AUTONOMOUS MODULE BUILDER

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Abstract

Conventional cotton harvesting requires many seasonal laborers. To reduce labor requirements, equipment manufacturers have recently introduced harvesters with on-board module building capabilities; however, this feature is only available on pickers and these machines are expensive. Conventional module builders offer automatic tramping systems as an option, but these systems do not distribute cotton in the builder or prevent cotton from being pushed out of the builder by the tramper. Module builder operators are often inexperienced and may build poorly shaped modules. The goal of this research was to develop an autonomous module forming system by retrofitting a conventional module builder. Sensors were installed on a module builder to determine the position of the carriage, tramper, and location of cotton in the module builder. Software was developed to control electro-hydraulic valves so cotton was properly distributed and compressed in the module builder. The boll buggy operator remotely controlled the system using a wireless display. Modules were constructed by the autonomous system with a 64% smaller water collection area in an average time of 37.4 min. Cotton producers indicated that the system was simple to use and significantly reduced labor requirements. The autonomous system can construct quality modules and reduce labor requirements with only a small additional investment in equipment.

Introduction

Cotton harvesting requires a large labor force to operate harvesters, boll buggies, and module builders. Increasing labor costs and the difficulty in finding adequate labor have resulted in a demand for alternative harvesting systems with reduced labor requirements. Shelby and Parish (1975) developed an automatic control system for a module builder; however, effective distribution of cotton was not performed with this system. Commercially available automatic tramping systems are similar to the system developed by Shelby and Parish. Equipment manufacturers have developed systems to automatically build cotton modules on pickers (Gola et al., 2000; Covington et al., 2003); however, these systems have several drawbacks.

These on-board module builders are only available on pickers. During the 1994-1995 harvest season, 23% of the total volume of U.S. cotton, and 85% of Texas cotton was stripper harvested, primarily in the High Plains (Glade et al., 1996). Recent shifts in cotton production have resulted in a larger volume of U.S. cotton grown in regions primarily stripper harvested– approximately 43% of the estimated 2009 crop was produced in Texas, Oklahoma, and Kansas (USDA-NASS, 2009). While a greater proportion of producers in these traditionally stripper harvested regions are using pickers, a significant amount of cotton in the southwest remains stripper harvested. These producers currently have no options other than using conventional module builders.

Some producers utilizing cotton pickers may find that automating existing module builders is more economical than investing in pickers with on-board module builders. The pickers with on-board module builders cost over $100,000 more than comparable conventional pickers. Retrofitting a module builder to autonomously build modules could potentially be more economical than purchasing new pickers with on-board module builders.

Along with reducing labor needs, an autonomous module builder would also consistently build properly shaped modules that resist moisture penetration. Inexperienced workers operating module builders and the need to build modules quickly contribute to the construction of modules with less than desirable shapes. Operator fatigue and poor visibility can also lead to the construction of poorly shaped modules. One-half of surveyed modules in Texas had depressions in the top surface where water could collect (Simpson and Searcy, 2004). Simpson and Searcy (2005) examined the effect of module shape on lint quality for modules subjected to significant rainfall. Regardless of cover quality, poorly shaped modules lost an average of $200 in lint value when compared to properly crowned modules. The modules produced with an autonomous module builder also have the advantage of using existing covers and gin equipment.

Objectives

This research developed from efforts to maintain cotton quality during storage in modules. The primary goal of this research was to develop an autonomous module forming system to reduce labor requirements during cotton harvesting while consistently building high quality modules. The main objectives of this research were:

- Develop algorithms for efficient movement of seed cotton in the module builder.
- Design a wireless communication system and boll buggy interface for control of the autonomous module forming system.
- Evaluate the autonomous module forming system performance by measuring module shapes and recording the time required to build modules.

Materials and Methods

Specifications

The autonomous system was designed to build modules without requiring a module builder operator. The only human interaction required should be the commands issued by the boll buggy operator while unloading. The minimum range needed for this bidirectional wireless communication between the boll buggy and module builder was 50 m (164 ft). Additionally, the autonomous system should have the capability for use with multiple boll buggies and module builders.

The sensors and software were designed to prevent undesirable functioning, regardless of operating conditions. One undesirable behavior would be repetitive actions due to a sensor malfunction or programming error that would prevent the cotton from being compressed by the time the boll buggy returns to unload. Another example would be pushing cotton out of the builder as the module nears completion.

