Outline

Sensors → Data → Data processing → Information → Decision making → Decision → Action

- Matching requirements of algorithms
  - Reliable
  - Cheaper
  - Faster

- Cleaning
- Calibration
- Interpolation
- Standards

- Match to data / information
- Automation (smartness)
- Flexibility (match to conditions, on-farm-research, machine learning)
- Standards
- User friendliness

- Applicators need to be precise and reliable
- Automation (robots)

Applications: Tillage, crop protection, horticulture ...

Cooperation: PA centres & schools
Soil sensors for mapping
## Soil sensors for mapping: Overview

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<tr>
<th>Mechanical</th>
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<tr>
<td>Fuel consumption</td>
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<tr>
<td>Draft force</td>
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<tr>
<td>Vertikal penetrometer</td>
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<td>Horizontal penetrometer</td>
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<tr>
<td>Galvanic (SoilDoctor)</td>
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<tr>
<td>Ionenselective elektrodes (pH)</td>
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<td>Field effect transistors</td>
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<td>Artificial nose</td>
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<td>Antibodies</td>
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<tr>
<td>Vis-NIR spectroscopy</td>
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<td>Camera</td>
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<td>Raman spectroscopy</td>
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<td>Plasma spectroscopy</td>
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<td>Geoelektrical (Res, EMI, Cap)</td>
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<td>TDR, FDR</td>
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<td>Geo-radar</td>
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<td>THz</td>
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<td>Gamma spectroscopy (pass.)</td>
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<tr>
<td>Impulse neutron (active)</td>
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<td>Röntgen fluorescence XRF</td>
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<td>Seismics</td>
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<th>Pneumatical</th>
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<tr>
<td>Conductivity of air</td>
<td>-</td>
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### Symbols:

- **+** Commercial, acknowledged / regularly used
- **?** Commercial, rarely used / problematic
- **0** Research only
- **-** Under development, promising / intensive research
Soil sensors for mapping: Global Workshop on Proximal Soil Sensing 2013

- Soil spectroscopy and EC received most attention
- Gamma spectroscopy gained a lot of interest
- Sensor fusion
- Calibration issues
- New sensors
  - Lab scale: THz, photo-acoustic spectroscopy, ...
  - Field scale: Geophilus, Capacitance
Soil sensors for mapping: New geo-electrical sensors

Geophilus
- Galvanic coupled resistivity sensor
- 5 depths
- Different frequencies
- & Gamma ray sensor

Jörg Rühlmann, IGZ, Germany, www.igzev.de

geocarta MPG
- Capacitively coupled sensor
- 3 depths

Michel Dabas, geocarta, France, www.geocarta.net
Soil sensors for mapping: Veris pH-Manager ionselective elektrodes

Antimony elektrodes
Soil sensors for mapping: Veris pH-Manager ionselective elektrodes

- **Field A**: $y = 2.94 + 0.62x$, $r^2 = 0.71$
- **Field B**: $y = 2.70 + 0.59x$, $r^2 = 0.63$
- **Field C**: $y = 3.97 + 0.40x$, $r^2 = 0.84$

**Graphs:**
- **Summer barley yield [t/ha]**
- **Lupines yield [t/ha]**
Soil sensors for mapping: Challenges

- Need for "true" nutrient sensor
- Need physical soil condition sensors (tillage)
Crop sensors
Crop sensors: Multiplicity of commercial products

N-Sensor (YARA), hyperspectral VNIR, passive

N-Sensor ALS (YARA), multi-spectral VNIR (54), active

CropSpec (TOPCON), 2 WVB, active (laser)

MiniVeg (Fritzmeier), fluorescence, active (laser)

Isaria (Fritzmeier), 5 WVB, active

CropMeter (Claas agrocom), mechanical, passive

Multiplex (Force A), induced fluorescence (3), active (LED)

GreenSeeker (N-Tech, Trimble), 2 WVB, active

P3 (Agri Con), ultrasonic, active

P3 (Agri Con), ultrasonic, active
Crop sensors: On-line measurements with map-overlay

Early N application becomes more important!
Crop sensors: Renaissance of yield mapping?

- Yield maps are important for decision making
  -> better yield monitors, better training

- Claas reports increase in sales of yield monitors after a period of decline

Importance of yield map correction
Crop sensors: Summary

- Combination of on-line and off-line approaches
- Need for discrimination of stresses (N, H2O, pests)
- Crop protection: Weeds, infections, pests
- Don’t forget yield mapping
Cell phone = Swiss army knife

I can do everything
Cell phone: Sensors

- Radio receiver / transmitter for GSM, GPRS, EDGE
- Accelerometer
- Gyroscope
- CPU
- WLAN and BlueTooth
- Positioning unit GPS, GSM and WLAN
- Audio chip
- Touch screen controller
- Storage 32 GB
- Digital compass
- Power management
- UMTS processor
- Front
- Back

Technology Review 03/2011, p. 71, modified
Cell phone: YARA ImageIT app, determination of N-requirements of rape seed in spring

Stefan Reusch,
YARA, Germany
http://www.yara.de/media/apps/imageit/index.aspx
Cell phone: FieldScout GreenIndex+ Nitrogen App
and Board: Determination N requirements of Corn

Spectrum Technologies, Inc.
UAV* = Another Swiss army knife?

