

# Engineers using 'digital twins' to improve agriculture, health ...

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## Engineers using 'digital twins' to improve agriculture, health, manufacturing and more

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Every week, researchers visited a campus greenhouse, pulled out their phones, and took videos of millet plants, a hardy cereal crop grown worldwide.

They recorded the plants' structure and growth from sprouts to grain producers. With the help of an artificial intelligence tool called NeRF (for neural radiance fields), they converted their 2D videos into 3D digital models of the plants.

Shambhavi Joshi, an Iowa State University doctoral student from Indore, India, called up one of the digital models during a recent visit to a laboratory operated by Iowa State's [Translational AI Center](#).

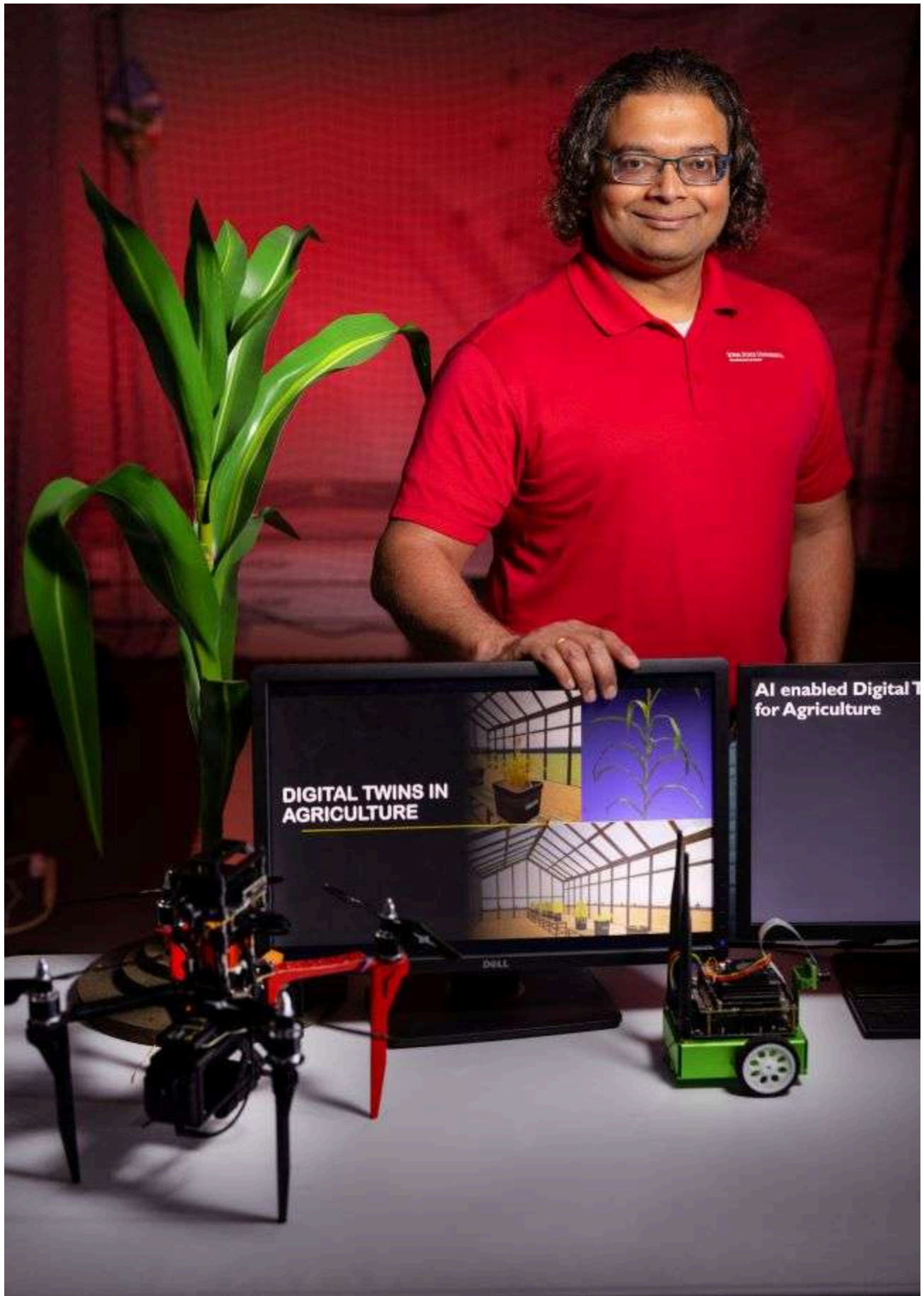
Spinning in its greenhouse pot, allowing you to study the full plant from any side, was a finger millet plant at stage 59 of its development. That's when 90% of the plant's reproductive structure emerges from its final leaf and stem.