The autonomous system should construct modules at least as fast as an experienced human operator, so that harvesting operations are not delayed. The algorithms for moving seed cotton in the module builder needed to facilitate unloading of boll buggies to ensure rapid module construction. Modules constructed autonomously should have shapes that prevent the collection of water on their top surfaces. The condition required that the autonomous system place a greater mass of cotton in the center of the module than at the ends (Hardin and Searcy, 2008).

Design

The autonomous system was designed to replicate the sequence of actions an experienced human operator would use to build a properly shaped module as rapidly as possible. Significant compression of the cotton in a module builder does not occur until at least three 8-row stripper harvester baskets are unloaded into the module builder. In this phase of the module building process, cotton was moved towards the ends of the module builder. This action created a lower region of cotton in the center of the module to facilitate faster unloading of the boll buggy (or harvester). After the final load of cotton was placed in the module builder, cotton was moved back towards the center to produce a crowned module.

The operator can not immediately begin leveling as the module nears completion or cotton would be pushed out of the module builder. An experienced operator will move the carriage into the cotton, extend the tramper, and move the carriage in the opposite direction. This sequence compresses the cotton and creates a space where loose cotton can fall. After performing this action across the entire the length of the module builder, subsequent compressions will further increase the available volume for unloading cotton. The autonomous system utilized this series of actions to aid in unloading boll buggies (referred to as the quick tamp routine) and prevent spillage of seed cotton. Hardware was selected to acquire the information needed to accomplish these tasks.

The module builder used for this research was equipped with an automatic tramping system. This system included a High Country Tek DVC10 valve control module that was programmed to control valve actions based on analog and digital inputs to the module. Sauer-Danfoss PVG 32 solenoid valves controlled the carriage motor and tramper cylinder in the automatic tramping system and were also used with the autonomous system. Sensors included with the automatic tramping system were two Pepperl+Fuchs 30 mm proximity sensors (model number NBB10-30GM50-E2-V1) for indexing carriage position to the front or rear of the module builder and a GP:50 model 1002-RX-2-AA pressure sensor for measuring system hydraulic pressure.

An operator feedback system had been installed to provide information about the position of the carriage and the height of the module (Hardin and Searcy, 2007). The autonomous system also utilized this information. The position sensing apparatus used inductive proximity sensors to record rotation of the carriage drive shaft. The tramper position was determined by using an ultrasonic sensor to detect a target plate mounted on the tramper support column.

The autonomous system also required knowledge of the level of cotton relative to the tramper, for maintaining contact with the cotton while leveling and maximizing the speed of the compaction cycle. The ultrasonic sensor only provided the tramper position relative to the carriage. Thru-beam mode infrared photoelectric sensors (Pepperl+Fuchs ML17) were mounted on both sides of the tramper (figure 1). Cotton blocking a beam (front or rear of the tramper) indicated that the specified side of the tramper was in contact with the cotton in the module builder. The ultrasonic sensor could then be used to determine the height of the tramper relative to the cotton surface in the module builder.

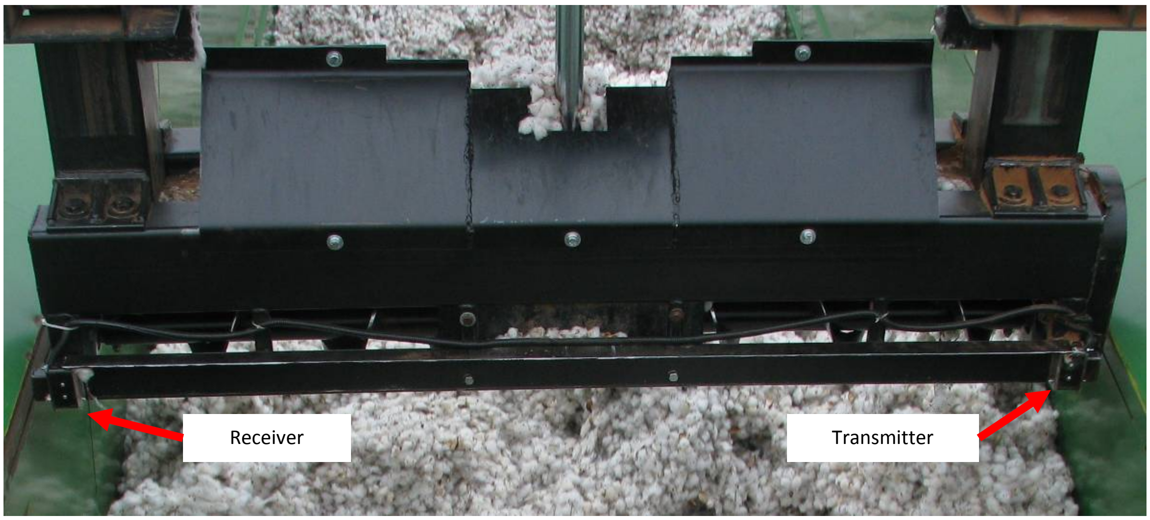


Figure 1. Tramper photoelectric sensor. This sensor pair was duplicated on the back side of the tramper.

