Trends in Automation of Agricultural Field Machinery

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Agenda

- Machinery Trends
- Evolving Technologies
- Next Generation Machines
- Control Strategies
- Going Forward
What limits equipment size?

- Shipping Weight
- Transport Width
- Available Power
- Total Vehicle Weight
AGCO MT975B
Engine – CAT C18, 464 kW
Ballasted Mass – 27,200 kg
Fuel Consumption – 125 L/h
Life – 20,000 h
intelligent Total Equipment Control
(John Deere iTEC Pro™ Guidance Systems)
Case IH Axialflow 9120 (Class IX)
Engine – Iveco 12.9L, 390 kW
Grain Tank – 10.1 T
Loaded Mass – 31.6 T
Harvest Rate – 11.8 ha/h
Loading Time – 220 s
Unloading Time – 125 s
Corn Head Width – 12.1 m
Yield – 14.1 T/ha
Harvest Sensing and Control
(New Holland CR 9000)

GRAIN CAM™ PURITY

INTELLICRUISE™
Balzer 2000
Capacity – 54.5 T
Total Loaded Mass – 69.3 T
Unloading Time – 120 s
AGCO RoGator 1396
Boom Width – 36.6 m
Spraying Rate – 88.3 ha/h
Tank Capacity – 4,160 L
Loaded Mass – 17,860 kg
Spray Application Total Variation

Field 2
Estimated Application Rate

Target Rate (TR) = 93.5 L per ha

- < 50% TR
- 50% TR - 90% TR
- TR +/- 10%
- 110% TR - 150% TR
- > 150% TR
Current Trend Summary

• Machines are controlled operated by humans
• \[\uparrow\text{Machine Size} = \downarrow\text{Labor Costs}\]
• \[\uparrow\text{Power, mass and storage}\]
• Metering and distribution problems
Current Trend Summary

• Capitalization ($) remains a problem
• Grain producers are forced to farm in combine units
• Combine unit – land required to cash flow a new combine (about 2,000 ha for class IX machines)
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CAN Message Structure
(DIN 9684, SAE J 1939, ISO 11783)

- Identifier Field
- Control Field
- Data Field
- CRC Field
- Acknowledgement field
- Fixed part

Inter-frame space
CAN Bus Structure
(DIN 9684, SAE J 1939, ISO 11783)
Field Operations Data Model (FODM)
(Ted Macy – MapShots)
VRS RTK continues to grow!

TRIMBLE DELIVERS MORE ACRES OF SUB-INCH ACCURACY

VRS™ infrastructure network technology is an integrated system that consists of Trimble® GPS/GNSS reference stations spread out over a large area, typically 30-45 miles (50-70 km) apart.

A central server that uses Trimble proprietary software (RTKNet™ or VRS®Net™) creates a correction model for the region covered by the network. Your AgGPS/GNSS receivers communicate using a cell modem with this VRS server to receive RTK type corrections.

TRIMBLE AGRICULTURE—THE LEADER IN RTK
Over 400 million acres under Trimble Ag RTK in the USA

VRS SOLUTIONS

TRIMBLE VRS NOW™ SERVICE
- Leader in network RTK
- Most accepted solution in the world
- Over 3000 reference stations in more than 50 countries

HOW VRS NOW WORKS IS AS SIMPLE AS 1-2-3
1. Power your Ag Rover and cell modem and connect to the VRS Network
2. Trimble VRS Now delivers RTK corrections tailored for your geographic location
3. Complete your farming and precision agriculture operation
WLAN continues to grow!
FlexRay?

Automotive Design & Production, Gardner Publications, Inc.
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An Equal Opportunity University
John Deere’s Autonomous Vehicle Development Program
Valtra’s RoboTrac Concept Tractor
Hannes Seeberg - 2007
Initial Autonomous Tractor

Darr et al. (2003)
UKAT II
UKAT II - Simplified Design w/ Hydrostatic Drive!
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Vehicle Controls Development
Collision Avoidance Sensing
Plus+1 I/O Set-Up GUI
Control Methodology- IRCA

Individual Robot Control Architecture
Obstacle Avoidance - IRCA

Obstacles

Static Obstacles
- Soft Obstacles (Grassed water ways)
- Hard Obstacles (Trees, Rocks)
- Virtual Obstacles (Mapped Field Boundaries)

Dynamic Obstacles (Humans, Animals and Machinery)
- In-Sight
- Out of Sight

Soft Obstacle

(a) Sensors (GPS)
(b) Environment
(c) Obstacle Detection
- Obstacle Avoidance
- Spray Nozzle Control Module
- Actuators

Hard Obstacle

(a) Environment
(b) Sprayer (5ulk)
Control Methodology-MRSCA

Robot I
- Reactive Behavior
- Deliberative Behavior
- Overall Control Action Architecture
- Actuators

Robot II
- Reactive Behavior
- Deliberative Behavior
- Overall Control Action Architecture
- Actuators

Robot III
- Reactive Behavior
- Deliberative Behavior
- Overall Control Action Architecture
- Actuators

Legend:
- IRCA: Individual Robot Control Architecture
- Central Processing and Communication Line(CPCU)
- Hardwire Communication
- Wireless Data Transmission to CPCU from Robot 1
- Wireless Data Transmission to Robot 2 from CPCU
- Inter Robot Wireless Data Transmission from Robot 1 to other Robots
- Inter Robot Wireless Data Transmission from Robot II to other Robots
- Inter Robot Wireless Data Transmission from Robot III to other Robots
- Transmitter
- Receiver

Image: Row of robots in a facility.
Wireless Communication

Implicit Communication:
- States \((x, y, \theta)\)
- Velocities \((V, \omega)\)

Explicit Communication:
- Point to point communication of commands

Explicit Communication:
- Request
- Reply

UAgV 2

move

UAgV 1

monitoring station

laptop

implied communication (spatial location and speed)

explicit communication (specific commands)
The fusion of coordination strategy and inter-robot communication with IRCA constitutes the MRSCA.
MRSCA for Agricultural Operations

Homogeneous MRS (no cooperation)
Heterogeneous MRS (absolute cooperation)
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A few thoughts…

- Liability will require humans to remain on large machines
- Leader-follower systems will be common place for harvesting
- Point to point and point to multipoint communications will be essential
More thoughts…

• First autonomous tractors will be used in permanent crops
• Low-power vehicles will minimize liability
• Must develop intelligence - capacity to sense, assess and react to problems
Ideal Autonomous Tractor

- Low-draft applications (<30 kW)
- Light weight (<2,000 kg)
- Reduced design life (<5,000 h)
- Symmetry to minimize parts and service
- Green design, easy to recycle components
Grazie!