The role of mechatronics in crop product traceability

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Chicago (USA)
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The role of mechatronics in crop product traceability

1 Introduction

2 Overview on precision crop farming

3 Applications of mechatronics
   Automated data acquisition
   Site-specific crop management
   Fleet management
   Guidance and field robotics

4 Traceability
   Efficient sensors
   Distributed controllers
   Standardized communication
   Integrated security / safety concepts

5 Conclusions
Food and society

People in industrialized countries lost the relationship to food production and the real production itself:

- Milk comes from the super market. If milk has a connection to the cow it is because of TV advertising for chocolate with the colourful (violet) cow.

- The well-protected environment is required by all people, agriculture is the primary enemy of the environment.

- Crises like BSE and Foot and Mouth Disease support the consumer in his distrust against agriculture – agriculture means environmental pollution and profit.

- The work in the house and in the garden, with flowers and pets, loved by almost all people, leads to a self-overestimation – everyone becomes a specialist in agriculture.
Landwirtschaftliches BUS-System (LBS) by DIN 9684/2-5 and ISO 11783 (ISOBUS)

DIN = CAN V2.0A, 125 kB/s
ISOBUS = CAN V2.0B, 250 kB/s

T-ECU Tractor internal Electronic Control Unit

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Information technology (IT) applications in arable farming

Precision Farming

Automated data acquisition
- Fieldbooks and bookkeeping
- Basic data for Precision Farming
- On-farm research
- Administration
- Quality management

Site specific farming
- Tillage
- Drilling
- Fertilizing
- Spraying
- Irrigation
- Harvesting (with online decision)

Fleet management
- Location monitoring
- Central equipment monitoring and control
- Route planning with autonomous sequence control
- Route planning with central sequence control
- Obstacle/danger signalising (map matching)

Field robots
- Implement control/Automatic guidance
- Manned guiding vehicle and unmanned following vehicles
- Unmanned vehicles of existing concepts
- Unmanned vehicles of new specialised concepts

Farm management
Crop management
Machine management
Labour management

Traceability (documentation)

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Examples of automated data acquisition with LBS

- schematic -

Gerätekenner (IMI)
- Anmeldung (Gerätebezeichner)
- Icon
- Systemort
- Grundparameter

Erfassung von
- Anbauzeit
- Betriebszeit
- Leistung

Grundbodenbearbeitung
Bestellkombination
Futterernte
Transport

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System configuration automated process data acquisition

Task - Controller

Algorithms for acquisition of:
- position data
- LBS-base data
- available process data from IMI

draft force (EHR)

Terminal

GPS

Implement Indicator IMI

LBS_{Lib} for communication on Bus

defined informations:
- implement name
- implement type
- working width
- mounting position

process data:
- working status, -area, -distance, -time
- total time, total area

RS 232

Personal Organizer

Data Log file

PC

analyzing with IMI\_izer (SQL DB) with queries and reports

target values

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Automated field data documentation

(Field_tracer)

Input

Pre Processing

SQL-database

Process data analysis
- referring to tasks or years -

Time Way
- total time
- part time
- work way
- standing time

Used material Yield
- used materials
- used fuel yield

Tractor Implement
- working depth / height
- working intensity capacity

Geo data analysis
- GIS -

Traces
- tracks
- velocity
- working position
- standing time
- turning ways / pattern

Grids
- labour time interruptions
- used materials
- yield
- soil resistance

Outline
- labour time interruptions
- used materials
- yield
- soil resistance

Execution

Materials

Maschine use

Work sequence optimisation

Location information

Location evaluation

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**Parameters from automated process data acquisition**

<table>
<thead>
<tr>
<th>Date</th>
<th>Start time</th>
<th>End time</th>
<th>Field</th>
<th>Tractor</th>
<th>Implement</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001.04.30</td>
<td>19:45 pm</td>
<td>20:30 pm</td>
<td>TH01</td>
<td>MB-trac</td>
<td>spreader</td>
<td>fertilising</td>
</tr>
</tbody>
</table>

**Time consumption in field**

<table>
<thead>
<tr>
<th></th>
<th>total</th>
<th>working</th>
<th>turning</th>
<th>standing</th>
<th>time / field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>2001.04.30</td>
<td>19:45 pm</td>
<td>20:30 pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td><strong>0.59 h</strong></td>
<td><strong>61 %</strong></td>
<td><strong>23 %</strong></td>
<td><strong>16 %</strong></td>
<td><strong>0.10 h/ha</strong></td>
</tr>
</tbody>
</table>

**Driven distance in field**

<table>
<thead>
<tr>
<th></th>
<th>total</th>
<th>working</th>
<th>turning</th>
<th>distance / field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>2001.04.30</td>
<td>19:45 pm</td>
<td>20:30 pm</td>
<td></td>
</tr>
<tr>
<td><strong>Distance</strong></td>
<td><strong>4.11 km</strong></td>
<td><strong>81 %</strong></td>
<td><strong>19 %</strong></td>
<td><strong>0.71 km/ha</strong></td>
</tr>
</tbody>
</table>