This was far more than an illustration. It was 80 to 90 million points in space – “a point cloud” – containing data about the plant's color, shape and 3D structure.

It's also the beginning of the creation of a “digital twin,” a research tool that a committee of the National Academies of Sciences, Engineering and Medicine wrote has “immense promise in accelerating scientific discovery and revolutionizing industries.”

In its 2024 report, “[Foundational Research Gaps and Future Directions for Digital Twins](#),” the committee continued: “Digital twins have the capacity to revolutionize scientific research, enhance operational efficiency, optimize production strategies, reduce time-to-market, and unlock new avenues for scientific and industrial growth and innovation.”

**Digital twins need data updates**



**DIGITAL TWINS IN  
AGRICULTURE**

**AI enabled Digital T  
for Agriculture**

So, what is a digital twin?

The National Academies' report says it's a virtual construct that "mimics the structure, context, and behavior of a natural, engineered or social system." It says a digital twin is regularly updated with data from its physical twin. It also says a digital twin can help make predictions and inform decisions.

Aerospace engineers started using digital twins to help monitor and manage aircraft frames and engines, according to the report. NASA engineers first used the term in 2010.

"A digital twin needs real-time data from its physical counterpart," said Baskar Ganapathysubramanian, the Joseph and Elizabeth Anderlik Professor in [Engineering](#) and director of the [AI Institute for Resilient Agriculture](#) based at Iowa State.

In other words, a digital twin of, say, a corn plant needs to be regularly updated with data taken from a real plant growing in a greenhouse or in a field. That makes a digital twin dynamic and changing, like its real-world counterparts, rather than a standard, static computer model or simulation.

"We are always aligning the digital with the real world," said Soumik Sarkar, a professor of [mechanical engineering](#) and a principal investigator of [COALESCE](#), a project developing a cyber-agricultural system capable of using robots, drones and other technologies to manage individual crop plants within a field.

## Breakthroughs across agriculture

Building and studying digital twins is a major feature of the AI Institute for Resilient Agriculture, a research center based at Iowa State that launched in 2021 with a five-year, \$20 million grant from the U.S. National Science Foundation (NSF) and the U.S. Department of Agriculture's National Institute of Food and Agriculture.

"Using advanced sensor technology, scientists can create digital twins – virtual simulations that mimic real-world plants, crops and farms," institute researchers wrote. "For every year of biological data, digital-twin based AI systems can create hundreds of reality-based simulations."

According to the researchers, those simulations can:

- "Streamline and revolutionize" plant breeding so crops can withstand environmental, pest and disease challenges while providing higher yields and quality
- Help farmers adopt techniques and technologies that boost profits and improve the health of land and soil resources
- Provide governments with data and insights for policies that encourage the greatest benefits at the lowest environmental costs
- Share data and knowledge with ag companies to help them develop precision agriculture tools and better plant varieties that thrive with less water, fertilizer and pesticides
- And drive economic development in rural areas.

With the help of digital twins of crop plants – plus collaborations with plant scientists such as Arti Singh, associate professor of agronomy, and Asheesh (Danny) Singh, the G.F. Sprague Chair in Agronomy – the researchers wrote they “believe these breakthroughs – and more – can be a reality in the very near future.”

## Digital twins in heart health

Ming-Chen Hsu, a professor of mechanical engineering, is working to develop personalized digital twins that could help doctors monitor and detect problems with cardiovascular aging, such as heart disease.

I like this project so much because we’re doing the fundamental development. And our project is making this technology very applied to human health.”

