MOBILE INTERNET SERVICES FOR ONLINE SUPPORT OF AGRICULTURAL MACHINERY

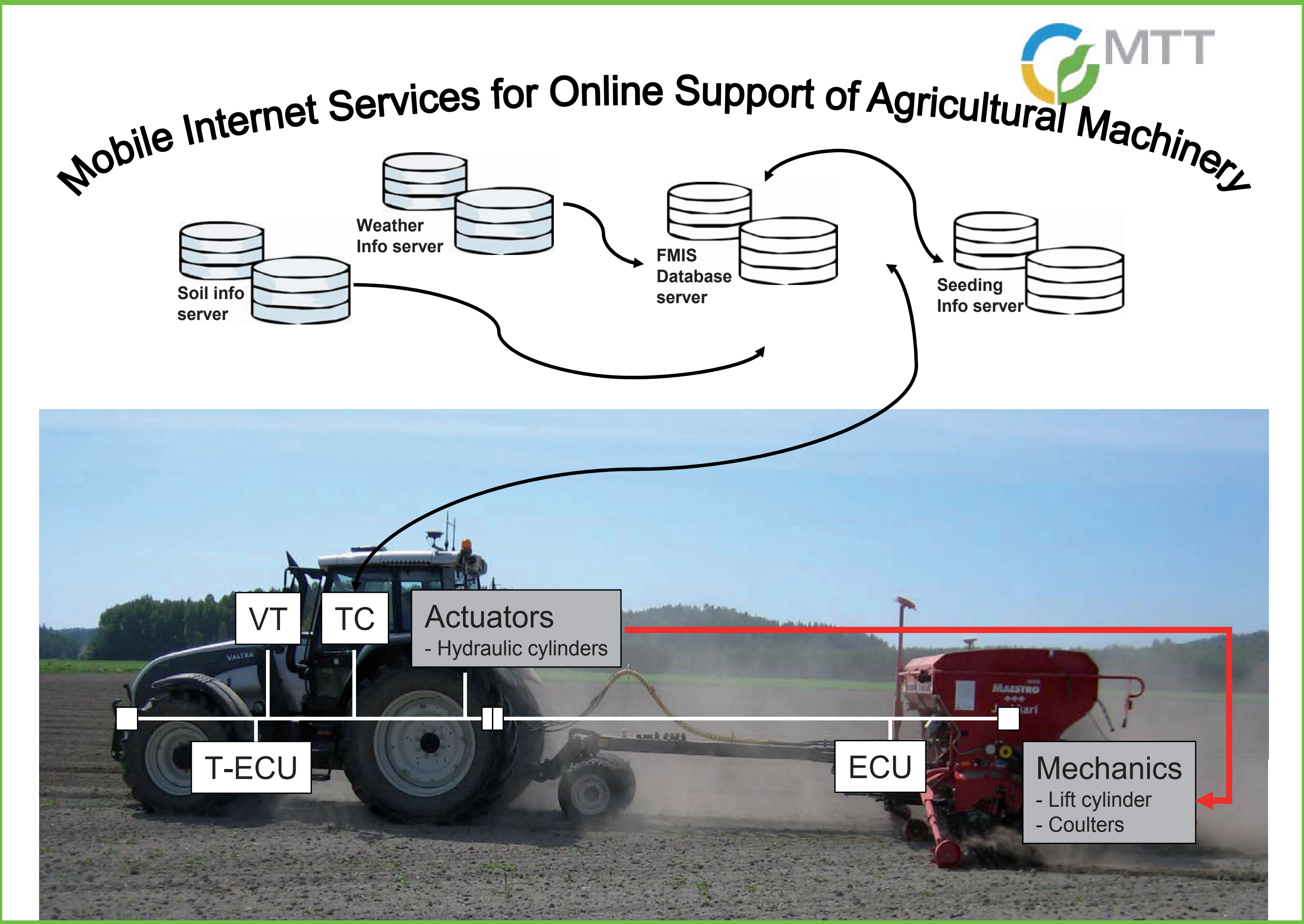
PROCEEDINGS OF NORDUNET AGRO SEMINAR

10TH AND 11TH JUNE 2010 IN HELSINKI AND VIHTI, FINLAND

INTERNAL RAPPORT · AGRICULTURAL SCIENCE NR. 28 · SEPTEMBER 2010

ALLAN LECK JENSEN · LIISA PESONEN

FACULTY OF AGRICULTURAL SCIENCES
AARHUS UNIVERSITY



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DEPARTMENT OF AGROECOLOGY AND ENVIRONMENT

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Finland

Internal reports mainly contain research results that are primarily targeted DJF employees and partners. The reports can also be used as handouts at theme meetings or they can be used to describe internal conditions and guidelines at DJF.

The reports can be downloaded at www.agrsci.au.dk

Print: www.digisource.dk

Contents

(Click on the headline to jump to the page)

Background

The project "Mobile internet services for online support of agricultural machinery" has received funding from the Nordunet3 (www.nordunet3.org) program from 2006 to 2010.

The participants of the project are:

- Aarhus, Faculty of Agricultural Sciences, University Denmark
- The Alexandra Institute ApS, Denmark
- MTT Agrifood Research, Finland

In addition, the project is followed without funding by Swedish Institute of Agricultural and Environmental Engineering, Lund Institute of Technology and Danish Agricultural Advisory Service.

The objectives of the project are:

1. to develop internet communication services for collecting data on farm machinery operations, and for instructing farm machinery from farm office applications, and
2. to test and demonstrate the performance and feasibility of the services by implementing and operating selected examples
3. to support the development of commercial operational services to facilitate the use of the technology in agriculture

The purpose of the seminar is to exchange results from the project with project partners, associates and relevant companies, and to discuss areas of needed further research and possibilities for collaboration.

List of patricipants:

Thursday, 10th of June in Tieteidentalo, Helsinki

1. Raphael Dobers, Alexandra Institute, DK
2. Jerker Hammarberg, Alexandra Institute, DK
3. Jens. P. Olesen, Jepotech ApS, DK
4. Mikael Gilbertsson, JTI, SE
5. Pasi Suomi, MTT, FI
6. Teemu Autio, Suonentieto Oy, FI
7. Jere Kaivosoja, MTT, FI
8. Allan Leck Jensen, Aarhus University, DK
9. Michael Nørremark, Aarhus University, DK
10. Mikko Laajalahti, Suonentieto Oy, FI
11. Pertti Savela, ProAgria, FI
12. Ibrahim Abdel Hameed, Aarhus University, DK
13. Hanna Huitu, MTT, FI
14. Liisa Pesonen, MTT, FI

Friday, 11th of June at MTT, Vihti

1. Allan Leck Jensen, Aarhus University, DK
2. Raphael Dobers, Alexandra Institute, DK
3. Teemu Autio, Suonentieto Oy, FI
4. Hanna Huitu, MTT, FI
5. Sirpa Thessler, MTT, FI
6. Ari Ronkainen, MTT, FI
7. Ibrahim Abdel Hameed, Aarhus University, DK
8. Jerker Hammarberg, Alexandra Institute, DK
9. Mikko Laajalahti, Suonentieto Oy, FI
10. Pertti Savela, ProAgria, FI
11. Jere Kaivosoja, MTT, FI
12. Mikael Gilbertsson, JTI, SE
13. Pasi Suomi, MTT, FI
14. Michael Nørremark, Aarhus University, DK
15. Liisa Pesonen. MTT, FI

