Computer vision system tracks plant growth to guide specialty crop monitoring

February 27 2025, by Jeff Mulhollem

The researchers discuss the project in its early stages. From left are Aline Novaski Seffrin, doctoral candidate in plant science; Francesco Di Gioia, associate professor of vegetable crop science; and Chenchen Kang, a former post-doctoral scholar in the Department of Agricultural and Biological Engineering. Credit: Penn State.

Soilless growing systems inside greenhouses, known as controlled environment agriculture, promise to advance the year-round production of high-quality specialty crops, according to an interdisciplinary research team at Penn State. But to be competitive and sustainable, this advanced farming method will require the development and implementation of precision agriculture techniques. To meet that demand, the team developed an automated crop-monitoring system capable of providing continuous and frequent data about plant growth and needs, allowing for informed crop management.

Their research is published in the journal *Computers and Electronics in Agriculture*.

"Traditionally, crop monitoring in controlled environment agriculture soilless systems is a critical, time-consuming task requiring specialized personnel," said team lead Long He, associate professor of agricultural and biological engineering. "And traditional crop-monitoring methods do not allow frequent data collection to capture plant growth dynamics throughout the crop cycle. Automated crop-monitoring systems allow continuous monitoring of the plants with frequent data collection and a more efficient and informed management of the crop."

In their findings, the researchers reported that an integrated "internet of things," artificial intelligence (AI) and a computer vision system tailored for controlled environment agriculture soilless growing systems, enabling continuous monitoring and analysis of plant growth throughout the crop cycle. An internet of things—often referred to as IoT—is a network of physical objects that can connect and exchange data over the internet, linking devices that are embedded with sensors, software and other technologies.

According to the team, the core innovation of their research is the implementation—for the first time—of a recursive image segmentation model that processes sequential images, captured in high resolution at predetermined time intervals, to accurately track changes in plant growth. In the study, the researchers tested their approach by monitoring baby bok choy, a leafy vegetable commonly called Chinese cabbage, but the researchers said it would work with many different crops.

In this study, the integrated machine vision system successfully isolated individual baby bok choy plants growing in a soilless system, producing frequent images that tracked increased leaf coverage area throughout their growth cycle. Credit: Penn State.

He's research group in the College of Agricultural Sciences, located at Penn State's Fruit Research and Extension Center at Biglerville, has focused on automated, precision agriculture for more than a decade, devising robotic solutions for agricultural applications such as crop picking, tree pruning, green fruit thinning, pollination, orchard heating, pesticide spraying and irrigation. The machine vision system employed in this research is an advancement of technology the group developed for other purposes in previous studies.

In this study, the integrated machine vision system successfully isolated individual baby bok choy plants growing in a soilless system, producing frequent images that tracked increased leaf coverage area throughout their growth cycle. The researchers said the recursive model maintained a "robust performance," providing accurate information throughout the crop growth cycle.

He credited Chenchen Kang, a post-doctoral scholar in his lab and first author on the study, for supplying the innovation and hard work needed to "teach" the computer vision system to track plant growth.

"Chenchen installed the sensors, collected and processed the data, developed the methodology and did the coding and programming work with the AI models," He said.

Study first author Chenchen Kang programmed the AI models and trained the computer vision system to track plant growth. Credit: Penn State.

The research was an interdisciplinary project between agricultural engineers and plant scientists, and it is part of a larger federal project titled "Advancing the Sustainability of Indoor Urban Agricultural Systems."

Francesco Di Gioia, associate professor of vegetable crop science and principal investigator on the overarching project, stressed the importance of integrating different expertise for the development of precision agriculture solutions. The interdisciplinary approach, he suggested, will be increasingly critical in advancing the efficiency and long-term sustainability of current controlled-environment agricultural systems.

"The ability to automatically monitor and collect data on the crop status, estimate plant growth and crop requirements along with the monitoring of the nutrient solution and of the environmental factors—radiation, temperature and relative humidity—combined with the use of IoT and AI technologies, is going to revolutionize the way we manage crops," Di Gioia said. "Minimizing inefficiencies and improving the competitiveness of controlled environment agricultural systems will enhance our food and nutrition security."

In the future, Di Gioia added, the integration of precision agriculture technologies in controlled environment agricultural systems may also offer the opportunity to enhance the quality of specialty crops and even tailor their nutritional profile.

Xinyang Mu, who graduated with a doctoral degree in agricultural and biological engineering from Penn State and is currently a postdoctoral scholar at Michigan State University, and Aline Novaski Seffrin, doctoral candidate in plant science, contributed to the study.

More information: Chenchen Kang et al, A recursive segmentation model for bok choy growth monitoring with Internet of Things (IoT) technology in controlled environment agriculture, *Computers and Electronics in Agriculture* (2025). DOI: 10.1016/j.compag.2024.109866

Provided by Pennsylvania State University

growth-specialty-crop.html