Canadian Museum of Flight's collection at Langley Regional Airport east of Vancouver. SFU researchers were tasked with capturing the images and positional data and feeding them into the pose estimation algorithm they had developed.

After long hours of image capture, data cleansing and algorithm training, the results looked initially promising. But after analysis, researchers determined that the algorithm was confused because the clouds were different when the images were captured compared to the test session, resulting in different lighting.

The teams realized the machine learning algorithm would require hundreds of thousands of images of planes from different angles, lighting, liveries and background hangars in order to obtain robust pose estimation. To collect these images with real aircraft, it would take an impractical amount of time.

Synthetic Solution
Enabling Machines to Learn

After identifying this issue, the teams decided to confront the data problem with synthetic data generation, a burgeoning area in machine learning. The concept is to create a synthetic, computer-generated image — like a cat, a car or a plane in a video game — that is convincing enough for a machine learning algorithm to accept it as real.

Fortunately, Unity is a leader in this new area of AI, using graphics-rendering technology. Working with the project team, Unity graphic artists and developers synthetically created images of the DC-3 with different liveries and various environments, lighting conditions and viewpoints.

Synthetic data generation quickly creates not only more diversity but also many more images; Unity generated 100,000 synthetic images in four to five hours, compared to about 3,000 real images collected over the course of eight hours at Langley Airport. Another advantage of synthetics is that the position of the camera relative to the virtual aircraft is known — much more difficult to achieve with real images.

ABOUT THE AUTHOR

Jack Hsu is a senior manager at Boeing Vancouver, where he leads various innovation projects using emerging technologies such as blockchain, knowledge graphs and augmented reality. Hsu has worked in the software industry for over 25 years in roles that have spanned software engineering, project and program management, product management and business development.

PHOTO: ANITA SCARROTTS/BOEING

Even so, to train the algorithm properly, synthetic images must be mixed with real images, with the optimal ratio of real to synthetic images still to be determined as the effort continues.

Next
Augmenting the Future

Using AR to display damage/repair indicators virtually on the surface of aircraft would be the first step in applying the technology to aircraft maintenance. Once accurate anchoring of a 3D model to an aircraft image is accomplished, many possibilities will open up, including the ability to display the structure and components or parts under the skin of the aircraft so repairs or modifications can be completed with less risk.

Accurate anchoring will also enable 3D maintenance "work guidance," where technicians will be able to see virtual 3D components anchored on top of real components. They can then view virtual screws getting removed or added in the ideal sequence, performing the repair virtually before it happens in real life. This animation of necessary repairs is just one of the exciting ways in which AR can augment safety, quality and efficiency in the future. **IQ**