Program

10 June 2010:

Presentations, Tieteiden talo (House of Sciences), Helsinki

13:00	Liisa Pesonen	Welcome and overview of the project
13:20	Jerker Hammarberg	Network Infrastructure for MoVeTracker
13:40	Raphael Dobers	Publish=Subscribe Middleware For Agricultural Applications
14:00	Allan Leck Jensen	Experience with MoVeTracker for optimization of maize and grass harvest
14:20	Jens Peter Olesen	MoVeTracker – the process from research prototype to commercial product
14:35		Discussion
15:15	Pasi Suomi	Data management in automation-assisted tractor-implement combination
15:35	Jere Kaivosja	Site specific information in farm machinery operations
15:55	Ibrahim A. Hameed	A platform for route optimization and navigation of vehicles in field operations
16:10	Michael Nørremark	Examples of agricultural ICT utilising web server based electronic control units (WebECU)
16:35	Allan Leck Jensen	Discussion on finalizing the project an possibilities for future collaboration

11 June 2010:

Implementations and demos, MTT Vihti (Vakola)

9:00 – 12:00 Implementations/demos:

- MoVeTracker
- CropInfra platform
- Data acquisition with tractor- combined seeder combination embedded with ISOBUS class 3 features
- Weather data to tractor cabin and field operation documentation in ISOBUS featured precision sprayer
- EnviSense project – sprayer part

Presentations *(Click on the title to jump to the presentation. Of the first page of each presentation it is possible to click on the title to go back to this page)*

Liisa Pesonen: Welcome and overview of the project

Jerker Hammarberg: Network Infrastructure for MoVeTracker

Raphael Dobers: Publish---Subscribe Middleware For Agricultural Applications

Allan Leck Jensen: Experience with MoVeTracker for optimization of maize and grass harvest

Jens Peter Olesen: MoVeTracker – the process from research prototype to commercial product

Pasi Suomi: Data management in automation assisted tractor-implement combination

Jere Kaivosja: Site specific information in farm machinery operations

Ibrahim A. Hameed: A platform for the optimization and automation of autonomous vehicles in field operations

Michael Nørremark: Examples of agricultural ICT utilising web server based electronic control units (WebECU)

Posters

Liisa Pesonen, Pasi Suomi, Raimo Linkolehto, Frederick Teye, Jere Kaivosoja & Ari Ronkainen: CropInfra - Production and information management infrastructure for crop production farms

Sirpa Thessler & Hanna Huitu, MTT Plant Production Research: SoilWeather: Wireless sensor network at Karjaanjoki river basin Finland

Ibrahim Abd El-Hameed, Dionysis Bochtis, Michael Nørremark, & Claus G. Sørensen: On-line field-track generation tool

Arto Visala, Timo Oksanen, Liisa Pesonen, Pasi Suomi & Jukka Ahokas: Assisting and Adapting Agricultural Machine AGROMASSI

Frederick Teye, Pasi Suomi, Raimo Linkolehto, Liisa Pesonen & Jere Kaivosoja: Integration of weather data in the precision agriculture spraying

Michael Nørremark: PC and Web server based vehicle and implement control

NordUnet Agro

Mobile Internet Services for Online Support of Agricultural Machinery

NORDUnet3 program

Liisa Pesonen, MTT

Seminar

10.-11.6.2010

Tieteiden talo

NORDUnet - Nordic Infrastructure for Research & Education

NordunetAgro 2006-10

Participants:

University of Aarhus*, (coordinator; Iver Thysen, Allan Leck Jensen)*
- *Faculty of Agricultural Sciences, Dep. of Agroecology and Environment*
- *Department of Computer Science*
- *Faculty of Agricultural Sciences, Department of Agricultural Engineering*

Alexandra Institute Ltd.

MTT *Agrifood Research Finland*

Danish Agricultural Advisory Service

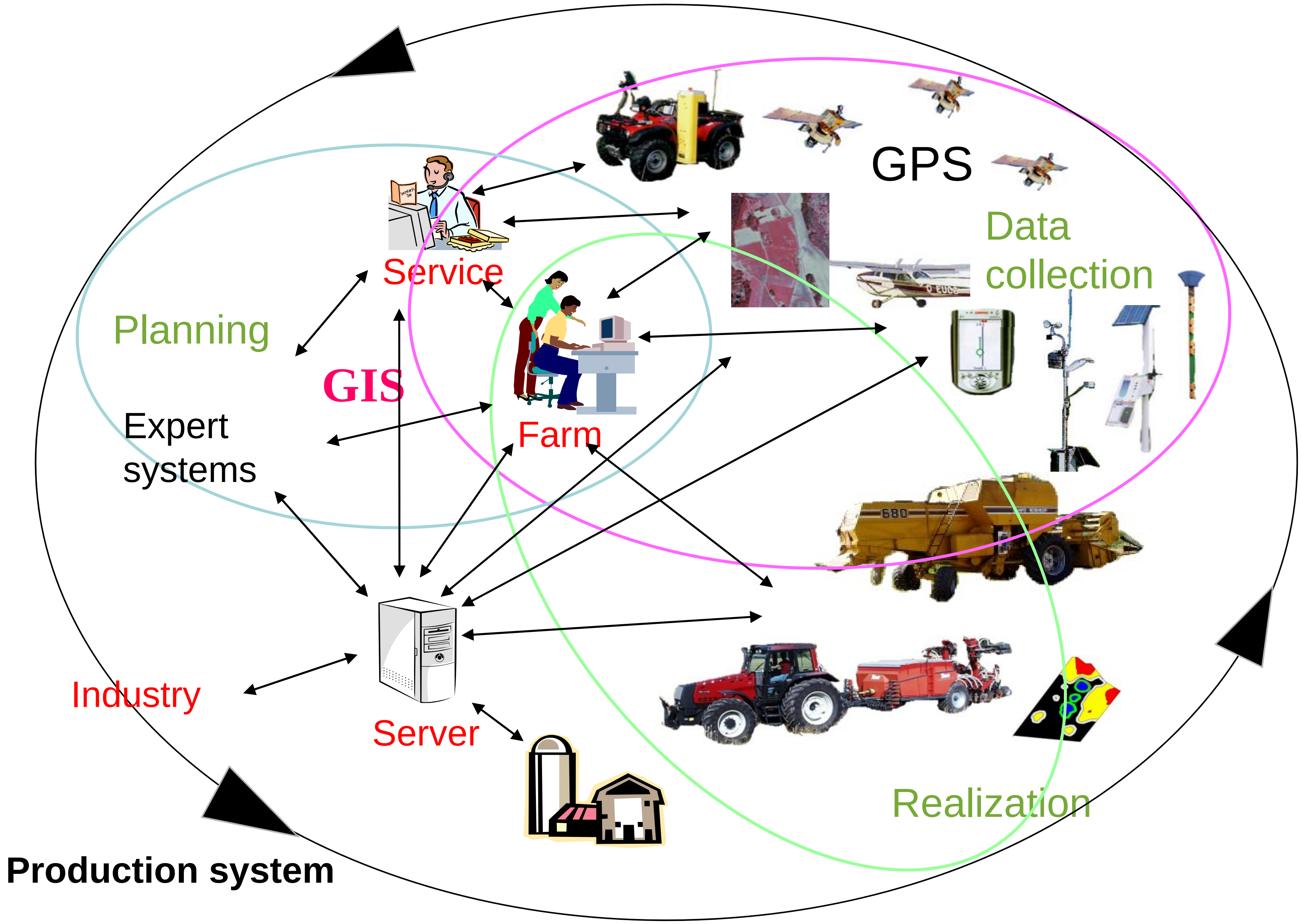
Lund Institute of Technology

ProAgria*, Finland*

JTI *Swedish Institute of Agricultural and Environmental Engineering*

Background

- Agricultural processes are diverse of kind
- Several production processes and their sub-processes are run parallel most of the time
- Actual work in farms consists of parallel and successive tasks
- In the Nordic Countries the number of farms has been degreasing and the size of the farms increasing
- Fewer workers run larger business and automation is increasingly employed


