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Wireless tracking of cotton modules. Part 2: Automatic machine identification and system testing

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ABSTRACT

The ability to map profit across a cotton field would enable producers to determine where money is being made or lost on their farms and to implement precise field management practices to facilitate the highest return possible on each portion of a field. Mapping profit requires knowledge of site-specific costs and revenues, including yield and price. Price varies site-specifically because fiber quality varies, so mapping fiber quality is an important component of profit mapping. To map fiber quality, the harvest location of individual cotton bales must be known, and thus a system to track the harvest location of cotton modules must be available. To this end, a wireless module-tracking system was recently developed, but automation of the system is required before it will find practical use on the farm. In Part 1 of this report, research to develop automatic triggering of wireless messages is described. In Part 2, research to enable the system to function with multiple harvesting machines of the same type in the same field – a common situation in commercial cotton farming – is described along with testing of the entire automated wireless module-tracking system (WMTS). An RFID system was incorporated, and it enabled the WMTS to correctly and consistently differentiate among various harvesting vehicles. The improved WMTS subsequently sent wireless messages to the correct machines when cotton transfers were made in the presence of multiple harvest machines. Overall testing proved that the automated WMTS worked largely as designed. When both complete and partial cotton basket dumps were simulated, the correct wireless-messaging decision was made 100% of the time.

1. Problem definition

1.1. Background[1]

An initial step in using precision-agriculture practices to improve profitability is to create a yield map of a field. This capability has been realized in cotton with the invention and commercialization of harvester-based yield-monitors (Wilkerson et al., 2001; Thomasson and Sui, 2003). If fiber quality information is also available, profit maps (discussed in Part 1 of this report) can be generated and enable the producer to determine which parts of the field require higher or lower levels of inputs from an economic standpoint.

With the recent development by Ge et al. (2006) of a wireless module tracking system (WMTS), producers now have the fundamental capability to accurately determine from where specific modules of cotton originate. The modifications to Ge's (2007) module tracking system detailed in Part 1 of this article enabled the WMTS to automatically determine when a wireless message ought to be sent to convey module identification from machine to machine. This initial capability greatly reduced the chance of human error in module tracking and allowed the operator to maintain focus on the harvest. Developing the system's capability to function with multiple machines of the same type (Fig. 1) was still necessary for complete automation and commercial applicability of the WMTS. Real-world cotton harvesting operations often involve multiple harvesters, boll buggies, and/or module builders in the same field, and thus many different machine-to-machine dump situations are possible and many opportunities for module tracking errors.

To accurately track the harvest location of cotton from within a field, the two harvesting machines involved in a single cotton transfer must be known. In the current system (Ge, 2007) the harvesting machine that is dumping merely sends out a wireless signal to any wireless-enabled harvesting machine within roughly a one-mile radius. If two module builders happened to be within that distance, each module-builder's tracking system would record hav-

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[1] Definitions of the following terms commonly used in cotton production are included in Part 1 of this report: Cotton Bale, Cotton Module, Cotton Harvester, Boll Buggy, and Module Builder.

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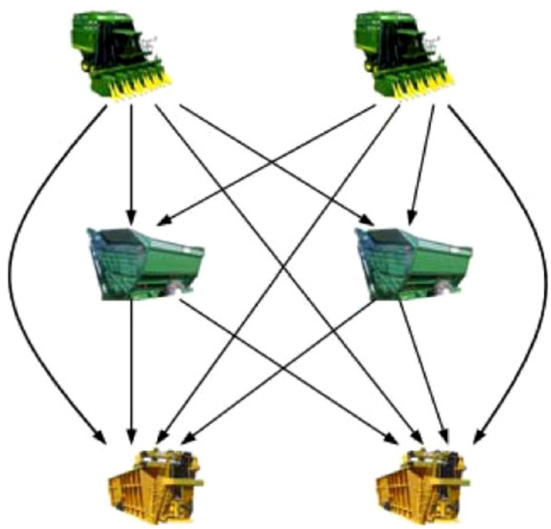

Fig. 1. Numerous dumping situations are possible with two harvesters, two boll buggies, and two module builders
(Ge, 2007, used with permission).

ing received cotton from the transmitting harvester or boll buggy, and both tracking systems would assign a module number, with one being incorrect and redundant – under normal circumstances, there should only be one module number per basket of cotton. Further software development and use of sensors were required to enable the system to determine which harvesting machines are involved in a specific cotton transfer.