**Working speed**

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>stddev.</th>
<th>mean</th>
<th>stddev.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.26 km/h</td>
<td>2.27 km/h</td>
<td>450 RPM</td>
<td>61 RPM</td>
</tr>
</tbody>
</table>

**PTO speed at work**

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>stddev.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>450 RPM</td>
<td>61 RPM</td>
</tr>
</tbody>
</table>

**Cultivated area**

<table>
<thead>
<tr>
<th></th>
<th>sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.75 ha</td>
</tr>
</tbody>
</table>

**Applicated volume / weight**

<table>
<thead>
<tr>
<th></th>
<th>sum</th>
<th>mean</th>
<th>stddev</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>915.6 kg</td>
<td>203.4 kg/ha</td>
<td>34.9 kg/ha</td>
</tr>
</tbody>
</table>
System approaches of site specific fertilization in crop production

Mapping-Approach

Yield target

Mapping-Software

Realtime approach with map overlay

Site specific reference (limitations)

Crop reference (set points)

Yield target (goal)

Mapping-Software

Growths \(\div\) target comparison

N, resistance, others

Crop

Farming by balance

1 Preceding crop

2 Beginning of vegetation

3 Fertilization

Farming by sustainability

Farming by growth

Realtime-Approach

Crop reference

Yield target

Growth \(\div\) target comparison

1

2 Soil moisture

3

TUM

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Part field management approaches of site-specific crop management

Site-specific crop management

Large-scale farming

- Determination of heterogeneities
- Determination of management zones (same yields) under consideration
  - Technical differentiation
  - Economical efficiency
  - Ecological efficiency

Part field determination by minimum field sizes
(> 3 ha to > 10 ha)

Small-scale farming

- Assembling of small fields with equal crop rotation
- Definition of part fields from ownership/field operators
- Field operations by common operation target
  - Ownership
  - Common yield target
  - Heterogeneity

Consideration of part fields from different land lords in a transborder field

Size of transborder fields limited by existing infra structure (roads, ditches, ... ) and crop rotation
Transborder Farming Systems

Existing structure

Yield orientation (economical)
- by ownership
- by common yield target
- by site specific farming

Environmental orientation (ecological)
- by erosion reduction
- by landscape protection

<table>
<thead>
<tr>
<th>Farmer</th>
<th>WW</th>
<th>WB</th>
<th>WR</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>4;6</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>11</td>
<td>7</td>
</tr>
</tbody>
</table>
Logistics of fleet management for sugar beet growing

- Communication:
  - MODACOM
  - Local radio
  - Package radio
  - Others

- Fleet Management:
  - GIS/DB
  - Planning
  - Management

- Route 1:
  - Sequence
  - Location
  - Field size
  - Part field size
  - Time and date

- Route n:
  - Sequence
  - ... 

- Harvester:
  - Location
  - Harvested area
  - Harvested quantity

- Loader 1:
  - Sequence
  - Location
  - Quantities
  - Vehicles
  - Time and date

- Delivery Strategy:
  - Positioning:
    - Location
    - Time

- Factory:
  - Soil
  - %
  - Quantity

- Vehicle Unloading:
  - Position
  - Time

- Growing Area Record

- Harvesting Logistics

- Take Away Logistics

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Vision of Future Agricultural Vehicles „Manned Guidance Vehicle with unmanned Satellite Vehicles“
Traceability in the production chain

There are three types of interfaces
- between processes in the chain from the crop to the consumer (field to fork)
- between processes and the administration (taxes, subsidies)
- between processes and society (confidence, belief)

→ Traceability must fulfill all requirements in the whole chain!
Information demand is still not defined

Administration
- Field location, field size, crop, treatment, yield expectation, yield
- Nutrient application, nutrient balance

Succeeding process
- Mass/volume, origin, route of transport, time of transport, occurrence during transport
- Processes, ingredients,

Consumer
- Farming type, farmstead, region, time of production, field operations
- Applications, fuel consumption, working conditions, soil stress / working distance/ha
- Ingredients, water content, quality rate/class
### Field operations in the product chain

#### Farm (direct marketing)

1. **Crop**
2. **Field processes**
3. **Farm processes**
4. **Customized processing**
5. **Storage**
6. **Distribution**
7. **Retail**
8. **Consumer**

#### Farm

1. **Crop**
2. **Field processes**
3. **Farm processes**
4. **Commercial processing**
5. **Storage**
6. **Distribution**
7. **Retail**
8. **Consumer**

#### Contractor

1. **Crop**
2. **Field processes**
3. **Farm processes**
4. **Commercial processing**
5. **Storage**
6. **Distribution**
7. **Retail**
8. **Consumer**

#### Farm

1. **Crop**
2. **Field processes**
3. **Farm processes**
4. **Commercial processing**
5. **Storage**
6. **Distribution**
7. **Retail**
8. **Consumer**

#### Commerce

1. **Crop**
2. **Field processes**
3. **Farm processes**
4. **Commercial processing**
5. **Storage**
6. **Distribution**
7. **Retail**
8. **Consumer**

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**Production information from farm level to consumer**

