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Plastic Detection and Removal Systems: Research and Working Solutions for Cotton Gins

Speaker:

Greg Holt, USDA - Agricultural Research Service, Lubbock, TX, USA

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Faserinstitut Bremen e.V., Bremen, Germany. E-Mail: conference@faserinstitut.de
Bremer Baumwollboerse, Bremen, Germany. E-Mail: info@baumwollboerse.de

PLASTIC DETECTION AND REMOVAL SYSTEM: RESEARCH AND WORKING SOLUTIONS FOR COTTON GINS

M.G. Pelletier[1], Holt, G.A.[1], Wanjura J.D.[1], Whitelock, D.A.[2], Funk, P.A.[2], Armijo, C.B.[2]
1. Cotton Production and Processing Research Unit, Agricultural Research Service, USDA, Lubbock, TX, USA
2. Southwestern Cotton Ginning Research Laboratory, Agricultural Research Service, USDA, Mesilla Park, NM, USA

ABSTRACT

The removal of plastic contamination in cotton lint is an issue of top priority to the U.S. cotton industry. One of the main sources of plastic contamination showing up at the classing office is the module wrap from the John Deere round module harvesters. Despite diligent efforts by cotton ginning personnel to remove all plastic encountered during unwrapping of the seed cotton modules, plastic still finds a way into the seed cotton fed into the ginning system. To help mitigate plastic contamination at the gin, two systems have been developed; a passive system using cameras to see plastic on the module feeder dispersing cylinders and an active system, which detects and ejects plastic from the seed cotton. The first system monitors the dispersing cylinders in the module feeder and alerts gin management of plastic detected on the cylinders by time stamping a picture, displayed on a screen in the control room. The second system utilizes cameras on the feeder apron above the gin stand to detect plastic that then actuates pneumatic air knives to eject the plastic, out of the seed cotton, onto the floor in front of the gin stand. Both systems were developed and evaluated at the USDA-ARS cotton gin laboratories and field tested in two commercial cotton gins for the 2018-2019 U.S. ginning season. Based on the success of the initial testing and field trials, the technology is being Beta tested at several commercial cotton gins for the 2019-2020 and 2020-2021 seasons. Additional lab testing is also being conducted in response to requisite improvements uncovered during commercial testing. Results of the laboratory testing and field evaluations are to be presented.

OBJECTIVES

The specific objective of the research is to assess the best method for early detection of plastic to exclude it past the module feeder and for plastic that does make it past, for detecting and removing plastic contamination at the gin-stand feeder apron.