GPS
Data
collection
Planning
Service
GIS
Farm
Expert
systems
Industry
Server
Realization
Production system

Background

- Demands towards the quality and traceability of production methods and produced raw materials are increasing
- Demands are set by governments, processing industry and customers
- Demands concern compliance with standards, environment, ethics and health

Information management in field work

- Information management plays important role in how well farms are able to deal with this all
- Task execution in fields with agricultural machinery has a key role in process data acquisition and documentation in plant production
- Task execution is carried out following the plan,
  - sudden changes in plan

    -> has to follow standards and regulations and help to improve the outcome

Information management in field work

- Project focus is on the technology that enables online support of agricultural machinery
- Field machinery is mobile
  -> data and information transfer between machine and external support source has to be wireless
- Internet serves a media to create connections from an individual machine to several support providers, among them other machines.

The goals of the project are :

- **to develop** internet communication services for collecting data on farm machinery operations, and for instructing farm machinery from farm office applications, and

- **to test and demonstrate** the performance and feasibility of the services by implementing and operating selected examples

- **to support** the development of commercial operational services to facilitate the use of the technology in agriculture

Work in Nordunet Agro

- Nordunet Agro has focused on scientific work carried out by the students as part of their further education

- Co-operation with the other on-going projects in participating countries has played an important role in achieving the set goals

- The co-operation has been fruitful
- => there has been clear synergy!

Welcome!

Network Infrastructure for MoVeTracker

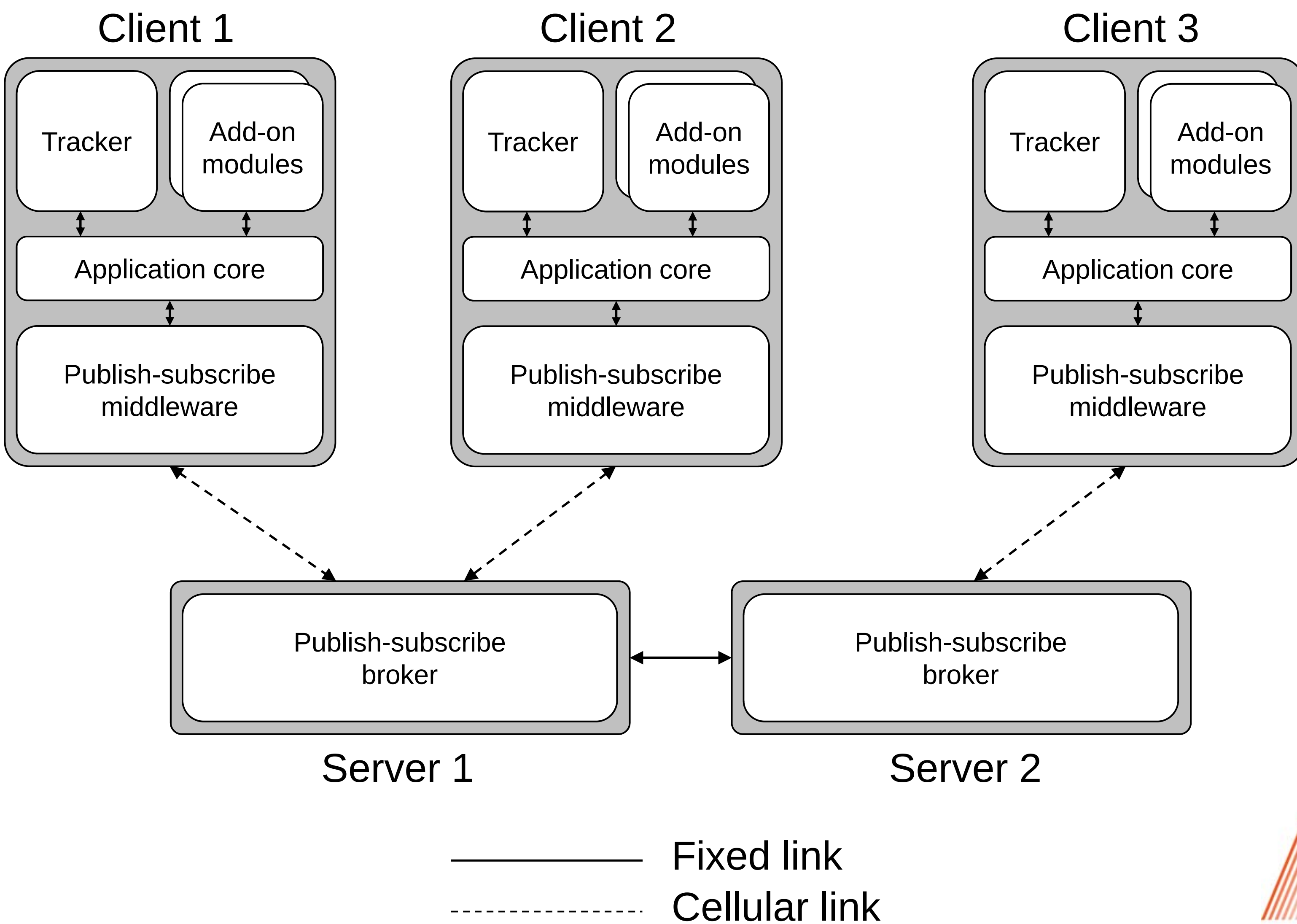
Jerker Hammarberg
Alexandra Instituttet A/S
Helsinki, June 10, 2010

Outline

- MoVeTracker
- Technology and challenges
  - Publish-subscribe
  - Cellular networks
- Techniques

