WIRELESS GPS SYSTEM FOR MODULE-LEVEL FIBER QUALITY MAPPING: SYSTEM IMPROVEMENT AND FIELD TESTING

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Abstract

A wireless GPS system for module-level fiber quality mapping has been developed at Texas A&M University. In its complete form, it includes subsystems for harvesters, boll buggies, and module-builders. The system was field-tested on a producer's farm near Plains, Texas in 2006. The field test identified the following problems: (1) lack of a needed boll-buggy subsystem, (2) limited wireless signal transmission range, and (3) software inefficiency. In 2007 improvements were made to tackle these problems: (1) addition of a boll-buggy subsystem, (2) placement of wireless antennas on top of the cabs of the harvester, boll-buggy tractor, and module builder via extension cables, and (3) redesign of software. Two additional field tests were conducted on the improved system on the Texas Agricultural Experiment Station cotton fields. The results showed that the system performed satisfactorily with no hardware or software malfunctions. Tracking of a basket load from harvester to boll buggy to module builder can be implemented automatically, with wireless transmission range being greatly enhanced. Spatial variation of certain fiber quality parameters (such as micronaire, Uniformity, Rd, +b) is shown in module-level fiber quality maps. The system is quite promising and can be mounted on commercial cotton harvest equipment for fiber quality mapping, so that site specific crop management can start to address fiber quality in addition to lint yields.

Introduction

Fiber quality mapping is an advanced site-specific crop management application that would have economic benefits for cotton producers. Several scientists have produced cotton fiber quality maps by means of manual sampling and spatial interpolation (Johnson et al., 2002; Wang, 2004; Ge et al., 2007). However, such a method has several disadvantages. First, it is very time-consuming and costly, and not suitable for large-scale fields. Second, manually harvested cotton differs significantly in fiber quality (such as length, color, and trash) from that being machine harvested and commercially ginned (Calhoun, 1996). These problems might be solved if an onboard fiber quality sensor were invented, similar to a cotton yield monitor for yield mapping. However, it is not realistic with current technology because such a sensing system must include a sampling device, an onboard gin, and an array of fiber quality sensors that can measure different fiber quality parameters.

Starting in 2006, a system including wireless and GPS technologies was designed and constructed in the Department of Biological and Agricultural Engineering, Texas A&M University, for module-level fiber quality mapping. The first version was comprised of two functional subsystems: a harvester subsystem (installed on a cotton harvester) and a module builder subsystem (installed on a module builder). The system could delineate the geographic area in the field where individual cotton modules were harvested. Combined with bale-level fiber quality data available from USDA classing offices, the module areas can be converted into module-level fiber quality maps that show the spatial variation of fiber quality in the field. The working theory of the system was described in detail by Thomasson et al. (2007). The system was field tested on a producer's farm near Plains, Texas. The test results were quite promising and the system satisfactorily implemented basket tracking as designed. The module-level fiber quality maps showed significant spatial variation in some fiber quality indices such as micronaire and loan rate (Thomasson et al., 2007), indicating the possibility of using them for site-specific crop management (SSCM) of cotton fiber quality in addition to lint yield. However, the field test also identified several problems with the first version of wireless GPS system. First, it lacked a boll buggy subsystem that is necessary in a harvest scenario where a boll buggy is used. Second, the wireless transmission range was limited with the current hardware layout, i.e., wireless antennas were placed together with the data processing boxes in field vehicle cabs. Third, module numbers were manually transmitted from the module builder subsystem to the harvester subsystem, which caused basket tracking omissions due to human error.

The objectives of this study were to (1) improve the first version of the wireless GPS system, (2) field test the improved version, and (3) demonstrate the system's capability for module-level fiber quality mapping.

Materials and Methods

System Improvement

Based on the problems identified in the field test, the following improvements were made. First, a subsystem to be installed on a boll buggy (boll buggy subsystem) was constructed and added to the system. This made the system suitable in the common application where a boll buggy is used to transport seed cotton from a harvester to a module builder. Second, ten-foot-long wireless extension cables were used to enable the wireless antennas to be placed outside vehicle cabs while the data processing boxes are still maintained inside. Third, the software was modified so that module numbers can be transmitted automatically in response to a request triggered at the harvester subsystem or the boll buggy subsystem when a basket dump occurs.