1 Farmer-only chain  
   - Responsibility only by the farmer  
   - Customized products are the demands of the consumers

2 Farmer – commerce chain  
   - Main responsibility by the farmer  
   - No influence to the end product by the farmer

3 Farmer – contactor – commerce chain  
   - Main responsibility by the farmer  
   - No influence to the end product by the farmer  
   - Contractor

4 Contractor – commerce chain  
   - Main responsibility by the farmer  
   - No influence to the end product by the farmer  
   - Contractual influence to the contractor
Product chain with supplementals in food production

Identification and process integration in field and/or farm

1. Crop
2. Field processes
3. Farm processes
4. Commercial processing
5. Storage
6. Distribution
7. Retail
8. Consumer

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# Information in agricultural crop processes as part of the product chain

## Farm

<table>
<thead>
<tr>
<th>Field conditions</th>
<th>Information gathering</th>
<th>Information processing</th>
<th>Information integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Sensors</td>
<td>Georeferenced acquisition</td>
<td>Field book</td>
</tr>
<tr>
<td>Environment</td>
<td>- manual (shape, taste, ...) - technical (mass, time, ...)</td>
<td>- working person(s) (identification) - integrated technology - material (type, amount, ingredients) - energy (fuel,oil, ...) - time (location, work situation) - site (farm, region, country)</td>
<td>→ Field flow</td>
</tr>
<tr>
<td>Crop</td>
<td>Actuators (real settings)</td>
<td>Memorization on-board</td>
<td>→ Cash flow</td>
</tr>
<tr>
<td>Soil</td>
<td>Location systems - Position - Time</td>
<td>Field book</td>
<td>→ Farm flow</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td>Quality management</td>
</tr>
</tbody>
</table>

## Out-of-farm

- **Process chain integration**
  - Supply - seed - fertiliser - pesticides
  - Delivering - products - by-products - other materials

## Field operations

<table>
<thead>
<tr>
<th>ISOBUS (ISO 11783)</th>
<th>ISOBUS (ISO 11783)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat</td>
<td></td>
</tr>
<tr>
<td>Resistance</td>
<td>By wire</td>
</tr>
<tr>
<td>Reflectance</td>
<td>Wireless</td>
</tr>
<tr>
<td>Fluorescence</td>
<td>Physical and syntactical standard</td>
</tr>
<tr>
<td></td>
<td>Syntactical standards</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Commerce

- Paper (additional)
- Paper (by-pack)
- Bar code (on the product)
- "Bio bar code" in product
- No/different standards

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Mechatronics in the farm processes

Mechatronics
- reacts on signals from crop, soil, environment
- guarantees optimised soil preparation
- adjusts defined application rates

through
- information gathering (sensor/actuator values)
- information processing (parameters)
- information integration into the farm management (quality management)
- information supply to/from the trade (commercial processing)
Mechatronics and sensors

Modern technology includes many sensors (without extra costs)

There are problems with mass and/or weight detection
- Calibration
- Robustness
- Reliability

New possibilities will be available in the detection of quality and ingredients
- NIR (near infra red reflectance)
- NIT (near infra red transmission)
- Bio bar code
- Others

Consumers would like to have additional information on
- Shape, size
- Colour
- Consistency
- Others
Mechatronics and electronic communication

Started in 1986 with LBS (DIN 9684) still no international accepted standard is available

The ISOBUS (ISO 11783) is still under definition (started in 1990) and would be able to be the standard if

- all interfaces follow this standard
- controllers for all technologies are available
- test installations of the standards can be used.

Nevertheless incompatibilities are created by multiple programming of same procedures with different understanding and different solutions of definitions, causing

- very long development cycles
- extensive and continuing tests on conformity
- frustrated users (remaining incompatibilities with not detectable reasons in a complex system)

An “Open Source Code” would overcome all problems in a very short period of time!
Sequence of an “Automatic process data acquisition system“ with worker identification and security components

**Memory card**
- Identification of working person
- Order
  - Empty order
    (used for random or additional processes)

**LBS-Terminal**
- Information check (driving allowance)
- Limitation of tractor usage

**Follow order**
- Driver information

**Check order**
- Empty order
  - Unlock limitation of tractor usage

**IMI(s) connected?**
  - no
  - yes

**Field coordinates**
- Field detection by coordinates
  - Virtual headland
  - Information gathering
  - Detection of field boundary
    (e.g. >5 WW outside field boundary)

- Field detection by first working activity
  - Field envelope
- Ongoing detection of field envelope
- Detection of field boundary
  (e.g. >5 WW outside existing field envelope)

**Close order and store all information**
Conclusions

• Agricultural machinery is becoming more and more intelligent. Position detection with GPS (Galileo after 2008), standardised electronic communication based on LBS / ISOBUS and a high number of different sensors will become basic components.

• Precision Farming seems to be the farming strategy and practise of the future.

• Product traceability needs information gathering, processing, integration into the farm management and supply to/from the trade.

• Within mobile agricultural equipment GPS and the standardised communication by ISO 11783 opens the best possibilities for traceability.

• Sensors available today sense a wide variety of process parameters. There is a big demand for the detection of product quality, ingredients and parameters defined by the consumers.

• Traceability exceeds existing security concepts. Manual input allows manipulation. Automation may be the adequate answer.