Sensors and Data Collection

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Introduction

- Link between Sensors/Data Collection to traceability is high
- Some sensors and data collection tools are available in agriculture, but are in the early phase of adoption on equipment.
- Evolution of sensors and automation are limiting factors.
Tracking individual fruits/vegetables

- Localized measurements
- Geometrically calibrated
Some Existing Traceability Systems

Cattle

Grain

Fruits/Vegetables

THE INFRASTRUCTURE IS DEVELOPING FROM AN INFORMATION PERSPECTIVE
Existing Cattle Traceability System

AgInfoLink’s “Pony Express” provides a technology backbone, supporting full food traceability with robust data analysis and reporting.
eFarm’s private network delivers complete traceability from seed to final product, enabling efficiency, new revenue and food security.
AGRIS Extend Ag enables closed-loop traceability for perishable food products.
Role of Sensors and Data Collection

- Quantification of information
- Simplification of the process for chain management
- Important for food chain diagnostics/prognostics
- Essential element for automation of the food chain
2.0 Data Collection Systems

Mobile Processor and Information Display

Position Receiver
Solution Packages

- Agronomic Management
- Environmental Compliance
- Identity Tracking
- Fleet Management & Maintenance
- Mobile Office
- Machine & Operator Productivity
- Mobile Office
Parallel Tracking Display

- Uses the GreenStar display and audible tones
- Free downloadable enhancements
  - Contours
  - 5 hz WAAS and SF1
  - RowFinder

Other manufacturers:
- Operator interfaces
  - Lightbars
  - More graphical displays

Research need:
- Man-machine interfaces.
- Haptic devices
How Does it Work?

- System records passes in the GreenStar Display as a series of straight line segments
- 65,000 line segments can be stored
  - approx. 450 acres with 9.1-m (30-ft) implement
- % memory left on Run Page 1
What Does it Look Like?

Navigation Bar

Vehicle Icon
What Does it Look Like?

- **Steering Indicator**
  - Horizontal line located above vehicle icon
  - Looks ahead six seconds
  - Points in the direction of the approaching turn
  - Length of indicator represents sharpness of the turn
RowFinder

Field View

Turning View
Shift Track

- Adjusts Track 0
  - Moves all subsequent tracks
- Moves in increments of 0.1 foot
  - 1 button moves left
  - 3 button moves right
  - 2 button centers track on vehicle’s current position
Shift Track Examples

Straight Track

Contours
Adjustable Tracking Tones

- User can set the off-track error that triggers tracking tones
AutoTrac
GreenStar AutoTrac

- Assisted steering system
  - Driver must takes control at the end of each pass
- Straight line guidance only
- Currently available for all John Deere Track Tractors
What is Needed for AutoTrac?

- **Common Components for all AutoTrac Vehicles**
  - GreenStar Display
  - Mobile Processor
  - StarFire Position Receiver
  - GreenStar Harness
  - Mounting Hardware
  - AutoTrac KeyCard

- **Vehicle specific components**
  - Some vehicles will require vehicle specific components
AutoTrac Operation

User interface of AutoTrac in the RUN screen.

1. Set track spacing
2. Define track 0 (A-B line)
AutoTrac Operation

- Auto Resume switch activates AutoTrac
- Auto Resume switch has dual functionality
- APS functionality is not affected
3.0 Sensors on Agricultural Equipment
GPS Positioning Signal Options

- **Dual phase GPS receivers**
  - Subscriptions are purchased to provide higher relative accuracy as needed
    - SF2 most accurate and reliable ($800/yr)
    - SF1 ($500/yr)
    - WAAS - still in test, less accurate (free)

- **RTK GPS receiver**
  - Requires a base station for corrections
  - High absolute accuracy (2 cm)

\[\pm 10 \text{ cm}\]
Pass-to-Pass Accuracy
Pass-to-Pass Accuracy
Dynamic Tests
Dynamic Tests

Outback (WAAS) Dynamic Test
(January 10, 2002, 1 Hour 38 Minute)

Pass-to-Pass Accuracy, cm
(Average +/- Std)

Overlap (-) or Skip (+)

46' 12"
Speed = 3 mph

19' 05"
Speed = 5 mph

14' 40"
Speed = 8 mph

11' 19"
Speed = 12 mph
Dynamic Tests

StarFire (SF2) Dynamic Test
(January 10, 2002, 1 Hour 25 Minute)

Pass-to-Pass Accuracy, cm
(Average +/- Std)
Overlap (-) or Skip (+)

30' 15"
Speed = 3 mph

22' 51"
Speed = 5 mph

13' 59"
Speed = 8 mph

11' 10"
Speed = 12 mph

I II III IV V I II III IV V I II III IV V
Localization Problems

- Unaided GPS navigation does not account for terrain variations.
  - Current product works well for fields with <3% slope
  - Customer workaround for constant slopes
  - Problems in moderate, variable, and steep terrain

- Other Localization Problems
  - GPS is affected by location and topography effects
  - Vehicle posture is difficult to measure in stationary vehicles.
Attitude Compensation

To develop a low-cost solution for unaided GPS bias error created by antennae inclination (roll, pitch, yaw) on sloped terrain.
Attitude Compensation Solution