The transmitters and receivers were mounted in housings constructed from 5.08 cm (2 in.) x 7.62 cm (3 in.) steel tubing with an acrylic cover to protect the sensors from both the applied mechanical force and cotton collecting around the sensor. The sensors were mounted on the ends of the tramper, 175 cm (69 in.) apart. This sensor has a sensing range of 20 m; however, at this distance the excess gain of the sensor is over 200. The excess gain represents the ratio of the actual received signal strength to the minimum signal strength needed to cause an output by the receiver. An excess gain of at least 50 is recommended for very dirty environments (Banner, 2003).

Sensors needed to detect when the cotton level was high enough in the module builder that some compaction was needed before leveling. Retroreflective visible light photoelectric sensors (Banner World-Beam QS30) were mounted on all four corners of the module builder (figure 2). Banner BRT-92 x 92 reflectors were affixed to the carriage. The excess gain was approximately four at the maximum sensing distance of 9.75 m (32 ft). These sensors were not in contact with the cotton, so the sensor faces remained cleaner, and a large excess gain was not required. Additionally, increasing the excess gain at the maximum sensing range would have required laser photoelectric sensors, which are considerably more expensive than visible light and infrared sensors.

Figure 2. Photoelectric sensor and reflector for detecting cotton on sides of module builder.

Control of the autonomous system was done from the boll buggy tractor cab. The interface used was a 26.4 cm (10.4 in.) touch screen color graphic terminal (High Country Tek model D210, figure 3). Touch screen buttons were provided for the operator to start and stop the autonomous system. Additional buttons allowed the boll buggy operator to instruct the module builder to quickly pack a partial buggy load while waiting to unload the remainder (referred to as the quick tamp function), to finish the module regardless of the volume of cotton in the builder, and to manually control the valves. An image of the predicted module shape was displayed to guide the operator in unloading cotton. Status information was also displayed; for example, if the module builder was ready to accept more cotton.

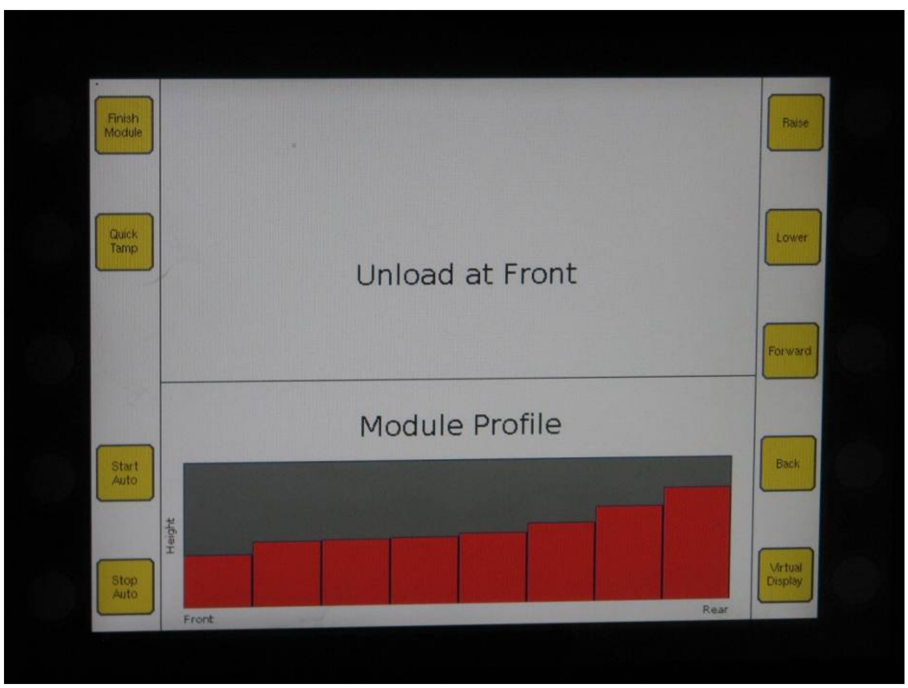


Figure 3. Autonomous system interface, mounted in boll buggy tractor cab.