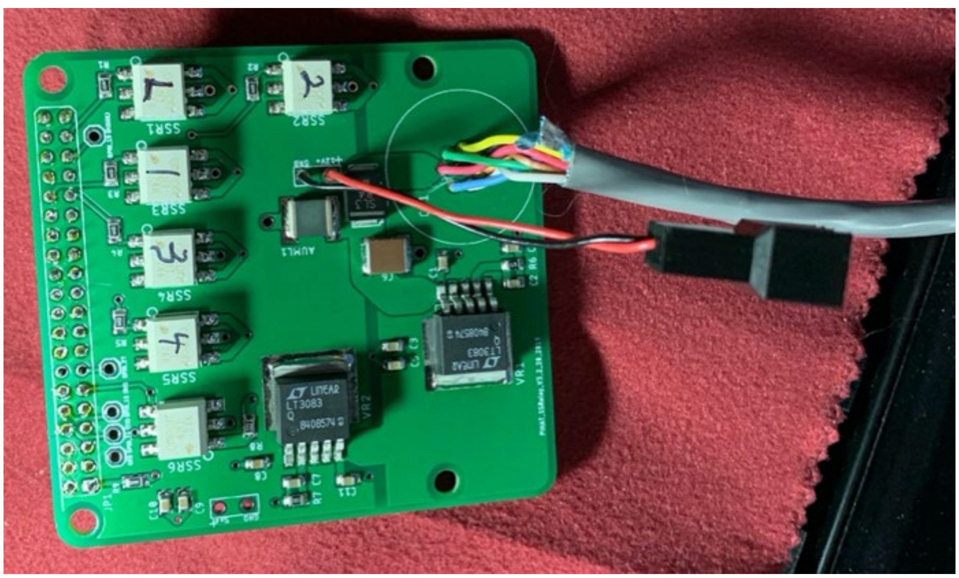
SIGNIFICANCE

Plastic contamination in cotton is thought to be a major contributor to the loss of a $0.02/kg ($0.05/lb). premium that US cotton used to command on the international market due to its reputation for one of the cleanest cottons in the world. Current data now shows US trading at a $0.01/kg ($0.025/lb) discount, relative to the market for a total loss of $0.03/kg ($0.075/lb), with respect to market conditions prior to wide-spread adoption of plastic wrapped cotton modules. The cost of this loss to US producers is in excess of $750 million (USD) annually.

In order to help address this loss; research was performed on the development of an automated low-cost high-speed machine-vision detection/ejection system for use in cotton gins to help remove plastic contamination.

MACHINE VISION SYSTEM DESIGN AND DEVELOPMENT FOR DETECTION AND REMOVAL OF PLASTIC CONTAMINATION

The research examined various technologies for plastic detection and determined that due to cost constraints, the technology with the highest probability of being adopted by industry would have to provide a very low-cost implementation to manufacturers. This led to the adoption of low-cost color imagers and processors, provided by the cell-phone industry. Off the shelf processors and cameras were utilized in the prototypes that were augmented with custom hardware, (Figure 1) for interfacing to pneumatic air-knives that were used to eject the plastic contamination from the cotton stream.



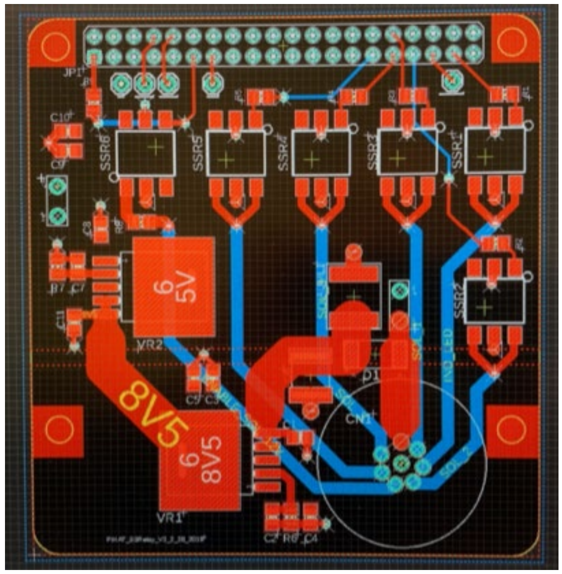


Figure 1. Circuit board designed to provide optically isolated high-current drive interface for the ARM micro-processor to drive the pneumatic solenoids as well as power regulation and filtering from noisy industrial environment.

A significant challenge for deployment of a machine-vision system into a cotton gin is keeping optics clean. To address this the research developed a custom housing for both the camera and the machine-vision processor. To provide cooling; pneumatic air was brought into the housing and then exhausted out across a protective lens via a custom air-knife to keep the optics free of dust and debris (Figure 2).

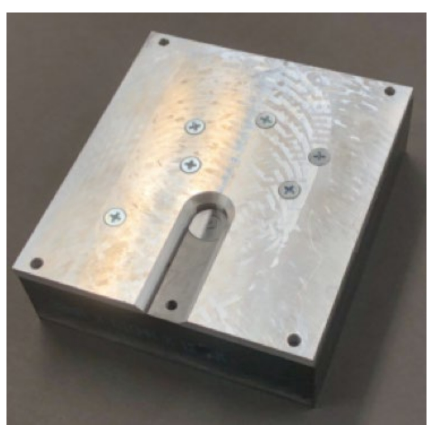


Figure 2. Camera housing design with cooling and integral air-knife for keeping optics clean in high dust environments.

