Augmented reality lets designers visualize parts like the motorcycle cladding, fuel-tank cover, and seat shown in green here.

THE MORE

From virtual service manuals to holograms you can touch, augmented reality could transform engineering design.

BY JEAN THILMANY

The industrial designer and the engineer stand before their individual workstations, both wearing wraparound headsets that shade their eyes. They're collaborating on a project and standing side by side, yet they don't speak and don't interact. They're immersed in their work. And no wonder.

The designer presses his mouse. An image of the handheld video game controller he's been creating lifts off the screen and appears to hover between the two.

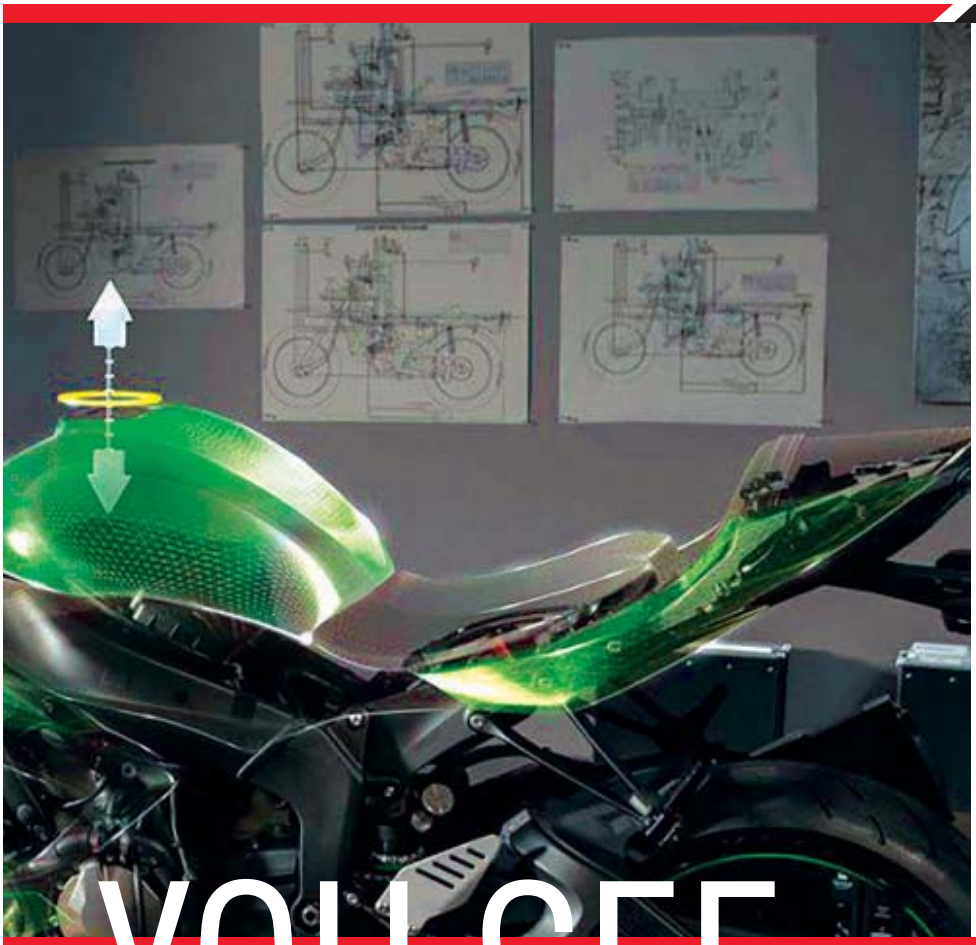
Then the engineer clicks. The assembly of internal parts he's designed lifts off his computer screen, hovers in mid-air for a second, then glides inside the image of the controller. At first the controller's internal assembly and the designers shell don't quite fit together, but after a small tweak, they do.

The two, depicted in a promotional video from Autodesk, have paired Microsoft's HoloLens headset with Autodesk's Fusion 360 engineering design software. And although the two are actors playing out a yet-unrealized scenario, the video may offer a glimpse into the future of engineering design.

That future? Just two words: augmented reality.

AUGMENTED OPPORTUNITIES

After years of anticipation by gamers and technology aficionados, in 2016 virtual reality



YOU SEE

took center stage as companies rolled out several high-profile VR devices, including the Oculus Rift, PlayStation VR, and HTC Vive.

The new headsets offer a wide field of view and high resolution, as well as positional tracking that closely follows a user's eye movement to prevent motion sickness. They advance VR beyond large displays and CAVES, the high-end, specially equipped rooms that scientists have used since the 1990s to immerse themselves in 3-D environments.

This year also saw the beta release or full release for several pivotal augmented-reality (AR) technologies, including Microsoft's HoloLens and the Meta 2 headset from the Meta Company.

Unlike VR, AR dangles text, graphics, or video into a person's visual field that describes, or augments, what they're looking at. (See sidebar, p. 33.) Think Google Glass, now taking a break as it retools, which displayed information or images just above the user's line of sight. Or think the AR game Pokémon Go, which created a sensation after its July 2016 release, persuading players by the millions to capture, train, and battle virtual cartoon creatures called Pokémons in the real world.