This display was designed to be connected to a DVC10 through a serial cable. Digi XBee-PRO 802.15.4 radio frequency (RF) modules were used in place of a serial cable and wirelessly transmitted data between the DVC10 and the display. These RF modules receive serial data from the device they are connected to and transmit a packet of data according to the IEEE 802.15.4 protocol. Conversely, received RF packets are output to the connected device on the serial bus. These RF modules will form a mesh network, where any module can communicate with every other module in the network. This feature will allow multiple module builders and boll buggies to communicate in an extension of this system. These modules were selected because of this networking capability, their low cost, ease of implementation, and maximum outdoor line-of-sight range of 1.6 km (1 mi).

The commercially available automatic tramping system contained the control hardware and some sensors needed for implementation of the autonomous module building system. Nine additional sensors, costing approximately $620, and wireless transceivers, costing $200, were also required. The terminal cost approximately $1800; however, the interface provided additional features used for testing that would not be required in a commercial system. A suitable interface could likely be purchased for less than $500.

Testing

Two cotton modules were obtained from a gin to use during the initial development of the autonomous system during the spring and early summer of 2008. These modules were repeatedly broken apart and placed in a boll buggy using a loader tractor. During this initial testing and development, sensors were installed and the basic algorithm for moving cotton was developed.

The autonomous system was first tested during harvesting on several farms near El Campo, Texas in August 2008. The quick tamp routine was added so the boll buggies could unload rapidly. Different parameter settings were tested to optimize the module shapes constructed and the speed of the autonomous system.

Continued testing was done at the Texas A&M IMPACT Center near College Station, Texas in September 2008. The display and wireless connection were initially used there. A boll buggy was not used during harvesting, so the system was controlled remotely from a truck. The system generally functioned as desired, building modules without an operator present on the module builder.

Additional testing of the autonomous system was performed on several farms near Anson, Texas from November 2008 to January 2009. The wireless display was installed in the boll buggy tractor cab, and boll buggy operators were instructed on the use of the autonomous system. Approximately 50 modules were built autonomously with 5 different boll buggy operators. Cotton producers in this area indicated a preference for modules with a more level top surface. Program parameters were modified so the profile of cotton was always judged to be acceptable after the final boll buggy load was added. This change prevented cotton from being pushed to the center.

A module height measurement system (Hardin, 2009) was used to record heights for 28 of the modules built near Anson, Texas. The autonomous system was used to build 16 of these modules. The measurement system recorded heights at multiple locations across the width of the module and was mounted on a truck, which was driven alongside the module to record heights along the length of the module. The measurement system generated a module height surface with 15.24 cm (6 in.) resolution laterally and longitudinally.

Evaluation

Parameters generated from the module height surfaces included the total depression volume, number of depressions, average depression volume, maximum depression volume, average depression depth, average depression surface area, the water collection area in a profile of average heights along the length, and the water collection area in a profile of average heights across the width.

These parameters from analyzing the module height data were used as dependent variables in an analysis of variance (ANOVA). The ANOVA model included use of the autonomous system as a main effect. An additional independent effect was added to the model to distinguish modules that were measured after being covered during 22 m s^{-1} (50 mi hr^{-1}) winds. These modules appeared to have significantly fewer depressions; therefore, a classification variable was included to distinguish these modules. All other modules were measured before being covered. The number of modules in each treatment group is shown in table 1.

Table 1. Number of modules in each treatment group.

Treatment Combination	Number of Modules
Conventional	7
Conventional, Measured after Covering	5
Autonomous	14
Autonomous, Measured after Covering	2

The generalized linear models procedure in SAS, *PROC GLM*, was used for the statistical analysis. An ANOVA was performed using a model with both main effects (autonomous system and measurement condition) and the interaction. For dependent variables with significant differences but an insignificant interaction effect, the ANOVA was performed again with only main effects. Least-squares means were calculated using the *LSMEANS* statement in SAS with the *PDIFF* option.

The time required for different actions of the autonomous system was recorded for eight modules to verify that the system could operate without increasing harvesting time. Users of the autonomous system were asked to provide their feedback regarding the speed of the system, quality of modules built, ease of operation, and interest in the system as a commercial product.

Results and Discussion

Efficient movement algorithms were designed during initial system development in summer 2008 at College Station, Texas using two modules that were repeatedly torn apart and rebuilt. Approximately 15 modules were constructed near El Campo, Texas. The autonomous system successfully distributed cotton in the module builder and the algorithms for the quick tamp routine and moving cotton from the sides of the module builder were developed. An additional eight modules were built near College Station, Texas. The wireless system and display were initially tested, and modules were formed autonomously. Approximately 50 modules were built near Anson, Texas entirely with the autonomous system by five boll buggy operators. Height measurements and timing data were collected on these modules.