- DGPS Measurements
- IMU
- Lever-arm Dimension
- Attitude-Corrected GPS Measurements
- Lever-arm Dimension
- SSU
Localization in Orchard

Trimble RTK
- Tree spacing .5m by 2m
- 4-5m height
- Satellite availability: 4

Green=4
Blue=3
3.3 Optical Sensing of Plant/Soil Properties
Optical Sensing Characteristics

- Identification of the proper optical responses that relate to plant/soil characteristic.
- The methodology for compensation of illumination effects.
- The development of indices that remove plant, soil or environmental influences.
- Developing management strategies that relate the sensor response to meaningful influences on the plant, or soil, property.
Handheld Units and Manual Measurements

- Early development of technology requires a lot of inconvenient approaches to validate sensors performance and characterization of crop responses.
The meter calculates the SPAD value based on a ratio of transmittance of two Red and NIR illumination provided by LEDs; 650nm and 940nm.
SPAD Value Calculation

\[ SPAD = K \log_{10} \left[ \frac{IR_t / IR_o}{R_t / R_o} \right] \]

- \(SPAD\) Spad value
- \(K\) Constant
- \(IR_t\) Transmittance of NIR (940 nm)
- \(IR_o\) Light power of NIR
- \(R_t\) Transmittance of R (650 nm)
- \(IR_o\) Light power of R

NIR light is used as a reference for compensating various leaf thickness, because a leaf does not absorb the NIR illumination.
Comparison of SPAD with Spectral Reflectance

SPAD meter

Spectral radiometer

Fifty leaf samples covered SPAD value from 20 to 60.
• 20 - high stress
• 60 - no stress
Spectral Reflectance of Corn Leaves in the Visible Spectrum

Decreasing Stress

Relative Reflectance (%) vs. Wavelength (nm)

- 24.7
- 30.8
- 36.9
- 43
- 47.9
- 50.1
- 56.4
- 61.2
Results using a radiometer and a SPAD meter

- **Red Response**
  - Reflectance - 6-10%
  - SPAD - 60-20

- **Green Response**
  - Reflectance - 12-23%
  - SPAD - 60-20

\[ x_1 \ldots \text{G-Reflectance} - 550 \text{ nm} \]
\[ x_2 \ldots \text{R-Reflectance} - 650 \text{ nm} \]
Photodiode Systems

- Patchen
- Multiple row units with zones of detection
- Applications:
  - Weed control
  - Nitrogen application systems on large sprayers
Image-Based Sensors
Image-sensors for Crop Health Response

- Image Pixel Statistics
- RGN AI Data
- RGN Duty Cycle
- GPS String

Portable Computer

Fuzzy Logic Controller

Sprayer Controller

Decision Making

IO Card

GPS

Com 1

Com 2

Com 5

Frame grabber (FlashBus)

MSI

Image-sensor

Segmented Image

AI
Crop Sensing Performance

The image shows a graph with the x-axis representing distance in meters and the y-axis representing response. The graph compares the performance of different sensors labeled as s305, s989, and s990 (adjusted). The data points indicate distinct trends in response over distance, with annotations for 'Healthy' and 'Stressed' states in the field.
Remote Sensing System

- Somewhat redundant with ground-based sensor systems
- Greatest advantage is its capability as a triage tool for in-season crop management
Remote Sensing System

- Aerial systems offer greater control than satellite systems, but will require greater management of data acquisition process
- Prototype sensors and software processes available, but will require considerable development and optimization
- Can easily be converted to desired maps with high spatial resolution
Stereo Images

- Stereo image is formed by a sensor that determines a range image from a left-right stereo pair.
Row Crop Guidance

Soybean canopy near harvest
- Perception of crop height, shape, row spacing, objects within row
Mapping Crop Information

- The 3-D nature allows for perception of
  - Path for guidance down row of trees
  - Estimation of tree height and volume, spacing, shape
Soil Characterization System

- **Soil Color**
  - Soil color can be related to soil organic matter, soil moisture, and several other soil nutrients
  - No commercial soil color sensors yet available, but radiometer technology can be adapted for sensor platform
  - Ground-based system avoids crop residue

- **Electrical Conductivity**
  - Recent acceptance as useful information layer
  - Veris uses coulter-based system
  - EM-38 induces electric field and doesn’t require soil penetration, but must be electrically isolated
Soil Physical Properties

- Immediate need for sensors for application on equipment
  - Precision-depth control
  - IVT tractor
  - GPS/GIS technology
Soil Physical Properties

- Machine-soil interactions are critical for the future of offroad vehicles
  - High speed operation
  - Autonomous vehicle performance
- The work expertise has been on a decline.
Conclusions

- The sensors and data collection systems that are available today provide a low-level foundation for the development of traceability systems.
- Data collection systems will need to expand to match the level of data needed for the traceability systems. Automated data transfer between elements of the systems will increase the effectiveness of traceability.
- Permanent storage methods are needed to provide a record of the responses measured by traceability.
- Additional sensors will be needed to facilitate the measurement of responses and to provide automated data transfer. Increased funding will be required to lead to the development of these innovative technologies.