Field Test

Two field tests were conducted on the improved version of the wireless GPS system. The first field test was on a group of cotton fields (referred to as the IMPACT Center) on the Texas Agricultural Experiment Station (TAES) research farm near College Station, Texas. These fields were machine-harvested in September 2007, and the harvest equipment included a John Deere 9996 picker and a CrustBuster/Speed King module builder. A John Deere 4440 tractor was used to move the module builder whenever a module was completed. The harvester subsystem and module builder subsystem were mounted inside the cab of the picker and the module builder, respectively. Because the picker is equipped with a John Deere's Starfire1 GPS, a separate GPS receiver is no longer needed. A John Deere harness cable (part number PF90350) was used to enable the Starfire1 to provide location information to the harvester subsystem via an RS232 port. Five complete modules were harvested in the field test, covering about 15 ha. The modules were transported to the Scarmardo Gin near Caldwell, Texas and ginned there into 84 bales. Figure 1 shows how the system was installed on the field vehicles in this field test.

The second field test was conducted on a separate cotton field (referred to as the Riverside Field) at the TAES research farm. Cotton was machine-harvested from 9 to 14 October 2007. The harvest equipment included the same John Deere six-row picker, a Big12 module builder, and a KBH Mule Boy boll buggy. The boll buggy and module builder were moved with a John Deere 7810 tractor and a New Holland TD95D tractor, respectively. The installation of the harvester subsystem was the same as in the IMPACT Center field test. Since the Big12 module builder does not have an operator cab like the CrustBuster/Speed King module builder, the module builder subsystem was mounted in the New Holland tractor that was used to move the module builder. Similarly, the boll buggy subsystem was mounted in the John Deere tractor used to move the boll buggy. The wireless system antennas were mounted atop the cabs of the tractors. As of the fifth day of harvest, the John Deere 7810 tractor was no longer available, so from that point forward the New Holland tractor was used to move the boll buggy, and a John Deere 4440 was used to move the module builder. Since the John Deere 4440 has a very compact operator cab, the module builder subsystem was mounted near the module builder's operation console. Eleven cotton modules were harvested in this field test, covering an area of 25 ha. The modules were also transported to the Scarmardo Gin and ginned there into 131 bales.

It is important to point out that, in both field tests, the module number was pre-determined with gin tags and input into the module builder subsystem before a module was built. These numbers were subsequently used by the gins and classing offices to identify individual modules. Figure 2 indicates how module number was input into the module builder subsystem.

Fiber Quality Mapping

After each field test, log files stored at the harvest subsystem were downloaded into a PC and analyzed with ArcGIS version 9.2 (ESRI, Redlands, California) to produce module boundary maps. Bale-level fiber quality data were averaged within modules and combined with module boundary maps to produce module-level fiber quality maps, using the module numbers as a link. HVI fiber quality parameters including micronaire, length, uniformity, strength, Rd and +b, which are in the USDA cotton loan schedule (USDA, 2007) and have economic significance to farmers, are of interest in this study.

Results and Discussion

System Performance

Results of the field tests indicate that all subsystems of the improved version of the wireless GPS system can be easily installed on field vehicles and operate reliably. The system was run for a total of 45 h in two field tests, and no hardware and software problems occurred. When the tractor had to be changed near the end of field test 2, both the boll buggy subsystem and module builder subsystem were detached and reinstalled quickly, without delaying the machine harvest process. In the first version, the location information was provided by a separate GPS receiver (G30L-RS232, LAIPAC Technologies, Inc., Richmond Hill, Ontario, Canada) with WAAS correction. Occasionally this receiver experienced GPS signal loss, leading to some missing points along the harvester's travel path. This problem never occurred with the improved system, where a much more powerful John Deere Starfire1 GPS unit was used.

Figure 1. System installation in field test 2: (a) harvester subsystem in picker cab, (b) module builder subsystem in module builder cab, (c) wireless antenna on picker's light bar, (d) wireless antenna atop module builder cab, and (e) John Deere harness cable connecting Starfire1 to harvester subsystem.

The field tests also show that the transmission range of the wireless transceivers was greatly enhanced. In field test 2 where a boll buggy was used, the largest transmission ranges from the module builder subsystem to harvester subsystem exceeded 800 m. An examination of the downloaded log files showed that all the module numbers had been reliably transmitted to the harvester subsystem. Such a transmission range would make the system suitable for medium-sized fields covering up to 50 ha.

Operators are no longer needed at the module builder due to the improved program design which incorporated automatic module number transmission. This improvement reduces the operating cost of the system in real applications and avoids basket tracking omission due to human errors.

