COTTON YIELD SENSOR PRODUCES YIELD MAPS

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Abstract

This paper describes the design and implementation of a Yield sensor utilizing electro-optic devices. The sensor combines emitters and detectors which are mounted on the conduit (duct or chute) of a harvester. As the cotton passes through the chute, it is illuminated by the emitters. The detectors which are positioned across the conduit detect the light pulses. The detection circuit then generates pulse train. The pulse count is relative to the mass of the cotton passing through the conduit. The cotton weight is displayed on the cab indicator and also stored on a recording media, together with the GPS position of the picker. The data can then be processed and displayed as a yield map.

Definition of Terms

GPS - Global Positioning System**.**
Sensor - emitter or detector unit containing the light emitting and detecting devices.
Detector - electrical circuit which performs the detection and signal conditioning (and discrimination from noise) of the Emitters light.
Emitter - circuits which illuminates cotton inside the chute for the purpose of detection and analysis.
Seed Cotton - product of the cotton field picking with today's harvesters. The product contains the cotton lint, cotton seeds and other plant residues.
Yield Map - a geographical map of a producing field showing in colors or contour lines the absolute yield, in kg or pound per acre, at each location.

Introduction

The ability to monitor cotton yield on the fly is a necessary component in the evaluation of the performance of a cotton field. The importance of the device has been recognized among growers in pursuit of precision farming technology (Development of Precision Farming Techniques for Southeastern Agriculture; 1995 Progress Report). The sensing system enables one to record a momentary yield and associate it with the location in the field. The user can create a "yield map" showing the variations of the yield across the field. Such information enables the user to prescribe treatment which is dependent on the location, where such treatment is required. Pressure yield sensors have been in use on grain harvesters for a few years. The design and implementation of optical sensors have been described by Jung (Jung, 1996) and Schrock (Schrock, et. al.; 1994). In comparison to these systems, the product described in this paper is an accurate, low cost solution. It is simple to install, has low maintenance and is fully automatic.

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System Description and Operation

The Yield Monitoring System, figure 1, consists of the following components: the Main Processing Computer (CPU), a data recording device, ZYCOM's Datakey (TM) or a PCMCIA (Personal Computer Memory Card International Association) card, a display device, user controlled keys and a differentially corrected GPS receiver, all are mounted in the cab. Optical flow (yield) sensors are mounted on the chutes of the harvester. Radio antennas, used by the GPS and the differential receiver, are mounted on the roof of the harvester. The mapping software is installed on the office PC.

Each of the chutes accommodates a single sensor. The sensors are connected to the CPU by wire which carries data and power to and from the CPU in the cab.

During the harvest the CPU, gathers position data from the connected GPS receiver. It also collects flow data from the yield sensors. Moisture, temperature and other information can also be collected from such sensors when attached. The data is then stored as a database record, in the Datakey memory. The Datakey can later be transferred to the map processing computer for display analysis and printing.

Sensor Design and Operation

The sensor is composed of Infra Red (IR) *emitters*, *detectors*, signal conditioning and processing units; figure 2. The emitters are built of IR lamps which are driven by pulsing driver circuits. The sensors components are enclosed in weather sealed enclosures which are mounted on the surface of the chute, using specially made brackets. Openings are drilled on the chute to accommodate the sensors. Electrical cables connect the sensors assemblies to the CPU in the cab.

The emitters illuminate the chute at high power from all sides of the chute. As cotton passes through the chute it blocks the IR light reaching across to the opposite side where the detectors are positioned. Light will also be reflected by the cotton back to detectors positioned in the same side as the emitters. These direct and reflected signals provide information about the size (volume) of the cotton passing through. The signals from all the detectors is being filtered, amplified and converted into digital format for further processing by the sensor's on board processor. The resulting measure of *flow* is transmitted on the system bus to the main processing computer, located in the cab.

Yield Calculation

The system estimates the flow of seed cotton in one second interval. The result is displayed to the operator in the cab as well as being stored on the system Datakey - memory card.

The total weight of cotton detected during a single recording interval is calculated using the following equations:

(1) $$W_i = c(a_n N^{n} + a_{n-1} N^{n-1} ... + a_0)$$

where:

W_i is the total weight passing through during interval i

a polynomial coefficients.
c weight coefficient
N pulse count calculated by the equation (2) below.

(2) $$N = \sum_{s} \left(\int g_R v_R dt + \int g_B v_B dt \right)$$

where:

N mass count
s signal detectors

v_r, v_E detected signals from reflected and blocked light sources.

g_R, g_B gain coefficients for reflected and blocked signals

The total weight of a field W is the sum of all intervals i collected during the harvest period T :

(3) $$W = \sum_{i}^{T} W_i$$

Tests and Results and Discussion

Several types of tests were performed while evaluating the sensors. The test for accuracy being the most significant. The accuracy of the sensor is defined, for the purpose of this presentation, as the ratio between the measured harvested crop weight, as measured by the system, and the actual weight as measured by a scale of high accuracy. During static tests small amounts of cotton were used and measured. They ranged from 2 lb to 30 lb. In field operation accuracy test are performed on larger amounts of cotton.

While the absolute accuracy of the system is of prime interest, the ability to detect variations of yield is even of higher importance when considering precision farming as the prime application for the system.

Data Records

The ***AGRIplan*** records the data collected during harvest in the DATAKEY memory. The data is collected in formatted records which contains the following information: GPS position, date and time, yield (flow), temperature, moisture, speed, and other system, user and field information. A record is stored every (fixed) *recording interval*. The records are stored in an ASCII text format and can be view after the transfer to the PC at the office.

