Sensors

Agricultural Cyberbiosecurity Education Resource Collection

Authored by David Smilnak, Dr. Robin White, Jaylan Day, and Dr. Hannah Scherer,

Sensors in Society

Sensors are prevalent throughout our society. For example, when you use a fingerprint to log into a smartphone, a **biometric** sensor is used. Similarly, "clap-on" lights use audio sensing to detect a clap signal to change the status of a light from off to on, or vice versa. In agriculture, sensors are used to measure things like soil moisture, nutrient concentrations, or animal activity. The breadth of applications for sensors within society demonstrates their importance in the modern world. As societies move faster and faster, sensors provide rapid measurements of important parameters.

Sensors are devices that measure some sort of physical property. For example, a lot of smartwatches can measure physical properties like heart rate or the number of steps taken. The measurement of physical properties is important because those measurements drive information or action. For example, wearers of those smartwatches may use those measurements to make decisions about their fitness routines. In agriculture, sensors measure various physical properties of a farm, field, or animal that help drive management decisions. Sensors are critical to the advancement of **precision agriculture** because they allow: 1) more measurements to be taken; 2) at a faster time scale; and 3) at a lower cost. These attributes of sensors are also what has made their expansion into society so prevalent.

One of the major advantages of sensors is that their measurement time is nearly instantaneous. Agricultural sensors like moisture monitors can continuously report on soil moisture measured in milliseconds, whereas traditional measurement of soil moisture requires time and labor to collect, weigh, and dry a sample. Providing data instantaneously, or in "real-time", allows a more precise capacity to respond to measurements

Types of Sensors

Within agricultural systems, a variety of sensing approaches are used. These approaches, in turn, drive a variety of decision-making options that have not historically been possible. Although not an exhaustive list, an example of some types of sensors, the types of measurements they collect, and how they inform decisions is provided below:

Location Sensors use GPS data to determine the exact locations of equipment, crops, animals, etc. Location sensors on equipment like drones and tractors allow for autonomous operation. Location sensors on animals can provide useful data about the animal's motion or behavior.

Figure 1: A tractor's GPS readout and controls "GPS Steers The Tractor" by cogdogblog is marked with CC0 1.0.

Optical Sensors use light to measure soil properties. Soil's ability to reflect light provides data about the moisture, texture, and organic matter of the soil.

Electrochemical Sensors use electrodes, like those found on the ends of batteries and starter battery cables, to determine pH and soil nutrient levels. Soil pH measures how acidic or alkaline the soil is, an important metric because plants can prefer different soil environments.

Figure 2: Ground penetrating radar measuring soil composition. "Ground Penetrating Radar" by Travis S. is licensed under CC BY-NC 2.0.

Mechanical Sensors measure soil compaction by determining the **resistive force** of the soil. A high resistive force means that the soil is compacted. Compacted soil means that less oxygen passes into the soil, less water drains into the soil, and the roots of crops must exert a larger force to penetrate the ground. Similarly, mechanical sensors are used to determine the pulling requirements of ground equipment like plows, harrows, and spreaders.

Airflow Sensors measure how well air can spread through soil. Airflow sensors produce information about soil compaction, moisture levels, and soil type.

Agricultural Weather Stations are usually a combination of sensors that provide information about ambient temperature, relative humidity, indicators of rainfall, wind speed, wind direction, etc. Several of these stations are placed throughout a growing field, and the data is compiled and sent to one central program. Agricultural Weather Stations are the most practical sensors for farms due to their low cost and mobility.

Figure 3: An agricultural technician checking weather data. "Weather Stations Synthesize Data for Individual's Needs" by USAID_IMAGES is licensed under CC BY-NC 2.0.

Sensors in Systems

Although sensors are an important component of precision agricultural systems, their job is primarily measurement. That means that sensors must work as part of a broader system to support decision-making. Specifically, the data from a sensor must be communicated to the device (or human) responsible for making decisions. In the example of the "clap-on" light, the audio sensor must send the audio data detected to the light switch. The light switch then responds to that data by changing from off to on. Similarly, in an agricultural application, a soil moisture sensor must send the data to the farmer, who then makes a decision about irrigation needs for that field. As a result, sensors are critical team players in technology systems, but they are not responsible for actions within those systems.

Sending data from a sensor to a decision-maker requires connectivity. There are lots of different types of connectivity. For example, data from sensors can be sent via the internet. Similarly, communication technologies such as cellular networks or Bluetooth can be used to send data from sensors. In practice, this connectivity means that a manager can know the status of the land, animals, buildings, etc. from anywhere in the world.

One major challenge with sensor-based decision-making is related to the reliance of sensors on connectivity. Specifically, sensing data over the internet or connectivity technologies like cell phones and Bluetooth provides greater vulnerabilities within the system. Imagine that the data coming from a soil moisture sensor was hacked to show adequate moisture during a period of drought.

Connection to Cyberbiosecurity

Sensors can provide a lot of data about a farm's operation. However, **data literacy** and a little research are required to use the data productively. For example, a sensor could reveal that the soil compaction in an area is high. It is up to the farmer to decide what to do with that information. They could conclude that the area is unsuitable for farming, or they could use a different farming technique to decrease soil compaction.

The data produced from sensors could be used to harm a farm, so it should be protected. For example, let's suppose that an autonomous drone was hacked. The hacker could use the drone to determine the size and location of everything in your farming operation, information that is valuable to competing farms. Also, that hacker could use the drone to disrupt other processes around the farm, such as disturbing animals when they are sleeping. If the drone was doing a task like spreading fertilizer, the hacker could use the drone to commit **bioterrorism** in the local area. These are just a few examples of a sensor cyberattack. Innovators in the cyberbiosecurity field will be challenged with trying to protect a farm's entire technological space.

Glossary

Biometric: Involving the automated recognition of individuals by means of unique physical characteristics, typically for the purposes of security.

Bioterrorism: The intentional release or dissemination of biological agents, typically to cause fear or violence, for political purposes.

Data Literacy: The ability to read, understand, and communicate data.

Precision Agriculture: Technology that maximizes the efficiency of a farm but is not critical to farm operations.

Resistive force: A physics term used to describe a force that is in the opposite direction of motion. Gravity pulling a thrown ball back down and the friction of sliding a box are two examples of resistive force.

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About the authors

This resource was developed by faculty and students at Virginia Tech: David Smilnak, Ph.D. Candidate in the Department of Agricultural, Leadership, and Community Education; Dr. Robin White, Assistant Professor in the Department of Animal and Poultry Science; Jaylan Day, Undergraduate Student in the Department of Chemistry; Dr. Hannah H. Scherer, Associate Professor and Extension Specialist in the Department of Agricultural, Leadership, and Community Education.

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About this project

Cyberbiosecurity is an emerging field that focuses on creating security measures for digital aspects of our food and agriculture systems, creating a structure and opportunity for a safe food system that can meet the large needs of a growing population and world. This educational resource was developed as part of a project to support formal and non-formal agricultural educators in integrating cyberbiosecurity topics and research-based strategies for engaging middle-school-aged girls in STEM into their educational programs.

The entire resource collection can be accessed here: https://doi.org/10.21061/cyberbiosecurity

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