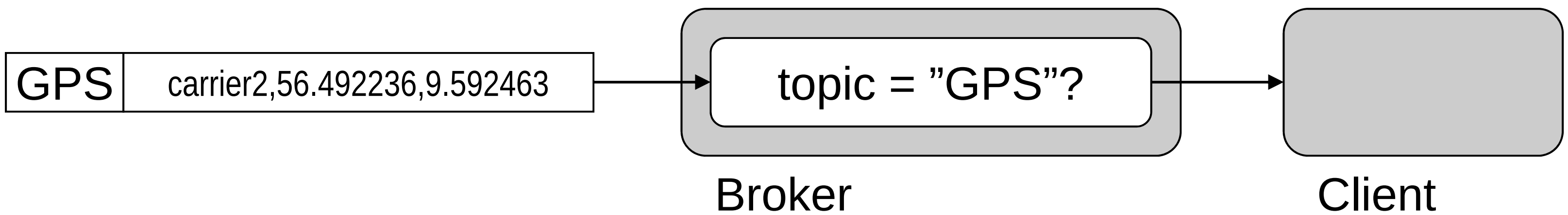
MoVeTracker

System Architecture

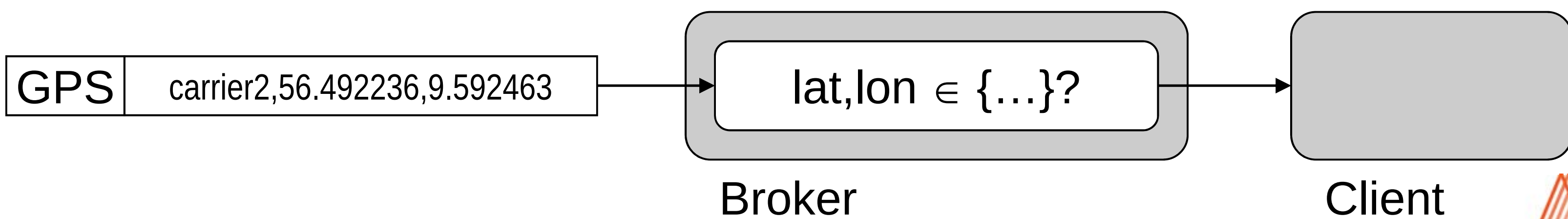


Properties of Publish-Subscribe

- Topic-based routing
  - Based on topic labels on messages
  - Example: ”GPS”

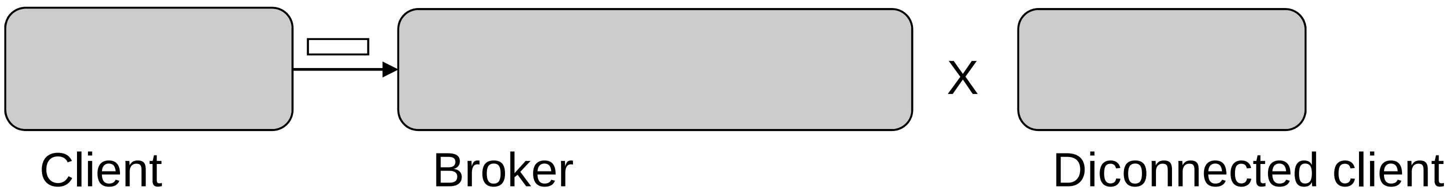


- Content-based routing
  - Based on logical conditions on content
  - Example: ”GPS positions within 5 km from my own position”

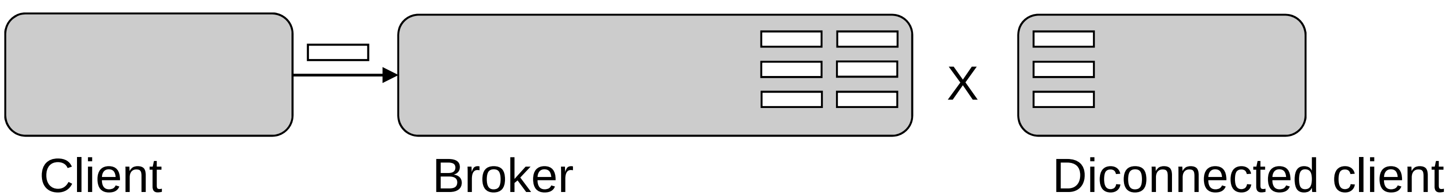


Properties of Publish-Subscribe

- Non-durable subscriptions
  - Unsubscribe on disconnection
  - Example: Real-time GPS positions



- Durable subscriptions
  - Subscriptions survive disconnections
  - Messages are buffered and delivered on next connection
  - Examples: Vehicle traces, task lists, obstacle locations



Cellular Internet Access

- GPRS/EDGE
  - Good coverage worldwide
  - Up to 115 kb/s (GPRS), 384 kb/s (EDGE)
- UMTS
  - Low coverage in rural areas
  - Modems fall back on GPRS/EDGE outside UMTS coverage
  - Up to 14 Mb/s
- CDMA2000
  - Typically good coverage in rural areas
  - Up to 3 Mb/s

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Properties of Cellular Networks

- Traffic costs
- Low data rates
- Delay
- Instability
  - Varying throughput
  - Communication halts
  - Modem disconnections
- Desirable properties of communication middleware
  - Minimal data traffic
  - Adaptive to varying link quality
  - Efficient recovery strategy

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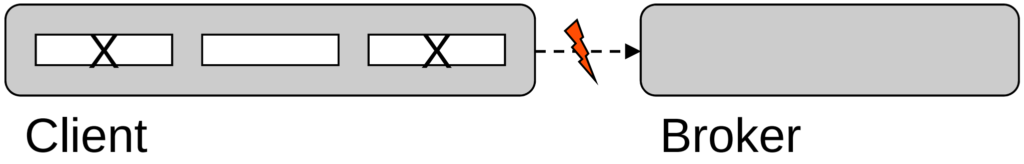
REDS

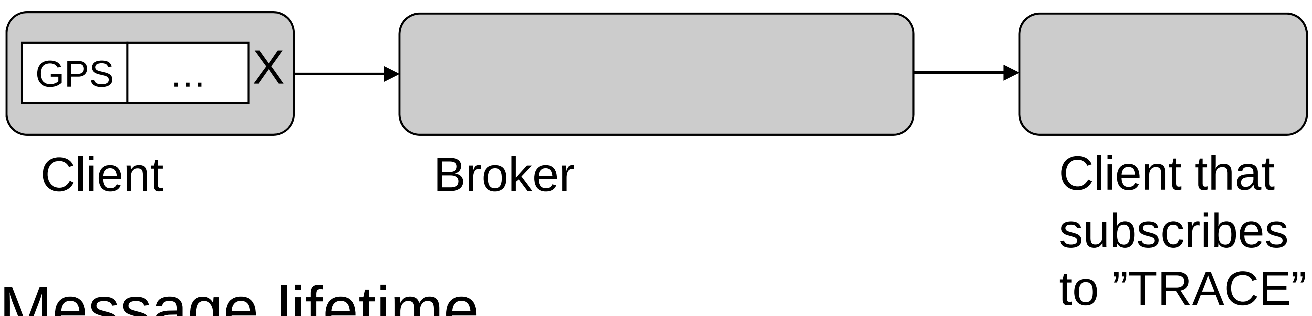
- Drawbacks with REDS
  - Designed for peer-to-peer communication on high-rate links
  - Large data traffic overhead
  - Unstable
- Our improvements
  - More robust handling of unstable links
  - Removed data encapsulation
  - Message lifetime



  - Tuned dead link detection parameters
  - Forced modem redial

Techniques for Less Traffic

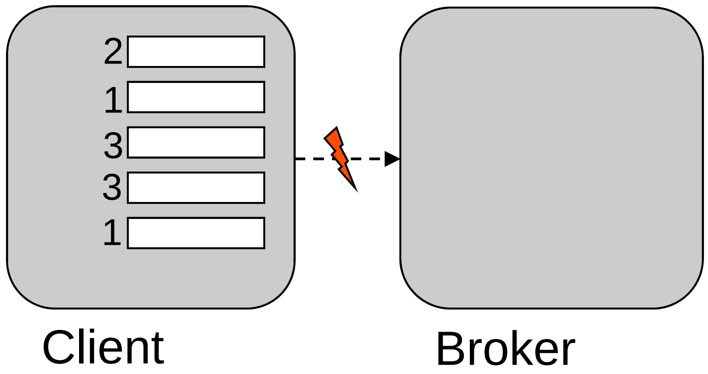
- UDP instead of TCP
- Minimal protocol overhead
  - No length field
  - Topic ID
- Avoid object serialization
- Quenching