AR's possibilities have spurred major engineering software companies such as Bentley Systems, Siemens PLM, and Autodesk, and even the software behemoth Microsoft to invest in AR for engineering, manufacturing, and plant design.

Siemens PLM, for example, has created AR brochures with images that spring into view. Bentley has created a homegrown AR system that helps architects and construction engineers convert 2-D blueprints into 3-D representations of buildings.

Merging engineering software and AR could let engineers suspend 3-D models in mid-air and tweak them in real time, said Garin Gardiner, business development manager for Autodesk's Fusion 360 design software. This would make for fewer physical prototypes. Engineers who aren't in the same room—or even the same country—could talk through changes to the model, and watch each

A KTM technician demonstrates how to visualize a malfunctioning motorcycle part on a tablet—and view AR instructions (green, in inset) on how to fix it.

other's hands as they make them, Gardiner added.

AR's is just getting started in engineering, but the potential is such that the AR app market for the field will grow 10-fold between 2014 and 2019, from $247 million to $2.4 billion, according to market-research report from Juniper Research.

"AR is unavoidable for engineers," Jon Peddie, a graphics industry veteran and market analyst who specializes in digital, online, and mobile apps. "The opportunities it presents are just astounding."

REALITY PLUS

Augmented reality got its start in 1990, when Boeing researchers Thomas Caudell and David Mizell proposed a new and simpler way to convey aircraft wiring instructions to workers assembling the aircraft. By overlaying computer-represented text and graphics on real-world images, they'd create a virtual service manual of sorts that could be updated easily, eliminating the need to lug around voluminous paper manuals.

In the years that followed, Caudell and Mizell developed such virtual service manuals, and in 2008 a Boeing engineer and a technician developed a method to help technicians perform building tasks in AR before carrying them out while building satellites, said Peddie, whose book, tentatively titled *Augmented Reality: Where We Will All Live*, is due out next spring.

Meanwhile, others new AR applications let auto mechanics gaze through headsets for visual guidance as they repaired car engines.

"The problem is the people using it were al-

ready experts," Peddie said. "They didn't need to know the nuts and bolts or the torques, so it didn't serve as a training device for them." As a result, people stopped using the virtual service manuals, and they languished.

But in AR's new era, wearable headsets are smaller, less bulky, and far more user-friendly than older AR devices. They're also reliable, affordable, and don't tie their wearers by cord to a computer system.

In 2014 Autodesk, the engineering software giant, and Microsoft decided to team up and give AR for engineers, designers and technicians another go.

Autodesk's Gardiner, who spearheaded the collaboration, and his colleagues first surveyed engineers who used Autodesk software on how they worked best. How did they collaborate on projects? How did they work with teammates in far-off offices?

It turned out that engineers struggle to visualize how on-screen images translate into 3-D products. To understand how to design parts and keep them from interfering with one another, "they'll walk to someone's desk and ask questions or they'll send an email," Gardiner said. This often leads to long conversations that can take days or weeks to work through.

To speed the design process, Autodesk and Microsoft launched a project called "Freeform." They built prototypes and tested scenarios of how engineers and designers could work with holographic objects, alone and in collaboration.

"We've found you can make quicker and better decisions by having the AR model right in front of you," Gardiner said.

TECHNICIAN'S GUIDE

Jens Tuma held an iPad up to the kickstand of one of his company's motorcycles, and an image of the kickstand appeared on the tablet, neatly framed and ready for a picture. Then he moved his fingertips on the tablet to zoom in, and a green animation appeared on the screen atop the image of the actual kickstand.

As head of customer service for the KTM Group, which makes off-road and street motorcycles, Tuma must ensure that customers whose KTM bikes need repair can find a technician who can fix them. But many motorcycle repair technicians within the group's growth markets lack experience fixing KTM bikes. Tuma figured an AR-based service manual would give these technicians some much-needed visual guidance.

Years after the first virtual service manuals fizzled out, companies have begun reviving them. And now Tuma, whose team used PTC software

"We've found you can make quicker and better decisions by having the AR model right in front of you."

— GARIN GARDINER, AUTODESK

to build a virtual service manual, was demonstrating to a gathering of analysts, investors, and PTC software users how a motorcycle technician would use it.

After running a diagnostics test that determined issues with the bike, Tuma held his iPad with the AR application running over a broken kickstand. An AR image appeared overlaying the real-life ones—along with drop-down instructions to walk technicians step by step through a repair.

To create a virtual service manual like KTM's, you first need to capture real-world measurements using a sophisticated imaging system that employs cameras and sensors.

For a motorcycle, sensors would gather data such as engine temperature, suspension velocity, and spring rate (the amount of weight needed to compress a spring one inch). Those numbers plug into a referential database—a database that can be referred to by the AR software, Peddie said.

Then, in real time, the system must cross-reference information from this database with real-world information from cameras and inertial measurement units on the AR goggles that track the wearer's movements and orientation in space. Then the system uses creates a 3-D model that appears to float in space, overlaid with text or graphics that guide the technician through a repair.