For computation and image acquisition, in order to ensure a cost competitive design, the system design adopted the use of low-cost processors and imagers from the cell-phone industry. Based on this a prototype was constructed and then tested in the laboratory to help refine the software and the electronic and pneumatic ejection system designs, Figure 3.

Figure 3. Testing of the plastic in cotton contamination detection-ejection system prototype laboratory apparatus.

As the system utilizes a camera + imager for every 5 cm of cleaning width; the software was designed to buffer the machine-vision software through a data-base so that the GUI interface software could easily setup multiple units in parallel. This development is covered in Pelletier et. al. 2020a. The design leveraged open-source data-base software, commonly used to power web sites all over the world. In leveraging this, the software was designed into layers that allowed for distributed control of multiple camera nodes, compute-imaging stations, from a single node that could be either on-site or remotely located and connected through the internet, Figure 4.

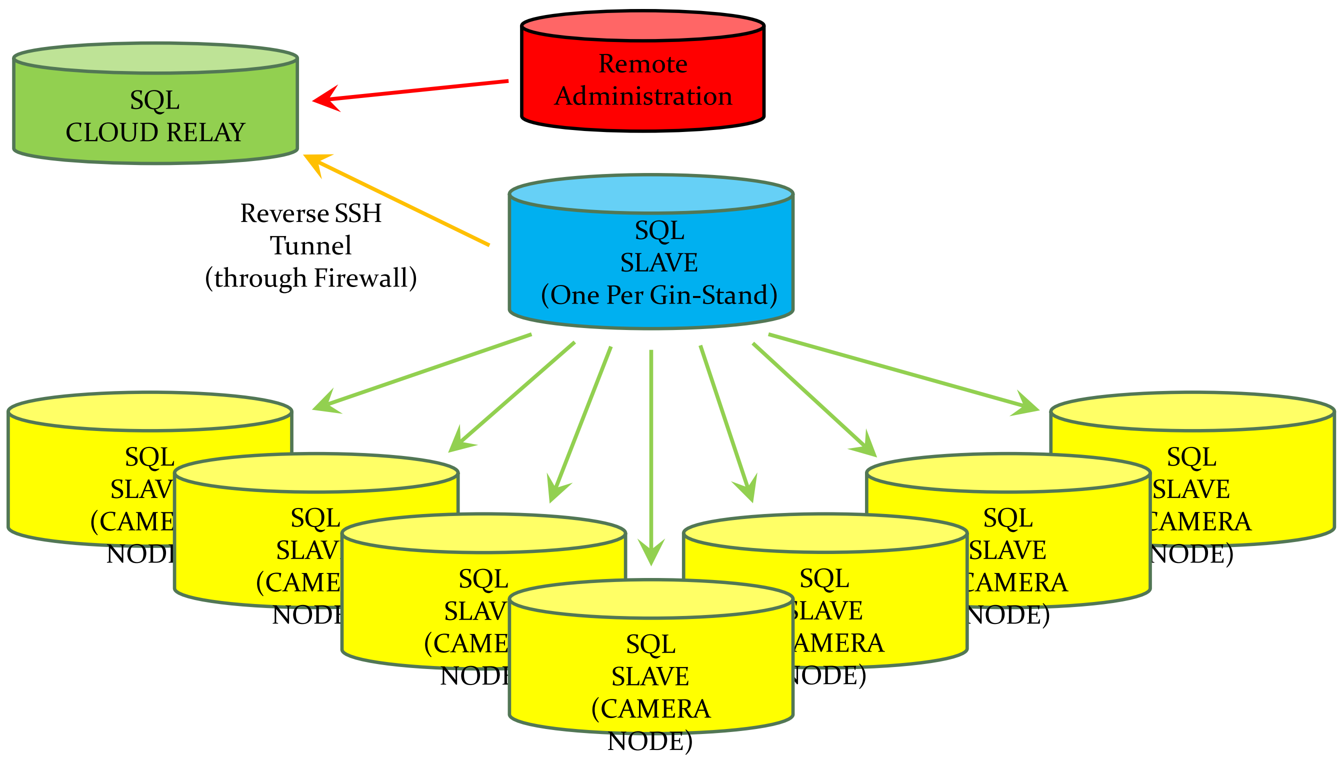


Figure 4. Distributive control scheme that allows for setup and configuration of multiple camera nodes from a single remote monitor.