- Message lifetime
- Content-based routing

Techniques for Adaptivity

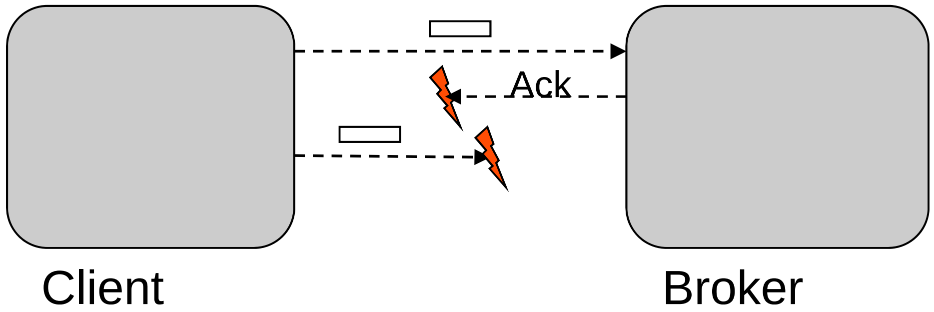
- Message priority



- Buffer element replacement

Techniques for Recovery

- Beaconing
- Retransmission timeout



- Forced modem redial
- Numeric parameter tuning
  – Experimental measurements, e.g. round-trip times
- Reasons for less aggressive approach
  – Traffic costs
  – Congestion

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Conclusions

- Feature rich publish-subscribe middleware facilitates application development
- Real-time applications are sensitive to network instability
- The communication middleware can compensate for unstable cellular networks

Thank you! Questions?

Publish-Subscribe Middleware

For

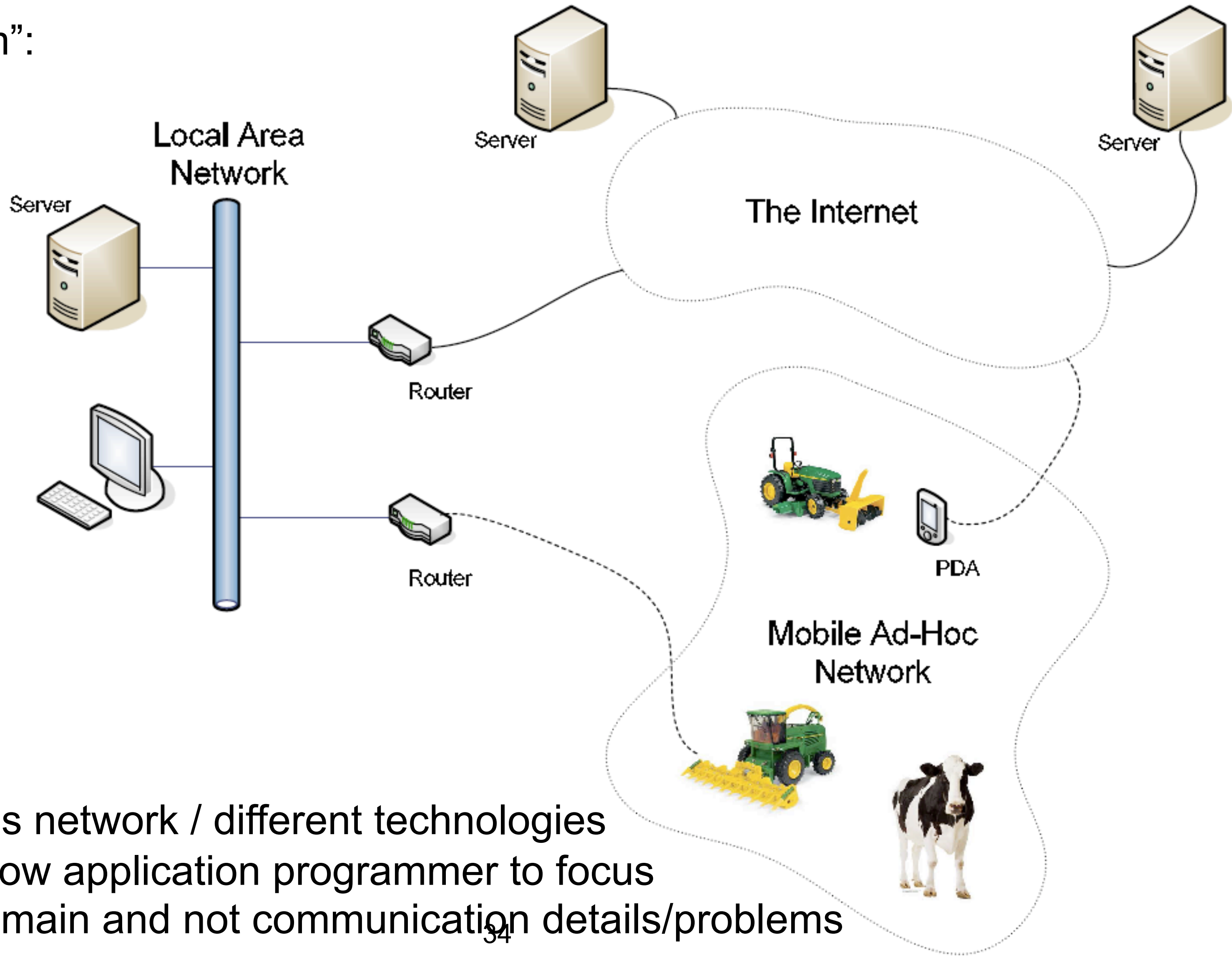
Agricultural Applications

Agenda

- Motivation for a Middleware
- Possible network issues
- Client-server vs. publish-subscribe paradigm