Figure 2. Module number being input into module builder subsystem before the module was built.

Module-level Fiber Quality Maps

Figures 3 and 4 show the geographic area corresponding to each cotton module harvested during the IMPACT Center and Riverside Field tests, respectively. The corresponding module-level fiber quality maps are shown in figures 5 and 6. While the spatial trend of fiber quality on the IMPACT Center is somewhat random, interesting spatial patterns are shown for the Riverside Field. It is clear from figure 6 that micronaire followed a high-low-high pattern along the southeast – northwest direction. Length and Rd showed a similar spatial trend, with high values in the northwestern portion and low values in the southeastern portion of the field; while uniformity and +b followed an opposite pattern, with high values in the southeastern and low values in the northwestern portion of the field.

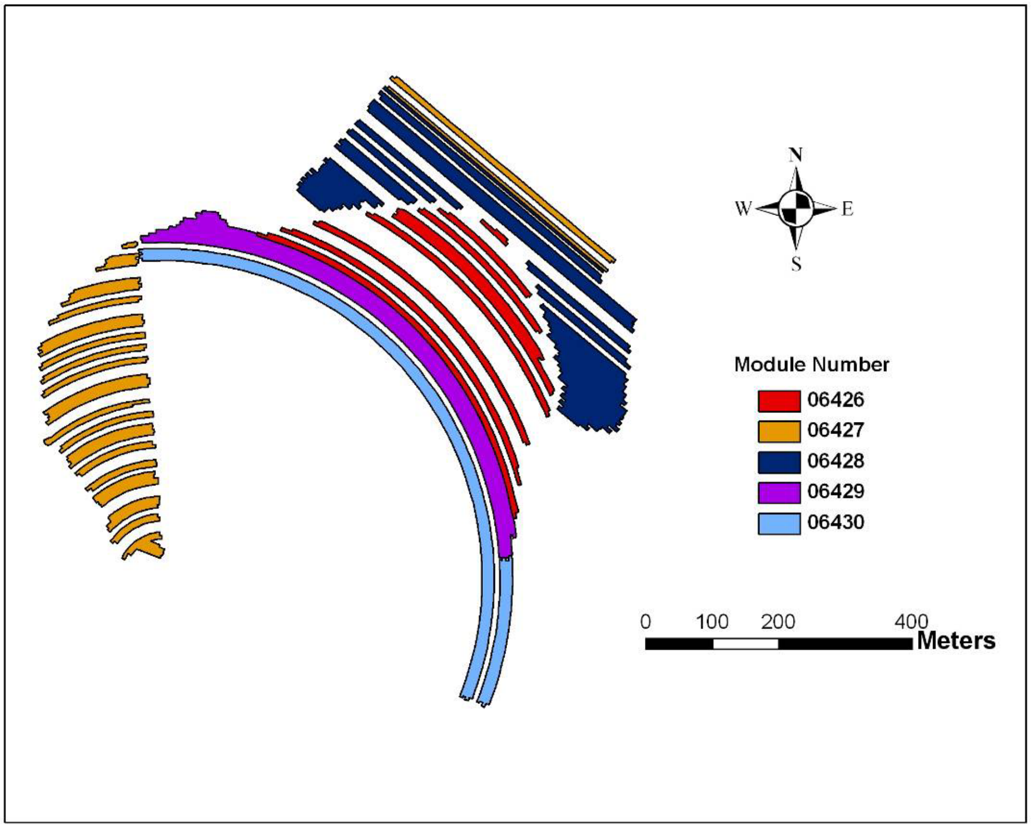

Figure 3. Geographic areas of five cotton modules harvested in the IMPACT Center field test.