Following the distributive control network design, user interface software was developed that allowed for a single user, on a single workstation, to log into multiple camera-nodes for setup and monitoring. The software was split with operator interface, Figure 5, localized to the viewer software and the actual machine vision detection ejection portion confined to an executable program located on each camera-compute node.

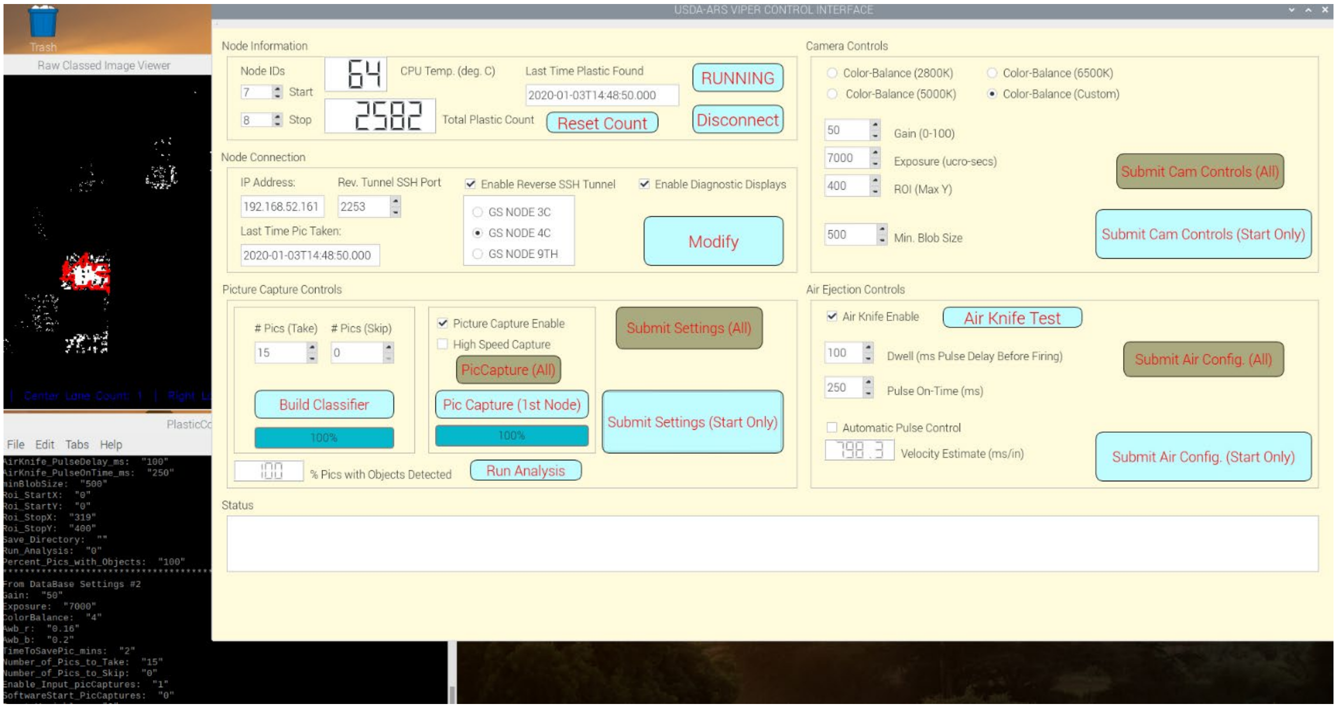


Figure 5. Interface software designed to control multiple camera nodes from a single workstation, for ease of installation, setup and on-site configuration.

Once deployed into a commercial gin, further software development was required to help calibrate, test and trouble-shoot the systems in use. Figure 6, shows one of the authors testing one of the camera-compute nodes with a painted stick designed to allow for assessing each of the active sensing zones on each of the nodes to ensure each unit is accurately sensing and ejecting cotton when stimulated with the painted end of the stick.