Module Shape Evaluation

The results of the ANOVA, with a full model including the effects of autonomous system use, measurement condition (before or after covering), and their interaction are shown in table 2. Significant differences between treatment combinations were observed for all three dependent variables with a significant ANOVA model (highlighted in bold).

Table 2. Analysis of variance table for all dependent variables.

Dependent Variable	F-Statistic	P-Value
Total Depression Volume	1.41	0.2651
Number of Depressions	**18.72**	**<0.0001**
Average Depression Volume	0.38	0.7706
Maximum Depression Volume	0.64	0.5981
Average Depression Depth	**3.77**	**0.0239**
Average Depression Surface Area	1.70	0.1932
Water Collection Area- Length Profile	**6.52**	**0.0022**
Water Collection Area- Width Profile	1.05	0.3886

Use of the autonomous system, the measurement condition, and the interaction all had significant effects on the number of depressions. The least-squares means for the number of depressions per module were 43.6 when built manually, compared to 32.6 for modules formed autonomously. The modules that had been covered during significant winds before measuring also exhibited a significant decrease in the least-squares means for the number of depressions, from 47.5 to 28.8.

While the statistical analysis indicated that the autonomous system had an effect on the average depression depth, all modules measured before covering had similar average depression depths. This effect of the autonomous system on the average depression depth was due to the two modules built using the autonomous system that were measured after covering. These modules had a significantly larger average depression depth than all other groups of modules because they had fewer small depressions. Eliminating the interaction term from the model caused the ANOVA for average depression depth to be insignificant. Furthermore, the small depressions that were present on other modules and eliminated by the wind compressing the cover against the modules are not likely to affect cotton quality. The cover will compress the cotton, possibly eliminating these depressions. If a good quality cover is used, wind moving the cover or evaporation would likely prevent any water collecting in these small depressions from penetrating the cover and damaging the seed cotton.

The autonomous system also had a significant effect on the water collection area calculated for the average height along the length. The autonomous system had a mean water collection area of 1179 cm^2, significantly less than the mean area of 3273 cm^2 observed with modules constructed manually. A comparison of the average heights along the length of a conventionally built module (figure 4) and a module built with the autonomous system (figure 5) are shown below (only the top 1 m of the profile is shown). The blue curve shows the average height of the module at multiple points along its length, while the red dashed line indicates the regions where water could potentially collect. The surfaces of these modules are shown in figure 6. Some conventional modules, such as the following one, will contain lower regions in the center, depending on the operator's actions. As long as the final load contains enough cotton (generally one stripper basket), the autonomous system will produce a module that does not contain lower regions in the center.

The module formed autonomously in figures 5 and 6 (right side) was significantly higher at one end because the boll buggy operator repeatedly unloaded cotton at that end of the module. This shape was extreme for the autonomous system, as most modules built autonomously had a peak closer to the center and less variation in module heights. However, this shape would be preferable to the shape of the module built by a human operator displayed in figures 4 and 6 (left side). Since the total depression volumes and values of other parameters describing the surface depressions for these modules were similar, the water collection area along the length profile provided a better indicator of this difference in shapes.