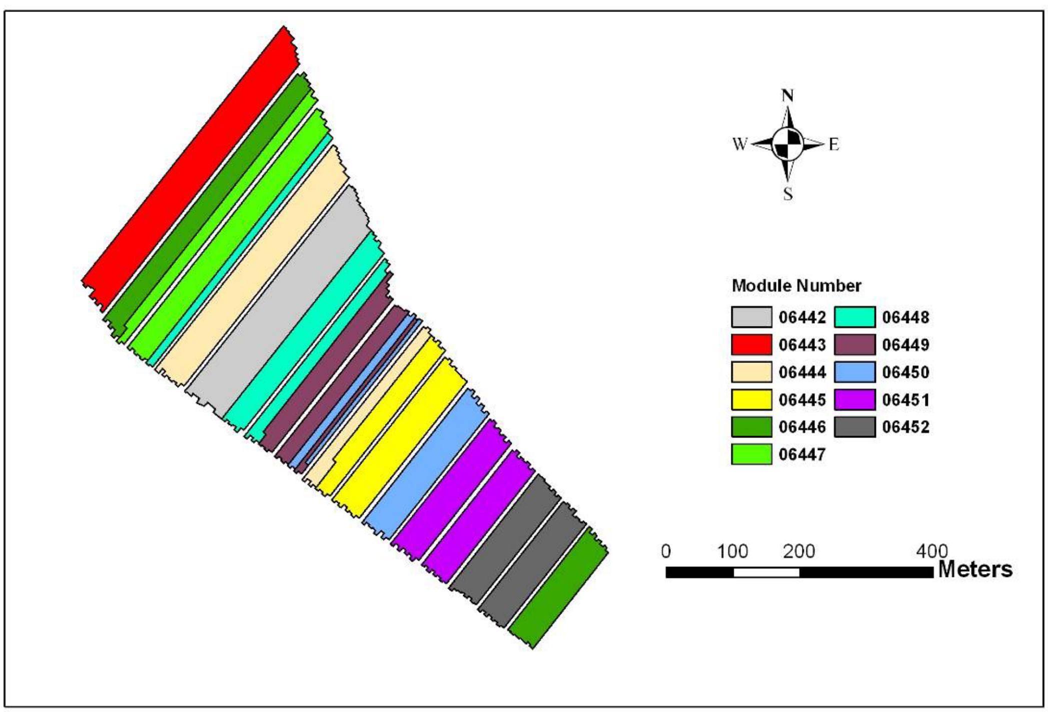

Figure 4. Geographic areas of 11 cotton modules harvested in the Riverside Field test.

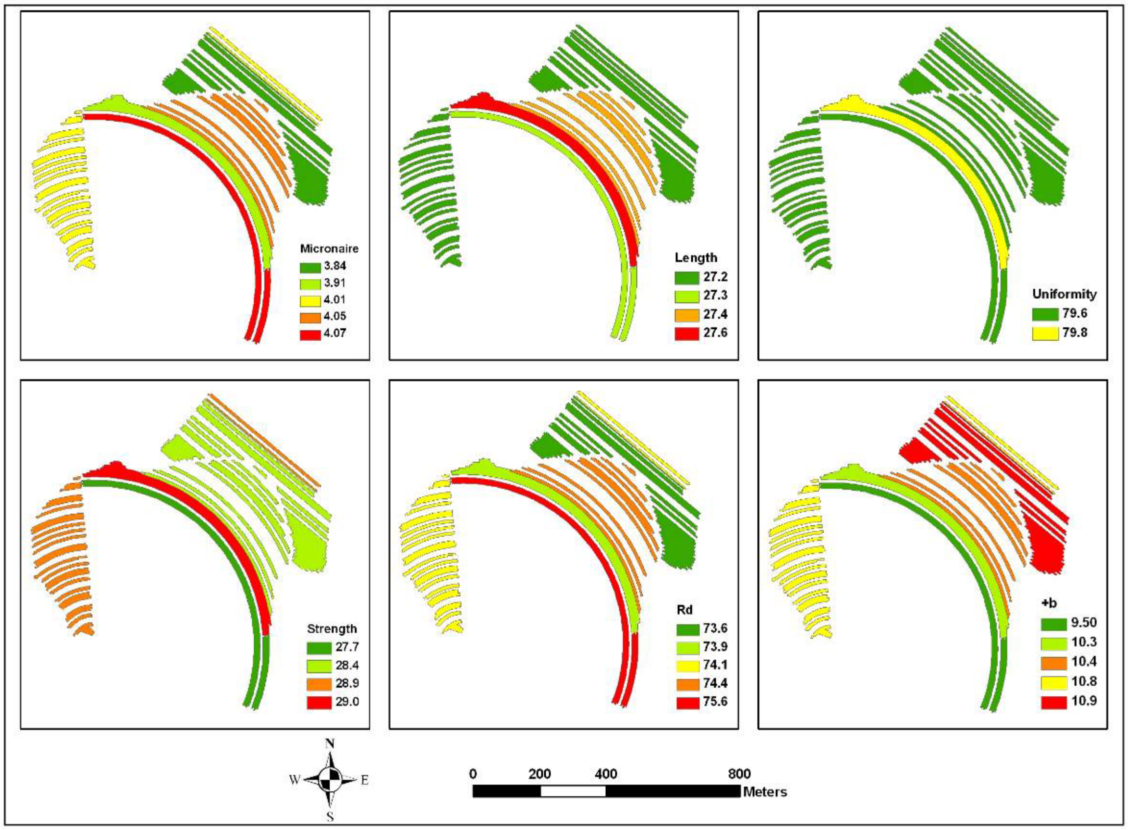

Figure 5. Module-level fiber quality maps of micronaire, length (mm), uniformity (%), strength (g tex^{-1}), Rd, and +b in the IMPACT Center field test.