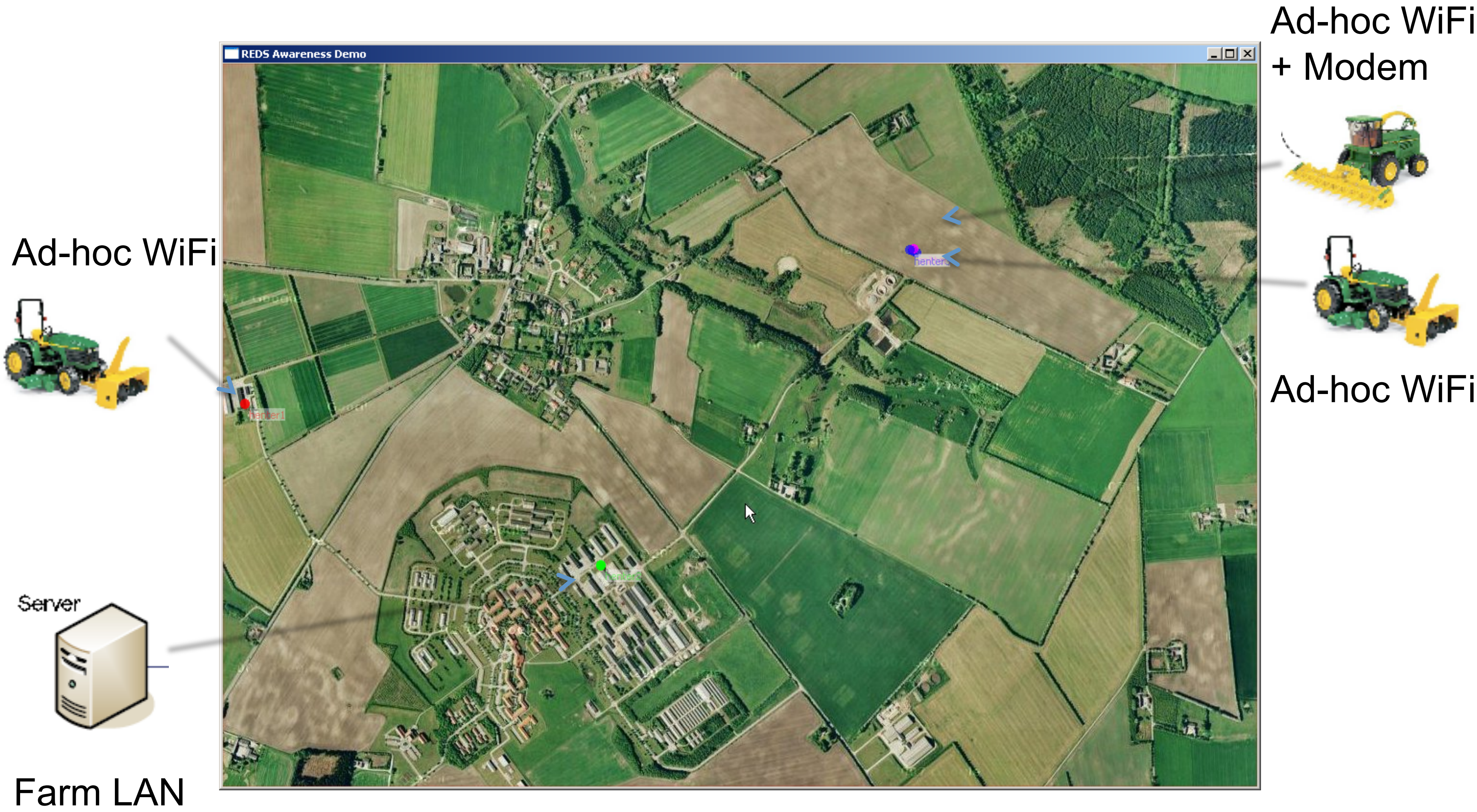
Motivation for a Middleware

"Future Farm":

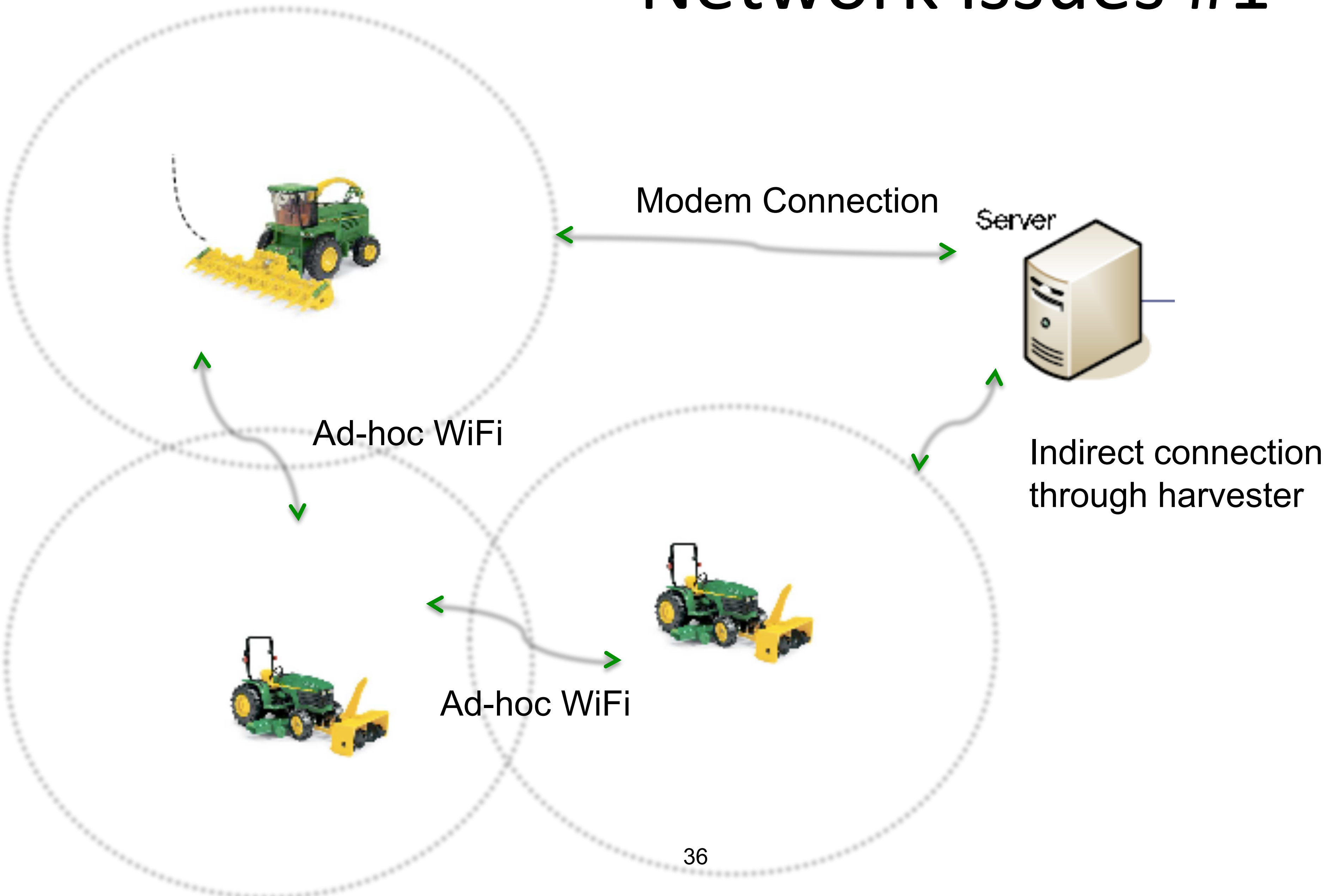


- Heterogeneous network / different technologies
- We want to allow application programmer to focus on problem domain and not communication details/problems