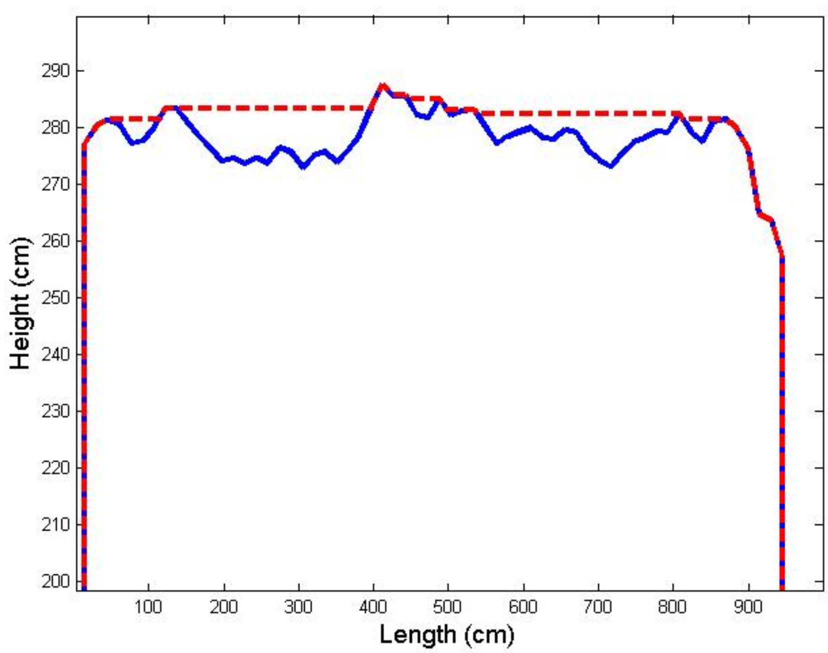
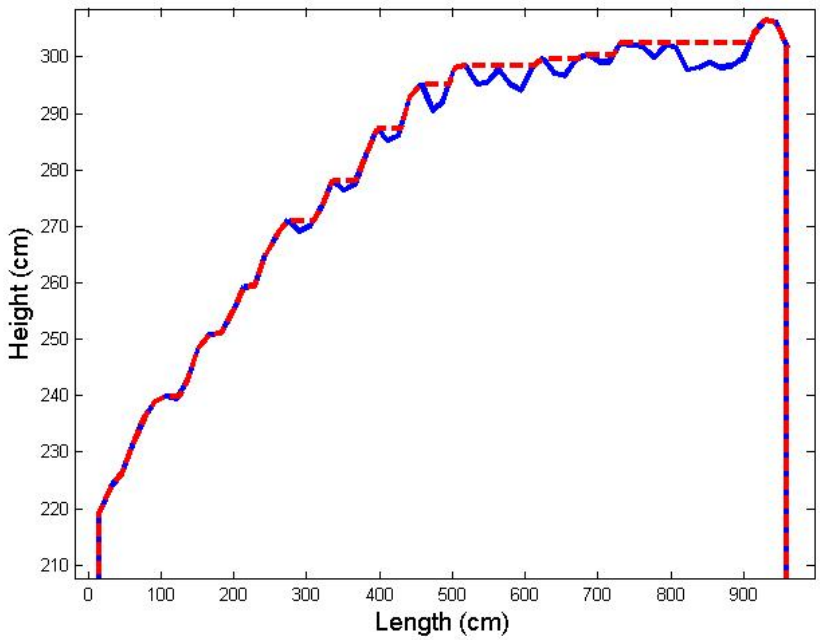


Figure 4. Average height along the length of a conventionally built module (water collection area = 3420 cm^2).



(b)

Figure 5. Average height along the length of a module built with the autonomous system with significantly more seed cotton unloaded at one end (water collection area = 975 cm^2).

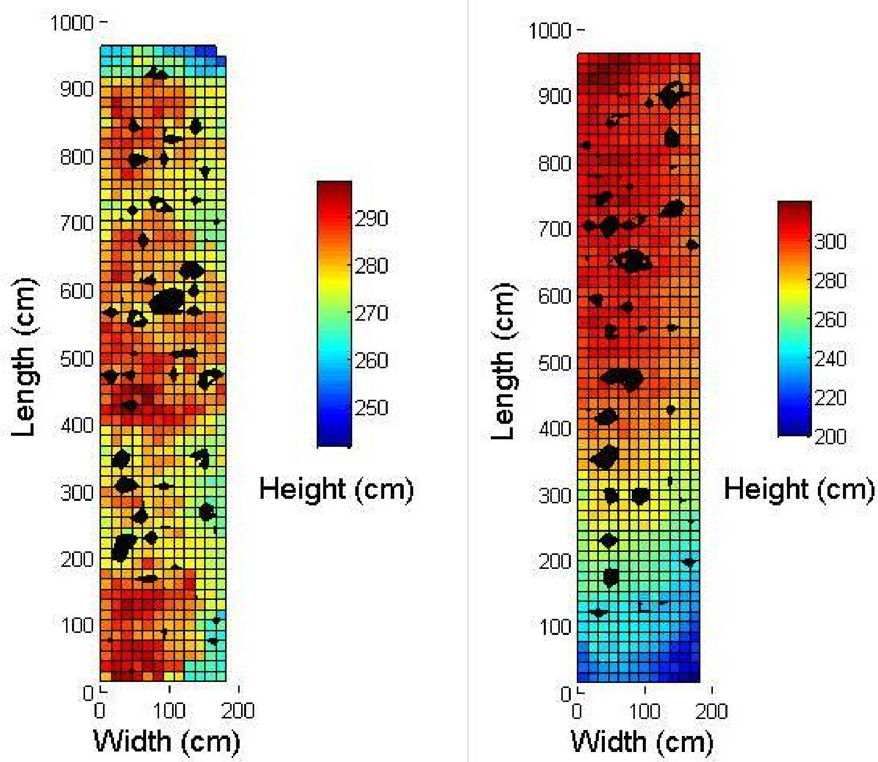


Figure 6. Surface of conventionally built module (left, depression volume = 12.4 L) and autonomously built module (right, depression volume = 15.5 L).