Tuma believes that with AR manuals like these,

The real-time benefits of AR

In this scenario, an engineer (left) and an industrial designer (right) use AR to design a video game controller.

With a click of a mouse, a hologram of the controller lifts off the screen and hovers.

technicians can make repairs faster than ever before. "We want to get rid of a room full of technician's books," he said.

TWENTY-THOUSAND APPS

To create its AR service manual, KTM used the Vuforia Studio platform, which engineering-software maker PTC purchased in November 2015 from Qualcomm Connected Experiences. Vuforia includes the VuMark, an open-source AR ap development platform. App creators have responded by building more than 20,000 AR apps for phones, tablets, and digital eyewear such as Sony SmartEyeglass and Vuzix M-100 from Vuzix.

Many new AR apps being created with the VuMark platform and by private companies are meant for gaming, including apps for Pokémon Go, a Mattel ViewMaster, and a Skylanders card game. Others are meant for marketing, including Siemens PLM's AR brochure.

> With this ability to control your PC using everyday gestures, "we're all going to be throwing away our external monitors."
>
> — MERON GRIBETZ, CHIEF EXECUTIVE OFFICER, META

Yet until Pokemon Go, few AR apps caught on with the public, and even fewer were targeted to the engineers and manufacturers who stand to benefit most. What's more, no standards exist yet for AR, which forces users to continue with the same headset vendor or risk losing their applications and information.

"Customers are trapped," said Mike Campbell, PTC's executive vice president for Vuforia Studio. "When you neutralize that with standards, many AR companies will go away or get acquired."

For these reasons, executives in many industries have hesitated to adopt AR technologies. It's also unclear how doing so can help boost their bottom line. But as AR capabilities advance, the technology may be hard to resist.

New capabilities have begun creating innovative ways for engineers and designers to interact with AR images. In the future, they might collaborate as the designer and engineer do in the Autodesk promotional video do, by clicking on images on their computer screen to make them hover above them, then testing whether those images merge smoothly.

It's not clear yet how they'll manipulate AR images, but it could be by using gestures, fingertips, a mouse click or a joystick jog. But developers are also creating new methods that allow users to interact with AR objects, Peddie said.

The Meta 2 AR headset, developed by a New York-based startup called Meta, lets a user fix an image on a computer monitor in mid-air, then browse the web by moving his or her hands around the virtual screen. He could also grab and drag a window around the suspended virtual desktop simply by making a fist and moving it through the air.

Meron Gribetz, Meta's chief executive officer,

The engineer's internal parts assembly slides inside the controller hologram.

It doesn't quite fit. An AR caution sign and other indicators shows where.

After a few tweaks to the parts assembly, the holograms fit. Voila!

demonstrated these capabilities at TED2016. He wore the company's signature headset and cradled a larger-than-life 3-D image of a brain, as an image on a large screen showed the audience what Gribetz was seeing. Then he grabbed the virtual brain with his hands and rotated it.

With this ability to control your PC using everyday gestures, called a gesture-led interaction, "we're all going to be throwing away our external monitors," Gribetz told the audience.

It may be a while, though. The Meta 2 sells for $949, and it's currently aimed at software developers. A consumer version of the Meta2 headset is under development but is not yet ready.

TOUCH AND RELEASE

Collaborators may also be able to treat a hovering image more like the actual physical object, Peddie said. "For instance, say I want a flange to be a little larger, so I made it bigger on the design. And you move it a little to the left. You could always have rotated the image [on a monitor], but now you can walk around it, to see from all angles how the changes would affect the design," he explained.

If a part couldn't be manufactured as designed, a manufacturing and a mechanical engineer with a tablet and headsets could redesign it right on the manufacturing floor—in seconds. This would eliminate the need for companies to send a part back to be redesigned, which would save them a lot of money, Peddie added.

Engineers may also be able to reach out and touch AR designs to get a feel for how they fit together. Autodesk and Microsoft have begun work toward a joint haptic system that would allow engineers to do this, though no release date has been set.

AR will also be useful for the Internet of Things and the Industrial Internet of Things, Jay Wright, PTC general manager for the Vuforia brand, has said. By visualizing data streaming back from sensors and controllers in real time, a farmer could get an instant look at crop moisture levels, or a shipping company could monitor and control a fleet of delivery drones and get instant feedback on delivery problems, maintenance issues and parts that need replacing.

At this point PTC and other companies are mostly brainstorming how to put AR to use in the Internet of Things, and they're hoping app developers will pick up the baton. In June the company released Vuforia Studio Enterprise (previously announced as Project ThingX), to help app developers integrate AR with the company's Creo 3-D CAD visualization and illustration software and its ThingWorx Internet of Things application.

AR today is like the Internet in its early days, when companies puzzled over how to leverage it to grow, Peddie said. But as engineers and manufacturers imagine new ways to use AR in their work, it could become almost old hat, just as television or CAD have today, Peddie said. "I predict that by 2020, we'll just stop talking about it." **ME**

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