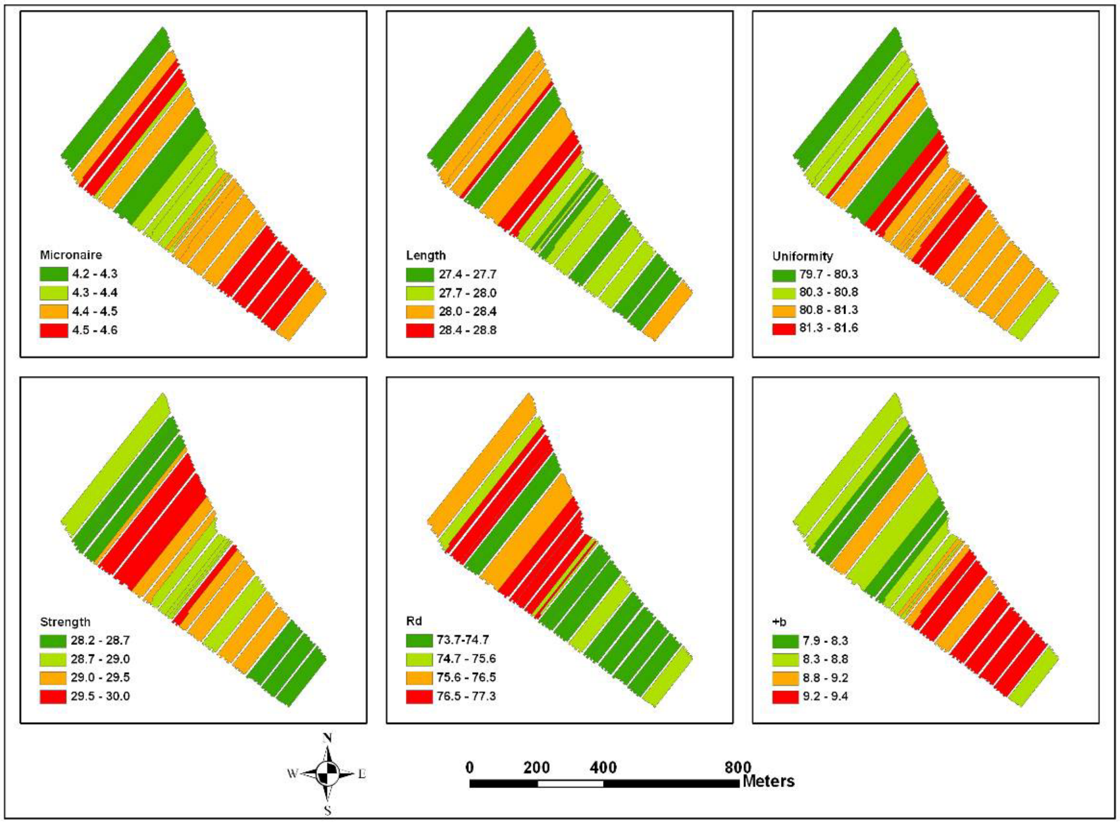

Figure 6. Module-level fiber quality maps of micronaire, length (mm), uniformity (%), strength (g tex^{-1}), Rd, and +b in the Riverside Field test.

Conclusion

An improved version of the wireless GPS system was field tested for module-level fiber quality mapping. The test results show that the system performed satisfactorily with no hardware and software malfunctions. Tracking of a basket load from harvester to boll buggy and module builder can be implemented automatically and reliably, with the wireless transmission range being greatly enhanced. Spatial variation of certain fiber quality parameters (such as micronaire, Uniformity, Rd, +b) were shown in the module-level fiber quality maps. This success indicates the potential for installing the system on cotton harvesting equipment for fiber quality mapping so that site specific crop management can start to address fiber quality in addition to lint yield.

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