1.2. Literature review

In order to make the system capable of working with multiple similar machines, some mechanism must be used to enable the machine that is dumping to recognize the receiving machine. Therefore, literature concerning the recognition of one machine by another is included along with consideration of how the given technology might be used in the WMTS.

One potential method for determining machine identity by determining the location of harvesting equipment involves global positioning system (GPS) receivers. Single-frequency GPS receivers were installed on a remote buoy and a moving ship off the coast of New Jersey to show how the distance between objects can be determined with GPS (Doutt et al., 1998). The researchers compared GPS coordinates from the buoy's receiver with those of two receivers on the ship. Distances between the buoy and each of the ship's receivers were calculated, while the distance between the ship's receivers remained constant. The three distances allowed for triangulation to be used to determine the ship's distance from the buoy with centimeter-level accuracy at a distance of 5 km (3.1 mi). By installing individual GPS units on each cotton harvesting machine, the position of each could be calculated relative to the others. For example, a harvester tracking system could wirelessly request GPS coordinates from all available harvesting vehicles during dumping and then, upon receiving the data, compare other machine positions to its own position. By simply subtracting corresponding latitude and longitude values the system could identify the machine closest to the harvester and therefore the one receiving its basket of cotton. However, in the event that two receiving machines are in close proximity to the dumping machine during a dump, the proximity calculation would have difficulty determining which machine was actually receiving the cotton.

Radio-frequency identification (RFID), which is becoming more and more present in agriculture, presents an alternative that could more easily be integrated into the current WMTS with little modification to the current overall program code. This technology uses two devices, a reader and a tag, mounted on separate objects, to transfer data wirelessly between the objects. When initiated by a user or automated system, the reader scans its surroundings for tags by sending out a signal at a specific frequency. All compatible tags within the reader's range are activated by the signal and respond by sending out stored data. Bekkali and Matsumoto (2007) created a tracking algorithm that calculated the distance and position of robots relative to stationary RFID antennas. Since they are stationary while a cotton module is being built, module builders could be set up as RFID antenna (reader) locations, and RFID tags could then be attached to the harvesters and boll buggies. Having multiple stationary reader locations would maximize the coverage area for detecting tags, but a complicated algorithm would be required to differentiate the various RFID signals. On the other hand, if readers were installed on the mobile machines (harvesters and boll buggies), a reader would not need to detect RFID tags farther away than roughly 6 m (20 ft), since reading would be required only during cotton transfers, and the machines involved in a transfer would necessarily be within that distance of each other. An RFID reader could be used on the dumping machines (harvesters and boll buggies) to initiate communication only during a dump, and RFID tags could be used on receiving machines (boll buggies and module builders) to respond to the readers' communication. Having multiple mobile machines with RFID readers moving throughout a field could allow a simpler algorithm to be used. The algorithm, running on the tracking system of each mobile machine, could be used to determine the closest receiving vehicle during dumping. The short and adjustable transmitting distance of some RFID systems could reduce the chance of detecting the incorrect receiving machine. Moreover, the RFID reader's antenna could be positioned to scan for RFID tags in a specific direction, such as only the side of the harvester where the receiving machine would be positioned. These qualities of RFID make it a simpler and more reliable choice for the WMTS.

1.3. Objectives

The objectives of this research are (1) to make the wireless module tracking system (WMTS) of Ge (2007) capable of automated wireless message triggering, and (2) to make the WMTS compatible with multiple instances of similar machinery (i.e., more than one harvester, boll buggy, and/or module builder) in a given field. Objective 2 is discussed within this article – Part 2 – as well as testing the overall automated system.

2. Materials and methods

2.1. RFID system

2.1.1. Component selection

Tracking an identification number (ID) associated with a basket of cotton can be accomplished by having the dumping machine's tracking system send the ID to the receiving machine when a dump is occurring. A gain-adjustable RFID reader (2.4 GHz active RFID reader, Simple Technology Inc., Henderson, NV) was selected for use in identifying the receiving machine. This reader has adjustable read distance, high reliability, and rugged construction as required for agricultural applications. The specifications of the RFID reader (Table 1) indicate that it operates in two modes, allowing the RFID tag messages to be either received and uploaded to the host computer automatically (direct mode) or saved by the reader and uploaded to the host computer when the reader is prompted (buffering mode). This capability is important in differentiating the