TECHNOLOGY & ADVANCEMENTS

Benson Hill employee Kevin Wang prepares a drone to evaluate field trials validating the company's CropOS cloud-based platform, which uses machine learning to predict plant cross-breeding outcomes.

BENSON HILL BIOSYSTEMS

Can Technology Solve World Hunger?

Machine learning is supercharging agriculture production

By Matt Alderton

ONCE UPON A TIME, the only way to produce more food was to farm more fields. When you consider challenges that include climate change, land scarcity and water insecurity, that's no longer a viable solution. Instead of more farms, humanity needs better farms, said Kumar Singa, project manager of the Living Lab at Siemens Corporate Technology in Princeton, N.J. In 2018, his team unveiled a project with a goal of applying automation technology to a growing concern: world hunger.

Singa said that Siemens' contributed modular plant towers that resemble a tiered cake of egg crates and soil. These Autonomous Agricultural Pods, or AgPods, are "micro vertical farming units" outfitted with grow lights and wireless sensors that measure moisture, pH, temperature and other variables. Part of the Internet of Things (IoT) — physical items that aggregate digital information and stream it to the cloud for the purpose of providing intelligence or services — these sensors stream real-time data to MindSphere, Siemens' cloud-based operating system, which continuously assesses plant health and automatically

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Benson Hill employees Soumitra Khair and Abree Lamke review corn phenotypes in the company's St. Louis greenhouse.

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adjusts crop inputs to provide optimal growing conditions. For example, when plants need water, the system alerts autonomous robots that subsequently transport AgPods to a watering station to receive the precise amount of needed moisture.

The system's linchpin is machine learning: Algorithms inside MindSphere ingest terabytes of crop data, then pair predictions with outcomes to isolate which inputs produce the best outputs with the fewest resources. In other words, computers do what farmers have done for millennia, but faster and more precisely: They observe how crops are growing, make guesses about what's helping or hurting them — too much water, for instance, or not enough — and then make adjustments. Over time, they watch how various tweaks affect crops and commit the lessons to memory, increasingly calibrating growing conditions each time to produce more and better crops, more quickly and with a smaller environmental footprint.

"By combining the IoT with knowledge of the crop, I can maximize my crop yield in the shortest possible time, using the least amount of power and the least amount of water," Singa explained.

Currently, AgPods are still in the testing phase, so not yet commercially available. Siemens is working with Rutgers University through a FutureMakers project to further test the technology. Eventually, Siemens hopes that the AgPods will be beneficial for "any grower ranging from a single farmer with a single AgPod to huge farms with self-managed AgPods."

Because they're compact, Siemens initially is testing AgPods with leafy greens that can be sustainably grown indoors in urban warehouses. With just

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AgPods constantly monitor what plants need.

SIEMENS

a few modifications, however, Singa said AgPods can be scaled up and re-fashioned for outdoor use to accommodate virtually any type of crop in practically any environment. Used on a global scale, Singa hypothesized, such a system could "help solve a huge food crisis."

It's just one example of how machine learning can address world hunger by pairing new capabilities with age-old farming techniques. Here are three others:

BENSON HILL BIOSYSTEMS: ENGINEERING BETTER CROPS

To the naked eye, corn is corn. But crops aren't clones. Like humans, each has distinct characteristics based on its individualized genetic profile. One corn variety, for example, might taste sweeter than another. Another might be more resistant to disease, or more tolerant of drought. Still another might grow bigger, taller, faster.

To grow healthier, tastier and more sustainable crops, plant breeders traditionally have isolated specimens with desirable traits and combined them through natural or artificial reproduction. Because it hinges on trial and error — breeders must guess which traits will pass from parent to progeny, then test their hypothesis over one or more growing seasons — the process takes many years spanning several generations.

St. Louis-based Benson Hill Biosystems has devised a way to speed things up. Called CropOS, its solution is a cloud-based computing platform that uses machine learning to simulate all potential offspring that might result from crossing one plant variety with another. The outcome is a road map that leads breeders to the traits they want in a fraction of the time, according to Benson Hill co-founder and CEO Matt Crisp, who said CropOS already is being used by research and development departments at seed and ingredient companies. He expects those efforts to yield new seeds for use by farmers within the next three to five years. In some cases, maybe sooner.

"CropOS allows us to process huge amounts of data to associate various genomes with their outcomes. The more we can understand about how plants produce something of value, the easier it is to breed them in a manner that supplies that outcome," explained Crisp, who said seeds won't necessarily cost farmers more money on the front end, but could result in more profit by yielding more and better products for which they can charge a premium.

The potential is even greater when breeders use CropOS in tandem with contemporary gene-editing technology, which allows scientists to streamline breeding by inserting, deleting, modifying or replacing the DNA in a plant's genome.

"It might take you seven to 12 years to breed a better product using conventional approaches. Using CropOS, you could breed the same product in half the time," Crisp said. "Using CropOS plus genome editing, you could get the same product in half of that time."

"Data combined with these sorts of machine learning algorithms brings tailored precision to farming at the field and sub-field level in a way that we've never seen before."