Autonomous System Operating Time

Timing data for the autonomous system was collected while used with an eight-row stripper, a four-row stripper, and a boll buggy. When fully operational, the autonomous system did not cause any delays in harvesting, although cotton yields were generally 3.7 bales ha^{-1} (1.5 bale $acre^{-1}$) or less. Previous testing was done using the autonomous module builder with two eight-row strippers, two boll buggies, and two conventional module builders in cotton yielding over 4.9 bales ha^{-1} (2 bale $acre^{-1}$). No delay in harvesting due to the autonomous system was observed during this testing.

The user was able to select three modes of operation– normal leveling and compaction, quick tamp, or finishing the module. The mean times for each phase of operation are displayed in table 3. The normal operation average only includes passes where all leveling and compression cycles were completed, excluding data where the system stopped automatically due to a low level of cotton in the module builder or manually due to arrival of a boll buggy.

Table 3. Mean times for different autonomous system operations.

Operation	Time (s)
Normal	603
Quick Tamp	136
Finishing	486

Four of the modules containing six harvester baskets had complete timing data to calculate the total time the automated system was operating. These times ranged from 34.8 to 39.5 min, with an average of 37.4 min. This figure did not include any time required to unload boll buggies. The variation in time was primarily due to the number of quick tamp routines that were performed by the boll buggy operator. Improvements to the autonomous system and an optimal pattern of unloading by boll buggies could result in an expected operating time as low as 30.5 min.

The maximum yield that could be harvested without exceeding the module building rate of the autonomous system was determined. This analysis assumed that a producer had one module builder per harvester and enough boll buggies so the harvesters did not have to wait to unload. Typical harvest efficiencies for cotton pickers are 70% (ASABE, 2006). Because stripper-harvesters generally have similar downtimes for turning and unloading, the same harvest efficiency can be used. Harvesting speeds of 6.4 km hr^{-1} (4.0 mi hr^{-1}) for a six-row picker and 6.0 km hr^{-1} (3.7 mi hr^{-1}) for an eight-row stripper were used (John Deere, 2009).

The autonomous system operated an average of 37.4 min while building a typical module with an estimated mass of 10000 kg (22000 lb). An estimated 10 additional minutes were required for unloading boll buggies and moving from a finished module to the next location. Therefore, the resulting minimum time required for the autonomous system to construct a module was 47.4 min. A six-row picker operating on 102 cm (40 in.) rows would harvest one typical module of seed cotton in 47.4 minutes if the average yield was 7.39 bales ha^{-1} (2.99 bales $acre^{-1}$) and the turnout was 35%. The yield that matched the autonomous system capacity with an eight-row stripper was 5.14 bales ha^{-1} (2.08 bales $acre^{-1}$) with 30% turnout.

This estimated capacity of the autonomous system would be adequate for most producers– the average U.S. yield was 4.2 bales ha^{-1} (1.7 bales $acre^{-1}$) in 2008, while the average Texas yield was 3.4 bales ha^{-1} (1.4 bales $acre^{-1}$) (USDA-NASS, 2009). Furthermore, the estimates were conservative, as 76 cm (30 in.) rows are commonly used and modules can be built larger than 9980 kg (22000 lb). Optimizing the autonomous system program and the unloading of boll buggies should enable the system to operate faster. For example, the second set of actions to move cotton to the end after unloading was ineffective and could be eliminated. The autonomous module forming system should not cause any delays during harvesting.

Autonomous System Operation

This final design functioned well, given the prototype nature of the system. The only total system failure occurred due to breakage of the cable to the photoelectric sensors on the tramper. Improved routing and protection of this cable should eliminate this problem. One cause of minor system malfunction was misalignment of the photoelectric sensors on the corners of the module builder with the reflectors on the carriage. This problem occurred twice during testing, and the sensors were subsequently realigned. A different sensing technique may be more suitable for detecting cotton on the edges of the module builder. For instance, mechanical sensors could be mounted on the carriage that output a control signal when cotton was contacted.

The photoelectric sensors on the tramper also were blocked once by dirt and leaf particles that filled the housings where these sensors were mounted. Proper sealing of these housings would prevent the ingress of this material. An additional operational concern arose from an improperly sized selector valve on the module builder. When initially compressing cotton, the tramper was not raised high enough. This was not due to an issue with the autonomous system. An excessive pressure drop across the selector valve caused the pressure sensor to record the maximum system pressure of 13.8 MPa (2000 psi) before the tramper was fully retracted. This high pressure reading caused retraction to stop, and loose cotton was pushed by the tramper.