Ming-Chen Hsu, Mechanical Engineering, Translational AI Center

Using data collected from wearable devices, medical imaging, blood tests and physical exams, project researchers are working to develop personal digital twins of patients’ cardiovascular systems. Because they’re regularly updated with patient data, the digital twins could offer early warnings of disease, even before symptoms are detected.

What makes the idea work?

“A lot of models in the past were a one-way street,” said Hsu, who specializes in computational modeling, including a project that [modeled heart valves in action](#). “They didn’t interact with real-world data. The computational models didn’t learn or evolve. These digital twins have to evolve.”

Because it’s not feasible to collect, say, heartbeat data over a human lifespan of nearly 80 years, Hsu is collaborating with Abhay Ramachandra, an assistant professor of mechanical engineering who specializes in animal models, to develop digital twins based on data from mice, which live about two years. The NSF is supporting their work with a three-year, \$605,825 grant.

“With the mouse data, we can control the experimental conditions, refine our models and use model predictions to design and test different scenarios for monitoring aging,” Hsu said.

Once the researchers have successfully tested their ideas with mice and their digital twins, they’ll study how the approach can be applied to human health.

“I like this project so much because we’re doing the fundamental development,” Hsu said. “And our project is making this technology very applied to human health.”

## Making manufacturing processes better

Adarsh Krishnamurthy, an associate professor of mechanical engineering, is using a digital twin to optimize a [new idea in 3D printing](#).

It’s part of a federal Materials Genome Initiative that’s focused on quickly advancing materials invention and use. As part of the effort, the NSF is looking for materials that “revolutionize and engineer our future.”

Using a 3D-printing process called Digital Light Processing – a process that uses light rather than heat to quickly cure and harden liquid resin into plastic layers – the researchers are exposing different parts of a single resin to two different wavelengths of light. That can produce complex structures with different material properties, structures with parts that are hard and parts that are flexible.

The digital twins he’s using – “computational models that simulate additive manufacturing” – are being used “to optimize the real-life manufacturing,” Krishnamurthy said.

In this case, the digital twins aren’t just visual. That’s because they’re not something the researchers need to actually see.

“For me, it’s the computations and the physics,” Krishnamurthy said. “We’re duplicating the physics.”

That can do two things for researchers and eventually manufacturers, Krishnamurthy said:

1. Working with the physics in the digital realm can help researchers optimize the geometries, the shapes, of what they’re trying to produce.
2. It can also help modify the real-time controls and parameters of a printing job to get the best result.

Krishnamurthy said he’s currently using digital twins for geometry optimization but has a goal to use the technology for real-time controls for 3D printing.

The real value of digital twins?

“We can run thousands of experiments in tandem,” Krishnamurthy said. “And we know for sure we’re replicating the physics of the real world.”

## **Helping find all the apples**

Nitesh Subedi, a doctoral student from Pokhara, Nepal, is studying how mini robots could be used to treat individual crop plants with the right amount of fertilizer or even harvest a crop.

He’s developed a virtual robot that’s using AI to learn to use its arms to move a plant so it can see behind it, just as a worker might move a branch to reach and harvest an apple. (See below.) That’s a difficult task for a robot. But, with artificial intelligence tools, the virtual robot is learning that too much pushing can damage a plant and whether it would be best to push to the right or to the left.



Soumik Sarkar

“You saw it was pushing the plant to the right, and that was too much,” Subedi said as a video of the virtual robot played. “It’s still learning, right? Now it’s switching back to push to the left.”

Nearby in the lab, a myBuddy 280 dual-armed robot stood before a plastic plant, ready to learn the exact same lessons in crop care and production.

The project is part of COALESCE, COntext Aware LEarning for Sustainable CybEr-Agricultural Systems. The research is supported by a five-year, \$7 million Cyber-Physical Systems Frontier award jointly funded by the NSF and the USDA’s National Institute of Food and Agriculture.

“This project aims to transform Cyber-Physical System capabilities in agriculture to enable farmers to respond to crop stressors with lower cost, greater agility, and significantly lower environmental impact than current practices,” project researchers wrote.

COALESCE is co-led by Sarkar, who also directs Iowa State’s Translational AI Center, a campus research center that was established in 2022. The center brings together AI researchers who are working in fields such as materials, manufacturing, health care, transportation, food, energy and the ethics of using AI technologies.