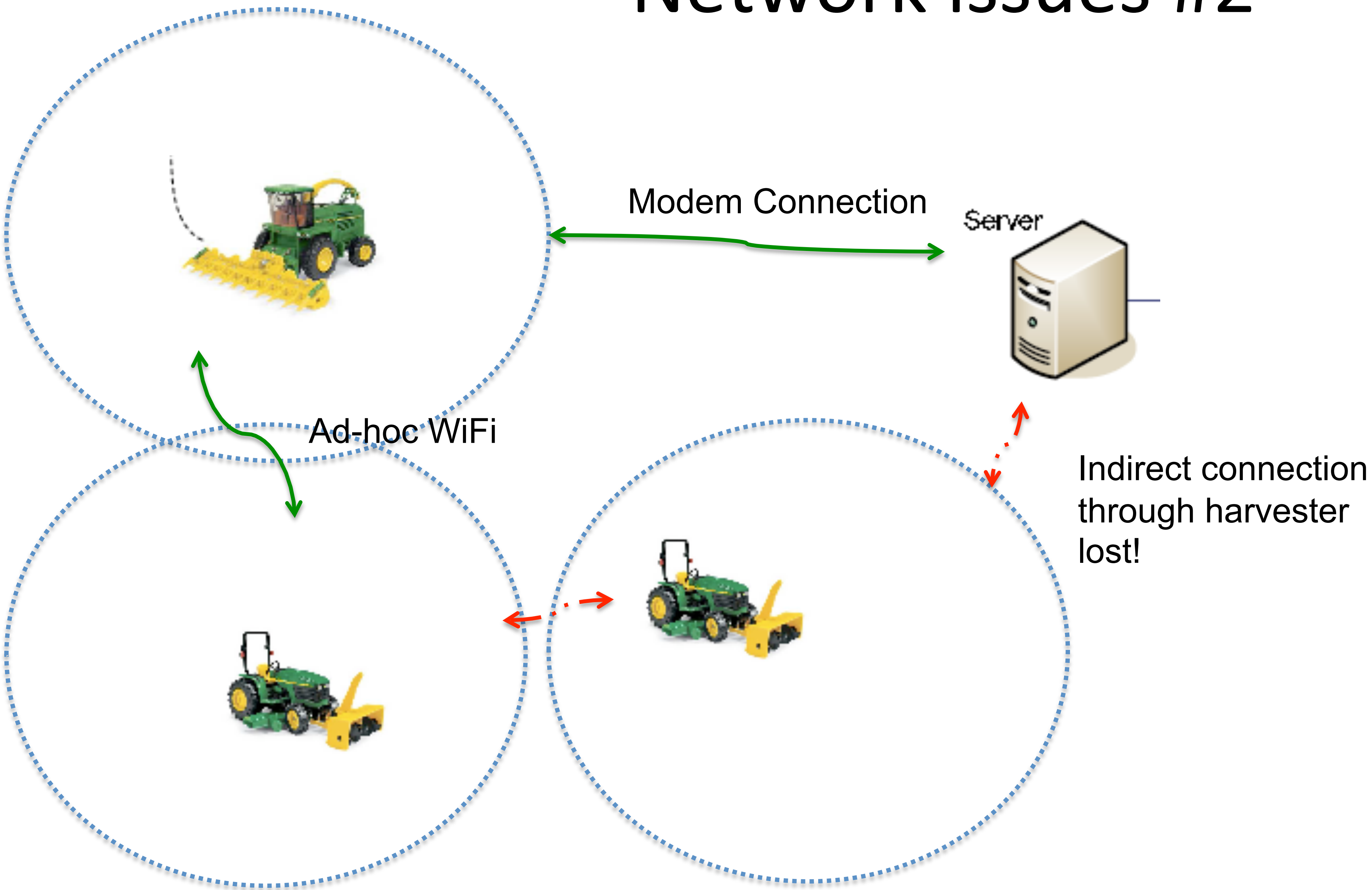
An example: Maize harvesting



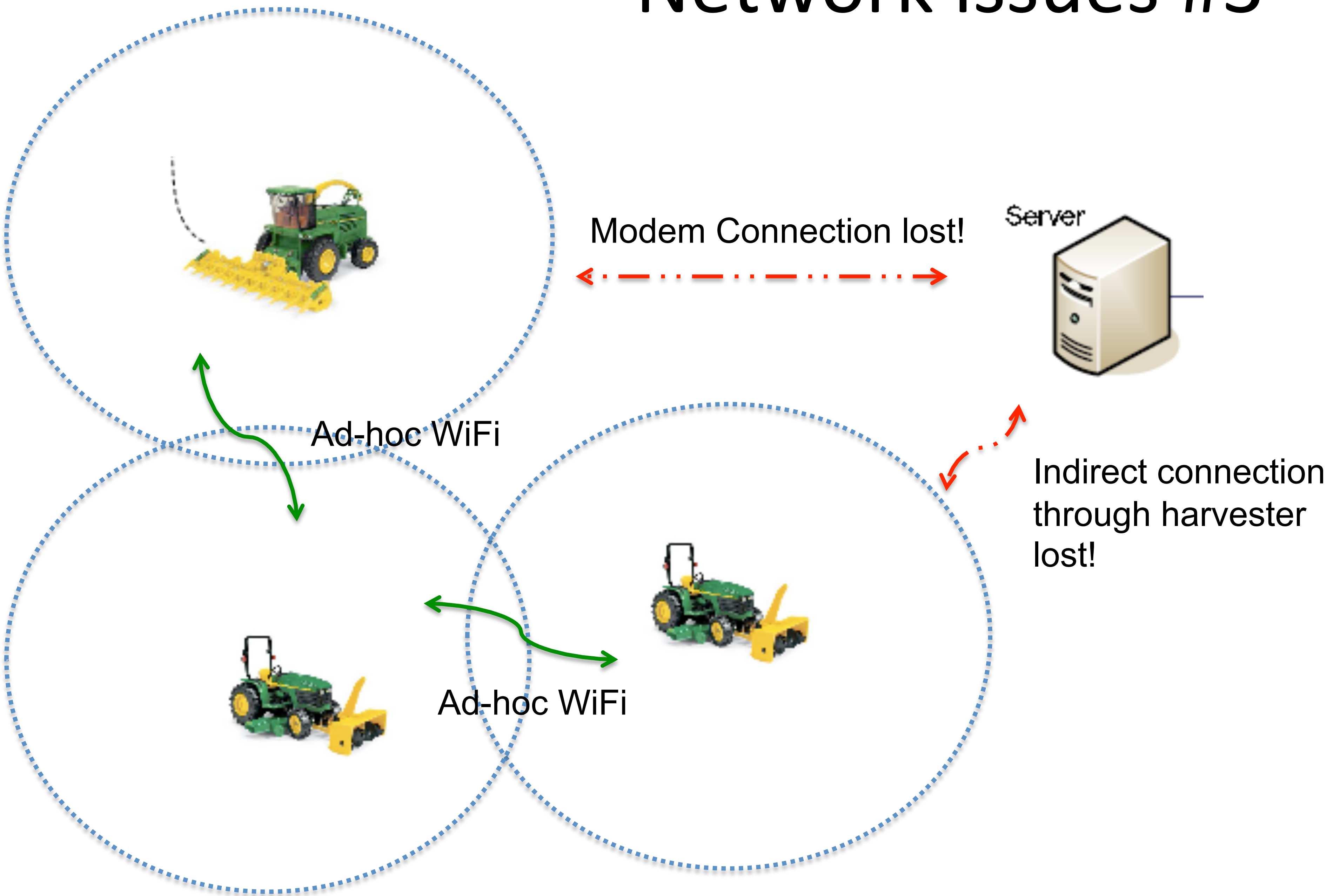
Network issues #1