The system functioned well, regardless of the location that cotton was unloaded. If the cotton was primarily unloaded at one end of the module builder, the resulting shape would be similar to the module constructed autonomously in figures 4 and 5. This shape will prevent water collection and no effect of unloading location on operating speed was observed. No more cotton was pushed out of the module builder while operating autonomously than while operated manually.

As a result of the system modification to prevent cotton from being pushed towards the center on the final pass, the location and quantity of the final load of cotton affected the final shape of the module. Generally, one full stripper basket needed to be placed near the center of the module to produce a crowned shape. Furthermore, cotton unloaded at one end of a nearly finished module also posed a problem. In one instance, an eight-row stripper unloaded directly into the module builder. This action required the stripper to back up beside the module builder and unload at the rear. However, this scenario would pose a problem for a conventional operator as well, since cotton cannot be moved from areas adjacent to the ends.

The wireless connection was generally only reliable when the boll buggy was stopped to unload at the module builder, although the module builder was controlled from a maximum of 400 m (1300 ft). This result was due to limitations of the architecture of the DVC system, since the DVC10 and display were not designed to be used over a wireless connection. The DVC10 controlled the display by sending large strings of data (greater than 1000 characters) over the wireless serial connection. All information displayed was resent from the DVC10 every 10 ms. Due to the large amount of information sent with no error detection and correction, one missing bit could result in the display not functioning properly. The wireless transceivers were capable of transmitting a significant portion of the messages correctly, but without any error correction, the display often malfunctioned at larger distances.

The wireless interface proved satisfactory for the initial development of the system. Reliable control of the module builder was achieved when the boll buggy was unloading next to the builder. The future extension of the autonomous system to a harvesting scenario with multiple machines will require greater range. A boll buggy will need to be directed to the appropriate module builder while in the field. Alternative boll buggy interfaces are available that should be more suited to wireless data transmission.

Acceptability of Autonomous System

Multiple boll buggy operators were trained to use the autonomous system. The simple interface with four commands was easily understood. Operators were able to use the interface after training on a limited number of modules. The major problem with this interface was that the display was not designed for wireless communication. This resulted in display errors, a lack of response to user input, and a more limited range of the wireless data transmission system. A simpler interface should function satisfactorily over a wireless serial connection. Harvesting crew supervisors commented that the system worked well and would be useful in addressing the difficulty in finding adequate labor.

Conclusions

The autonomous module builder was simple for the boll buggy operators to use. The algorithms for moving and compressing cotton were successful, regardless of loading conditions, and sensors generally functioned properly. Cotton could be unloaded in any reasonable manner (for instance, unloading all cotton at one end would likely not produce a desirable module) and a well-shaped module was built. The autonomous system pushed no more cotton out of the module builder while moving cotton than an experienced human operator would. The primary reliability issue was due to cable breakage, a problem that can be addressed in a commercial version by improved cable routing and protection.

The autonomous system built modules with more desirable shapes than a human operator. Use of the autonomous system reduced the water collection area over the length by 64%, from 3273 cm^2 to 1179 cm^2. The mean number of depressions was decreased from 43.6 to 32.6. If the load completing the module contained at least one harvester basket of cotton, modules built with the autonomous system did not have any low regions when viewed from the side. If a partial basket is harvested or cotton is vacuumed off the ground, the boll buggy operator should select the finish command for both the previous load (the final full basket) and the final load containing a small amount of cotton. The time required to build modules with the autonomous system, 37 min, was comparable to the time needed for an experienced human operator to build a module. No delays in harvesting operations due to the module builder were observed while testing the final prototype.

The autonomous module forming system was installed on an existing module builder with an automatic tramping system; consequently, the additional equipment costs for the prototype were small. The autonomous system eliminated the need for a module builder operator and constructed modules with more desirable shapes.

Future Development

The Texas A&M System Office of Technology Commercialization has pursued patent protection on the autonomous module builder. This invention has been licensed to Crustbuster/Speed King, Inc. for commercial development. A commercial system should be available on new module builders for the 2010 cotton harvest, with a cost not significantly exceeding a module builder with an automatic tramping system.

Disclaimer

Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U. S. Department of Agriculture and does not imply approval of the product to the exclusion of others that may be available.

Acknowledgements

This research was supported by Crustbuster/Speed King, Inc and Texas AgriLife Research. The authors are grateful for the assistance of many Texas cotton producers and ginners in testing and evaluating this system and the technical support provided by High Country Tek during software development.

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