Figure 6. Field testing of each of the plastic-contamination detection-ejection nodes.

During the course of the field-trial of the prototype, numerous plastic contaminates were detected by the imaging system and kicked out by the pneumatics. Figure 7, shows sample images that were detected on the gin-stand feeder apron by the prototype, while deployed into a commercial cotton gin for testing.

Figure 7. Plastic contamination detected by the prototype under deployment in a commercial cotton gin.

After the testing of the USDA-ARS prototype, the technology was transferred to Bratney Companies; who then further commercialized the system under the author's guidance. Figure 8, shows the first commercial testing of the USDA-ARS design after transferring the technology to Bratney Companies and Lummus Corp. as installed in a commercial cotton gin for validation and efficacy testing.

Figure 8. Commercial version of the USDA-ARS plastic-contamination-ejection system; as deployed into commercial cotton gin for testing and evaluation.

As the USDA-AMS classing office has determined that over 90% of plastic contamination is sourced from cotton module wraps; the commercial system version, from Bratney, was tested utilizing various colors of module wrap. The results of the laboratory and commercial testing indicates the system design has potential for reducing a significant fraction of the plastic contamination found on the gin-stand feeder aprons, Figure 9. Bratney Companies and Lummus Corp. are currently in the process of finalizing commercial variant with hope to bring it to market by the fourth quarter of 2020 or first quarter 2021.

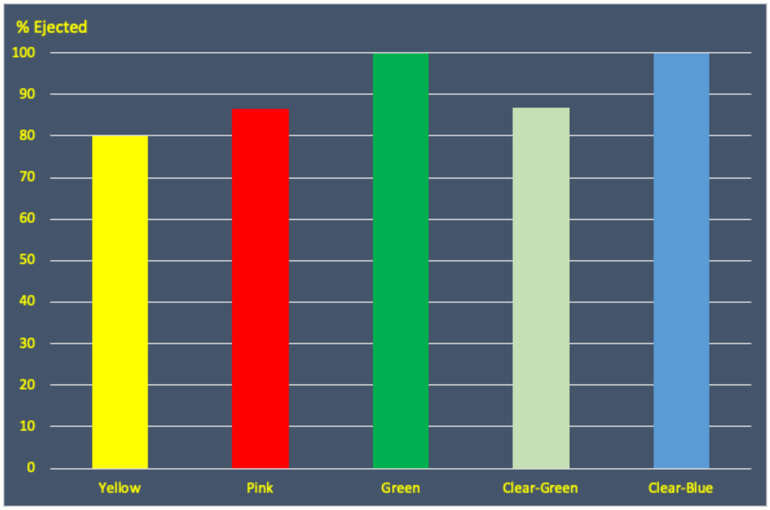


Figure 9. Results of the first round of testing of the commercial prototype of the plastic contamination removal system.

SUMMARY

The USA used to enjoy a reputation for one of the cleanest cottons in the world and as recently as 2014, used to trade at a premium on the international market of $0.02US/kg. In recent years the USA has lost this reputation, and with it the premium. Cotton Incorporated economists estimate that plastic contamination is one of the main driving forces behind loss of the price premium. The total cost of this lost premium to US producers is in excess of $750 million USD, annually. As such, the removal, or exclusion, of plastic contamination in cotton lint is one of top the priorities to the U.S. cotton industry requiring an immediate solution. In order to help address this loss; research was performed on the development of an automated low-cost high-speed machine-vision detection/ejection system for use in cotton gins to help remove plastic contamination. A system was developed for the module feeder, to help alert the gin personnel that plastic was built up on the module feeder dispersing cylinders and needs to be stopped and cleaned; thereby helping to prevent plastic from entering the gin. The other key aspect of the research was the development of a machine-vision detection-removal system placed on the gin-stand feeder apron. Commercial field testing found this system was able to remove over 80% of yellow and pink module-wrap plastics and over 90% of green and blue module-wrap plastics.