– SAM EATHINGTON, chief science officer at The Climate Corporation

The possible effect on the global food supply is evident in crops like soybeans, which over many generations have been bred to increase crop yields at the expense of protein content. The combination of machine learning and gene editing that CropOS utilizes could help farmers grow soybeans that are as nutritious as they are prolific.

"The intersection of machine learning with plant biology will allow us to create faster — and for less cost — crops that are healthier and more sustainable," Crisp said. "And that's really powerful."

THE CLIMATE CORPORATION: MAKING SEEDS SUCCESSFUL

Real estate agents are famous for the "location, location, location" mantra. As it turns out, so are farmers, whose output hinges not only on what crops they plant, but also on where they plant.

"Productivity on a farm is a function of genetics, management practices and the environment. It's quite a complex equation," said Sam Eathington, chief science officer at San Francisco-based The Climate Corporation, a Bayer subsidiary that focuses on agricultural data science.

It's the same equation that Benson Hill is trying to solve. Instead of using genetic data to breed new plant varieties, however, Climate is using it to pair

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The Climate Corporation created FieldView to allow farmers to monitor field maps in real time. Its newest project, Seed Advisor, uses advanced technology to recommend specific crops.

THE CLIMATE CORPORATION

existing plant varieties with individual fields based on the growing conditions in which they perform best.

"In a farming operation today, you look at what performed well for you last year. And if you're a little more sophisticated, maybe you get some data from local trials or from your seed providers. That's how you select what hybrids to plant on your farm next year," Eathington said. "We have a lot of data from our research programs and from our work with growers. So we looked at that and wondered: Could we take all that data and process it to make insights that help us recommend what hybrid a farmer should plant on their field?"

To perform these tasks, Climate created Seed Advisor, an agricultural matchmaker that uses machine learning algorithms to parse crop data with environmental data from farmers' fields in order to make recommendations about which crop varietals they should plant, where and at what rate. Based on inputs that include climate, soil type and yield, recommendations are tested, and the results used to further train and refine the algorithm such that it improves after each growing cycle.

During trials that began in 2017, Climate compared the varietals it recommended with those preferred by farmers and found that the former outperforms the latter 80 percent of the time, adding an average of nine bushels per acre to farmers' yields on the exact same ground.

"If we can increase yields by being smarter about what seeds to select, I believe we will also be able to increase things like water efficiency using the same method," explained Eathington, who said Seed Advisor is currently undergoing testing and is expected to make a full commercial rollout in 2020. At $4 per acre, Climate expects it to benefit small and large growers alike. "Data combined with these sorts of machine learning algorithms brings tailored precision to farming at the field and sub-field level in a way that we've never seen before."

BLUE RIVER TECHNOLOGY: WEEDING OUT WASTE

In agriculture, weeds are wicked. But then again, so are weed killers. Every year, farmers spend $25 billion to spray 3 billion pounds of herbicides, runoff from which can contaminate water and soil while also giving rise to herbicide-tolerant weeds that threaten long-term agricultural productivity.

To maximize herbicides' benefits and minimize risks, John Deere subsidiary Blue River Technology of Sunnyvale, Calif., has pioneered See & Spray machines that use computer vision and machine learning to apply herbicides with a surgical touch, ensuring that chemicals reach only targeted areas in small quantities in order to reduce waste and environmental fallout.

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Blue River's See & Spray smart machines reduce herbicide usage by 80 percent.

BLUE RIVER TECHNOLOGY

Here's how it works: Affixed to tractors that comb farmers' fields, the machines use cameras to identify plants, images of which are fed to computer processors that use machine learning algorithms to instantly classify them as weeds or crops. As if spot treating stains on a carpet, the machines apply herbicides only to the former. Finally, a second set of cameras checks the machines' work, conclusions from which are used to further train and refine the algorithms, resulting in a closed-loop system that gets perpetually better over time.

According to Blue River, the system reduces herbicide usage by 80 percent. Company co-founder and CEO Jorge Heraud said sprayers are currently in the "advanced prototyping stage," and he eventually sees his machines applying in the same precise manner — plant by plant instead of field by field — fertilizers, fungicides, insecticides and water.

"This has three big benefits," Heraud said. "No. 1 is sustainability — precisely spraying herbicides only where they're needed prevents herbicide-resistant weeds and reduces waste. Another benefit is profitability. One farmer told me he spends $250,000 a year to control weeds; imagine if he could cut that to $50,000 per year. And the third benefit is increased understanding; because our machines go through the same fields multiple times, you can use them to track plants from seed to harvest and see how they grow. Scaled across multiple fields, that can help us crack the code of how to farm better."

Ultimately, that's the promise of machine learning: Whether it's used to breed, seed or weed crops, it accelerates agricultural evolution.

Singa concluded: "Imagine a farmer who's been farming for 35 years. In that time, he will have seen 70 to 80 cycles of crops on his farm, learning along the way what issues his farm faces and how to mitigate them. As a result, his 80th crop is bound to be much better than his first crop. With machine learning, we can generate the same kind of knowledge faster and more efficiently."