* Unmanned aerial vehicle
UAV: Rotary wing

Ferry Bachmann, HU Berlin, Germany, ADLER - agricopter project, http://agricopter.de
UAV: Low cost

- Build a system for less than 3000 €

Ferry Bachmann, HU Berlin, Germany, ADLER - agricopter project, http://agricopter.de
UAV: Ortho-photo

Automatic mosaiking and ortho-photo generation with AgiSoft ( < m 2 error)

Ferry Bachmann, HU Berlin, Germany, ADLER - agricopter project, http://agricopter.de
UAV: Site-specific N application

Ruprecht Herbst, HU Berlin, Germany, ADLER - agricopter project, http://agricopter.de
UAV: Discussion

- Challenge to traditional remote sensing
- Many applications: crop protection, N-management, cattle management, fish ponds, meteorology

Limitations:
- Batteries (duration of flight) for rotary wing UAV
- National and EU wide privacy and security regulations
Applications
Precision horticulture – a continent still to explore
Applications: Precision horticulture

- Opportunity for PA: High value crops with intensive management (e.g. apple growers are spraying > 16 times per season)
Applications: Tree specific thinning

- Alternate bearing: Biannual cycle of yields with many small apples and a few big apples every other year (alteration between many and few flowers).
- Different from tree to tree
- Thinning of flowers can regulate alternate bearing

Different number of flowers → Different number of apples → Different sizes of apples
Applications: Tree specific thinning

www.gil-net.de/Publikationen/25_95.pdf
Applications: Discussion of precision horticulture

Problem: Diversity of applications
  - Segmented market
  - Lack of standards

Opportunities for small companies?
Decision making
From PA to “smart farming”
The term “smart farming” became popular at the agritechnica 2011

Decision making: Smart farming

- Sensors
- Data processing
- Decision making
- Action

Shift PA to smart farming
Decision making: Network of location-based services

Meteorological services → Weather data → Server

Cadastral & soil maps, regulations → Documentation for subsidies & environmental reg. → GPRS Internet

Administration → Orders → Farmer, office

Ag machinery services → Documentation → Farmer, mobile

Orders → Data → Ag suppliers

Data → Orders → Ag advisors

Recommendations → Farm data → UAV, lab
Decision making: iGreen project

iGreen 2009 – 2013

Aims

- **network of location-based services** and knowledge, integrating various public and private information sources based on “**semantic technologies**”
- **mobile decision assistant systems** which facilitate the decentralized support and optimization of cooperative production processes.

24 partners, including 12 private companies:
- SAP AG, John Deere, CLAAS , Krone, Amazonen-Werke, Grimme, LEMKEN, RAUCH

Results

- **Machine-Connector**: communication of machines from different brands
- **GeoBox & MapChat**: Geo data services ag services providers
- **Test case potato production**

www.igreen-projekt.de/iGreen
Growing demand. Farmers ask for:
- “smart” systems
- web based services
- mobile applications

Challenges
- Integrating / developing PA decision support algorithms
- Own experience (on-farm-research) vs instant black box (smart) solutions
- Data: privacy, security, ownership
Action
Action: COALA field robot „BoniRob“ (crop scout)
Action: COALA Field robot „BoniRob“ (crop scout) and remote farming

Remote Farming.1a: "Manual" remote weed control
Remote Farming.1b: Image Processing proposed weed control
Remote Farming.1c: Self-learning based automatic weed control
Improving PA research by focussing and cooperation: Towards European PA centres
Cooperation: Agricultural Industry Electronics Foundation (AEF)

Established 2008
Seven AEF founding members
About 140 members today

Aim
provide resources and know-how for the increased use of electronic and electrical systems in farming.

ISOBUS was the main focus initially (ISOBUS Test Center, Univ. Osnabrück)

Shift to standardization of agricultural applications in general, e.g. farm management information systems (FMIS), electric drives camera systems

Introducing of guidelines for ISO (International Organization for Standardization) standards

www.aef-online.org/de/
Cooperation: Competence Center ISOBUS

- Founded 2009 by AMAZONE, GRIMME, KRONE, KUHN, LEMKEN und RAUCH

- Common development of ISOBUS components:
  - **ISOBUS-Terminal CCI 100/200**
  - **CCI.Apps**

- Member in ag technology boards

- Information about ISOBUS for service suppliers, dealers and students

- New initiatives for data management, steering by implement (TIM), on-board high voltage power supply

www.cc-isobus.org/
2010 John Deere has officially opened its European Technology and Innovation Centre (ETIC) in Kaiserslautern, Germany.

Focus is on

- intelligent solutions,
- integration of electronics into tractors and harvesting equipment
- technologies that help to automate machine operation, reduce operator fatigue and increase machine productivity in the field.

John Deere has recently become a shareholder in the German Research Centre for Artificial Intelligence (DFKI)
Cooperation: The COALa experience from Germany

- Competence Of Applied Agricultural Engineering
- Outreach centre of the University of Applied Sciences Osnabrück, Germany
- Located in the heart of Germany’s “Agrotech Valley”

www.hs-osnabrueck.de/coala.html

Niedersächsisches Institut für Wirtschaftsforschung (2009): Die Agrartechnik-Branche im Osnabrücker Land. NIW, Hannover, Germany
Cooperation: COALA network
http://www.hs-osnabrueck.de/coala.html

Susanne Fittje, COALA,
www.hs-osnabrueck.de/coala.html
Cooperation: COALA results

BoniRob field robot

KOMOBAR
Decision support and communication structures for mobile machinery
Cooperation: COALA phenotyping system

Phenotyping system
Breed Vision

Arno Ruckelshausen, COALA, www.hs-osnabrueck.de/coala.html
Cooperation: COALA ultrasonic sensor
Cooperation: Summary

- Cooperation can promote precision ag
- Cooperation is possible, even with competing companies

- It takes time to get results
- It needs favourable conditions (people, infrastructure, money etc.)

- Towards European PA centres?
Summary

Step by step: Evolution not revolution

Applications: Tillage, crop protection, horticulture ...

Cooperation: PA centres & schools