Developing sensors for precision agriculture

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One of the prototype sensors Dr. Alex Thomasson and colleagues are proposing to use for taking measurements of energy sorghum variety trial plants. Such a system has the potential to take automated measurements of thousands of plants individually, at a much higher level of accuracy than humans — and even work at night. Credit: Robert Burns

Imagine, if you will, a tractor pulling a fertilizer wagon travelling at 8 to 9 mph along a field of thousands of sorghum test plants.

As the tractor moves through the field plots, an onboard computer linked to sensors measures everything from plant height and development to nitrogen needs.

While you're at it, imagine the tractor is driverless; that its operation may be monitored remotely by a human, but the minute-to-minute, hour-to-hour decisions are being made by computer software, said Dr. Alex Thomasson, Texas A&M AgriLife Research agricultural engineer, College Station.

And though such a scenario might sound like science fiction, the reality is not that far away, Thomasson said.

Thomasson has been developing hardware and software for precision agriculture and remote sensing for much of his career.

To date, precision agriculture has been largely about adjusting inputs to known variability within a field. For example, instead of applying fertilizer at the same rate across a 160-acre center pivot circle, precision agriculture systems use data on soil type and residual fertilizer variability to define different management zones within the 160 acres. Fertilizer is then applied to the management zones at optimal rates controlled by a GPS/computer-equipped tractor or through the irrigation system.

But Thomasson wants to take precision agriculture to another level. He wants to develop sensor/computer hardware and software that can determine individual plant status real time, as the tractor automatically transverses the field.

Thomasson is currently working on a system that will be able to aid plant breeders in sorting through the thousands or even tens of thousands of plants for the development of new varieties.

A team comprised of Thomasson; Dr. Bill Rooney, AgriLife Research plant breeder; and John Mullet, AgriLife Research biochemist, is designing such a system for selecting energy sorghums – cultivars used to produce bioenergy rather than food stocks.

"In general, energy crops are likely to be produced with minimal inputs in terms of nutrients, water, etc.," Thomasson said. "Therefore, developing cultivars that have high yield, drought tolerance and high nitrogen use efficiency is of vital importance to a successful sorghum-based energy supply industry."

Rooney and other breeders have been working on new varieties for years. Whether produced by conventional plant crosses or genetic manipulation, the first selections of any breeding program rely a great deal upon observable characteristics of individual plants – what's called "phenotyping."

"A major limitation in the genetic improvement of energy crops is the collection of large, good quality phenotypic data," Thomasson said. "Traditional plant phenotypic measurements rely on humans, and are slow, expensive and subjective."

The team's goal is to develop a phenotyping system for energy sorghum with the emphasis on three important traits: yield, drought tolerance and nitrogen use efficiency.

"It will enable the measurement of plants along their full growth cycle, allowing the traits such as speed and form of growth, flowering and final biomass yield/quality to be investigated," he said.

The team is currently considering development and testing of five types of sensors:

- Down-looking six-band, multi-spectral camera.

- Down-looking thermal imaging camera.
- Light curtain.
- Side-looking camera.
- Ultrasonic sensor.

The six-band, multi-spectral camera can be used to assess nitrogen content, growth status and plant size. The thermal imaging camera can measure plant canopy temperature and water content. The light curtain can measure plant height, projected plant profile and plant size. The side-looking camera can give a plant profile view. And the ultrasonic sensor can give yet another measurement of plant height.

"The redundancy is desirable as some sensors perform better in greenhouses, while others are more suitable for field applications," Thomasson said. "Having a complementary set of devices and techniques for plant measurements will enable us to have different systems suited to specific environments."

Other indicators of plant performance can be derived from a combination of measurements from the group of sensors.

"For example, combining projected leaf area with plant height can be a good indication of plant size and thus the amount of biomass," he said. "Combining the down-looking and side-looking images of the plant provides the opportunity for the 3-D reconstruction of the plants."

Another advantage of the automated sensor approach is that readings on a very large number of plants could be collected weekly or even daily at a high level of accuracy, a process that would not ordinarily be economically feasible using human workers, Thomasson said.

An equally challenging aspect of the project is software development. First there will need to be a program running on a computer to control and coordinate the sensors. Second, there will need be "robust image-processing algorithms" able to distinguish sorghum plants from the background. And finally, a specialized program will need to be developed to store sensor output in a relational database.

Most of the sensors Thomasson is proposing have been proven in one application or another, but not comprehensively for purposes of selection of breeding lines, and not on an autonomous platform, he said.

"There has been some sensor-based phenotyping research done in the past on plants, but a turnkey system doesn't exist," he said. "My goal is always to try to get the technology to a commercialization phase, and I think this has potential.

"At this point, however, we want to demonstrate that our platform can provide rapid and cost-effective ranking and screening of hundreds of candidate lines for the desired traits, and eventually lead to a more efficient energy sorghum breeding program," Thomasson said.

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