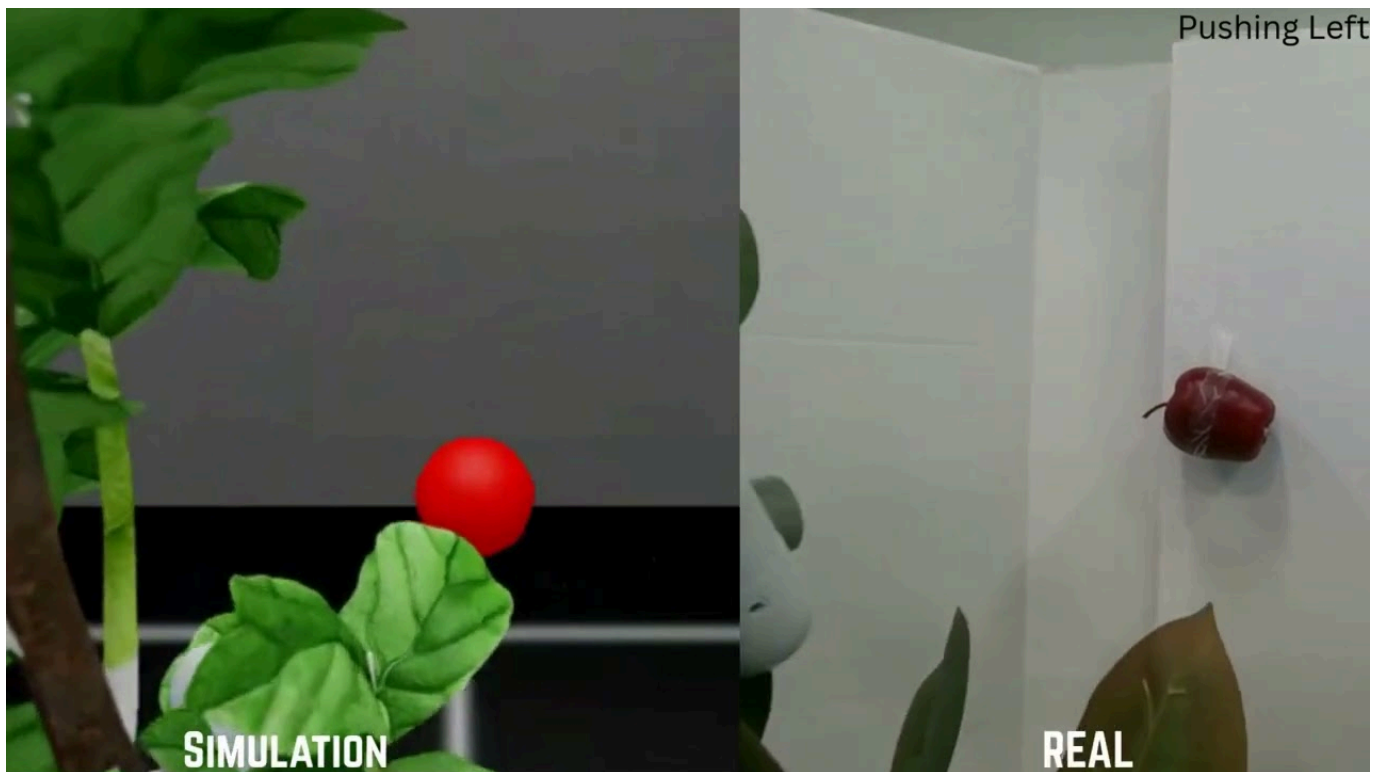
The center also helps manage major research projects, including ones developing digital twins.

“The Translational AI Center is helping us to manage these large efforts with many investigators and many students,” Sarkar said. “It helps with management, logistics, customers and stakeholders.”

It also helps to collect and share data. And it helps to attract and onboard students in computer science, agronomy, plant pathology, mechanical engineering and more.

The center is vital to these digital twins projects, Ganapathysubramanian said, because they “require artificial intelligence tools, interdisciplinary teams and deep domain science.”

The research teams’ findings could one day be vital to all of us, he said, because, “This is all leading to AI for end-uses.”



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