Static Tests

During static test the weight of the cotton is calculated while the harvester is not moving. The cotton is being fed into the chute opening through a conveyer belt or using a hand fed funnel. Several tests of this nature were performed with varying amounts of weights. The results of these tests are presented in the graph 1 below. Accuracies in the range of a few percentage points were achieved. All tests were performed during the months of November 1996 though April 1997 at a number of installations with third party observers.

Field Test

The first tests were performed during the latter part of the 1996 picking season with a number Georgia cotton of growers. Continuous field operation was performed during the month of May and June 1997 in Australia. Two systems were sent to Narrabri, NSW. At the time of the writing of this paper only a few field maps were available. In considering the accuracy of the system, the results achieved were better then 1.7% on module size volume, while only one chute of the picker was monitored. One should also consider the fact that during production the weight measurement in the field have errors in same order of magnitude. This is due to loss of cotton while emptying the harvester's basket, accuracy of the scale of the boll buggy (where cotton is being collected).

Several maps were produced showing the field variations with a number of distinct verifiable features.

Conclusions

The use of optical system in the estimation of the weight of cotton is achievable. The accuracy of such system was measured in the range of 1-3% points. This overall weight accuracy, is within the market expectancy and is in line with the accuracy achieved with other types of sensors used with other crops such as grain.

The limited time the product has been in use demands that additional study be performed to verify the results and support them with field operation. In addition, comparison of field operation with other monitoring methods, such as hand picking, should provide another method to determine performance accuracy and sensitivity. Variation in seed cotton content, moisture picker models and operating conditions (speed, yield levels, etc) should also be considered as variables which may affect the system accuracy and may need be added to the system as additional instruments of as system parameters.

Summary

The design and implementation of electro-optic cotton yield monitor was presented. The sensor with the attached GPS system was built and operated on a number of installations for the purpose of test, evaluation and for the generation of yield maps. Accuracies in the range of better then 2% were reached in field operation where module size amounts of cotton were measured and compared to standard scale reading. In static operation, where the picker and the system under test were fed cotton directly into the bottom of the chute, accuracy in the range of 3-4% were obtained with smaller amounts of seed cotton. While most results were encouraging, additional work needs to be done to confirm the system performance in the varying field operating conditions.

References

Jung; Hun J 1996, Solid state image sensor with shaped photodiodes United States Patent 5,488,239.

Development of Precision Farming Techniques for Southeastern Agriculture; 1995 Progress Report; The University of Georgia College of Agriculture and Environmental Sciences; Coastal Plain Experiment Station; National Environmentally Sound Production Agriculture Laboratory.

Schrock, et. al.; 1994; Apparatus for measuring mass flow of grain in a harvesting machine; United States Patent 5,318,475.

J.A Thomasson et. al. 1997.Mass Flow Measurement Of Pneumatically Conveyed Cotton. Proceedings Beltwide Cotton Conference 1997.

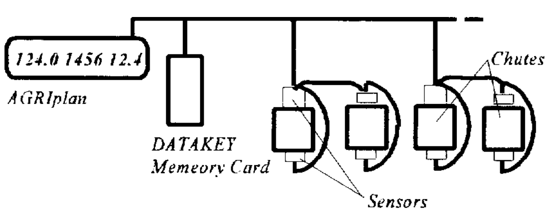

Figure 1. System architecture.

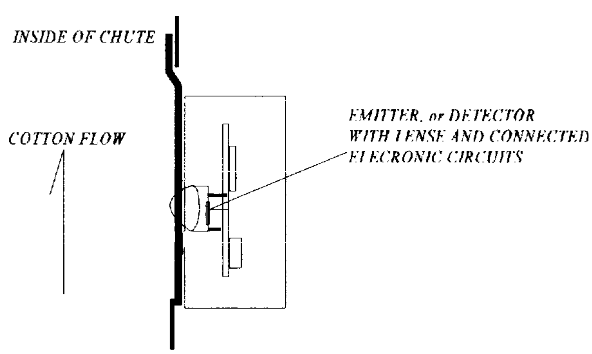

Figure 2. Sensor construction

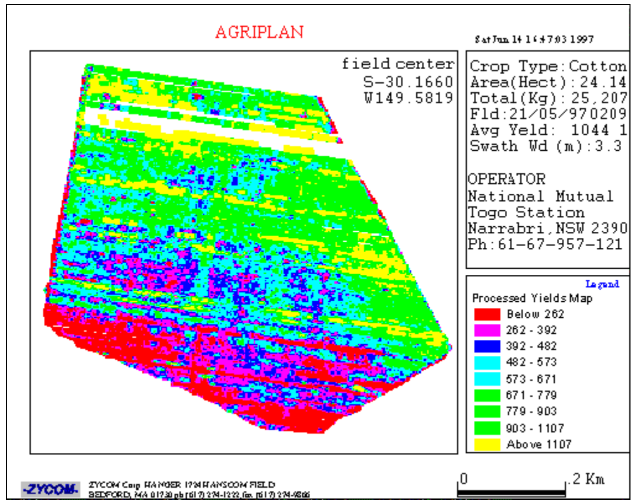

Figure 3. Yield Map

Table 1: Static test, results.

Actual Weight lb	System Weight lb	Error %
36	34.7	3.61
10.8	10.96	-1.48
7.2	7.22	-0.27
5	4.8	4
4.8	4.78	0.41
11.5	10.51	8.60
11.5	11.42	0.69
9.98	9.61	3.70
82	82.33	-0.40
12	12.82	-6.83
31	30.48	1.67
37	36.03	2.62
26.42	27.66	-4.69
7.42	7.76	-4.58
4.78	4.76	0.41
7.36	7.55	-2.58
4.76	4.57	3.99
7.3	7.26	0.54
4.74	4.82	-1.68
15.08	15.01	0.46