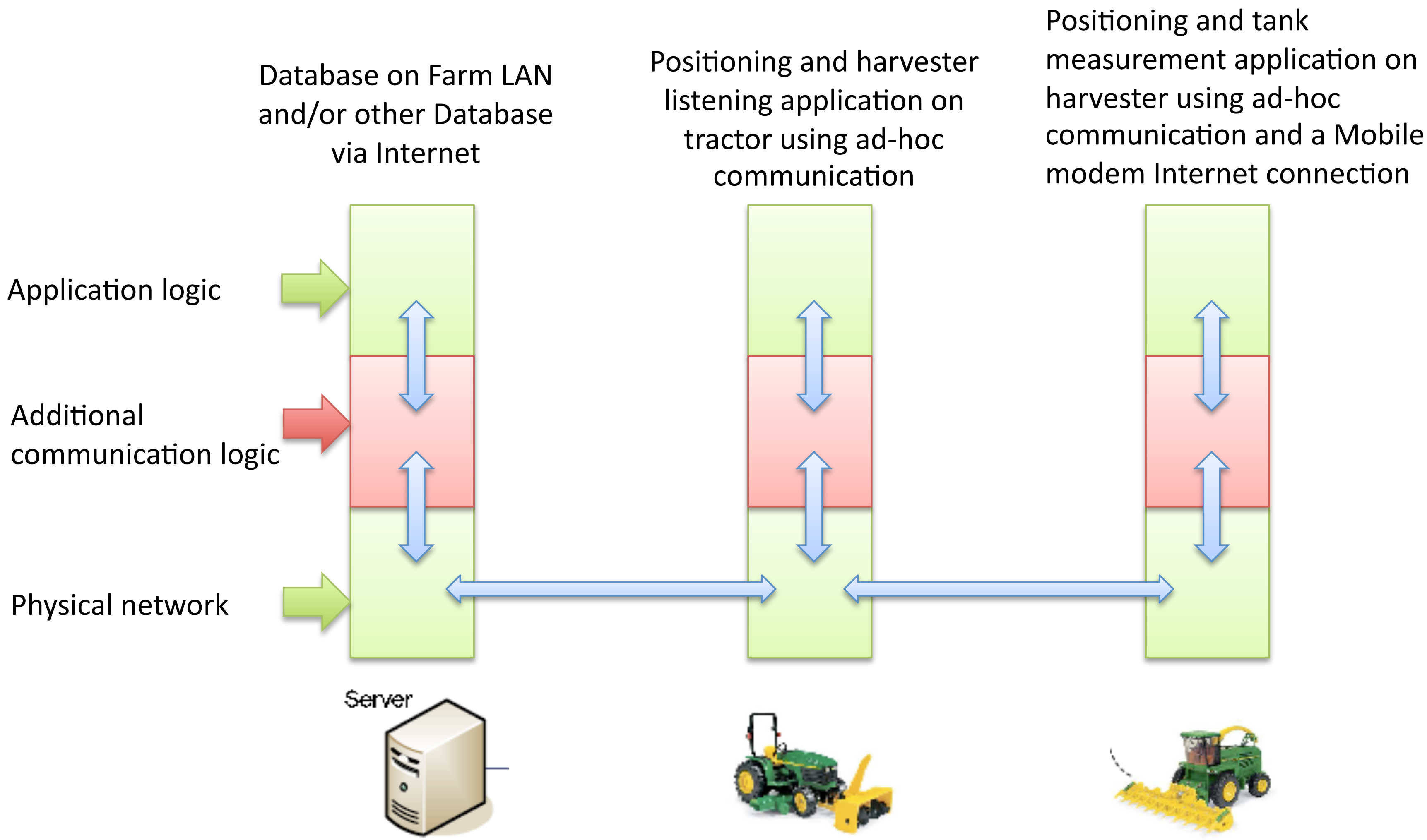
Network issues #2



Network issues #3

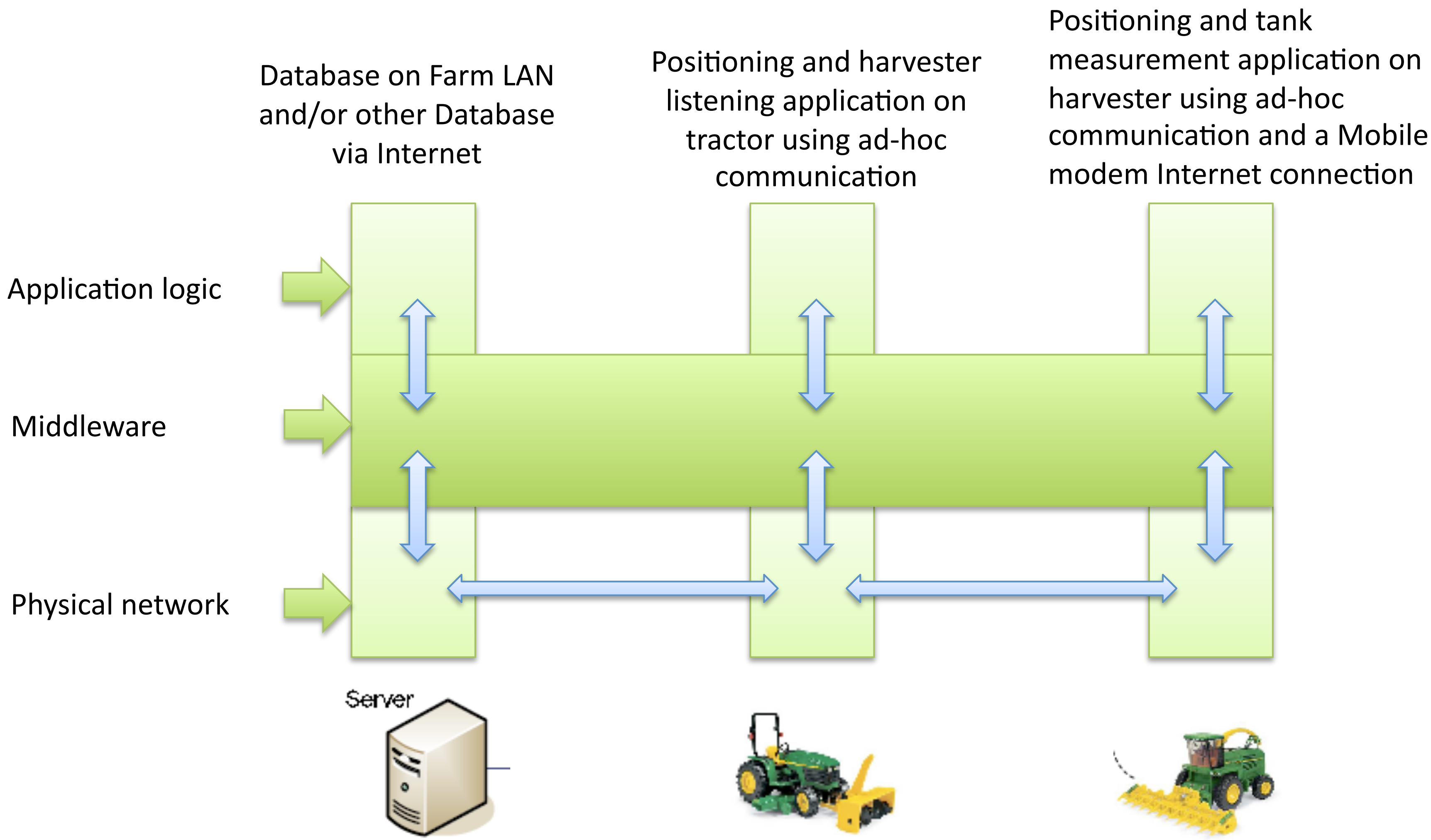


Abstract view of normal applications



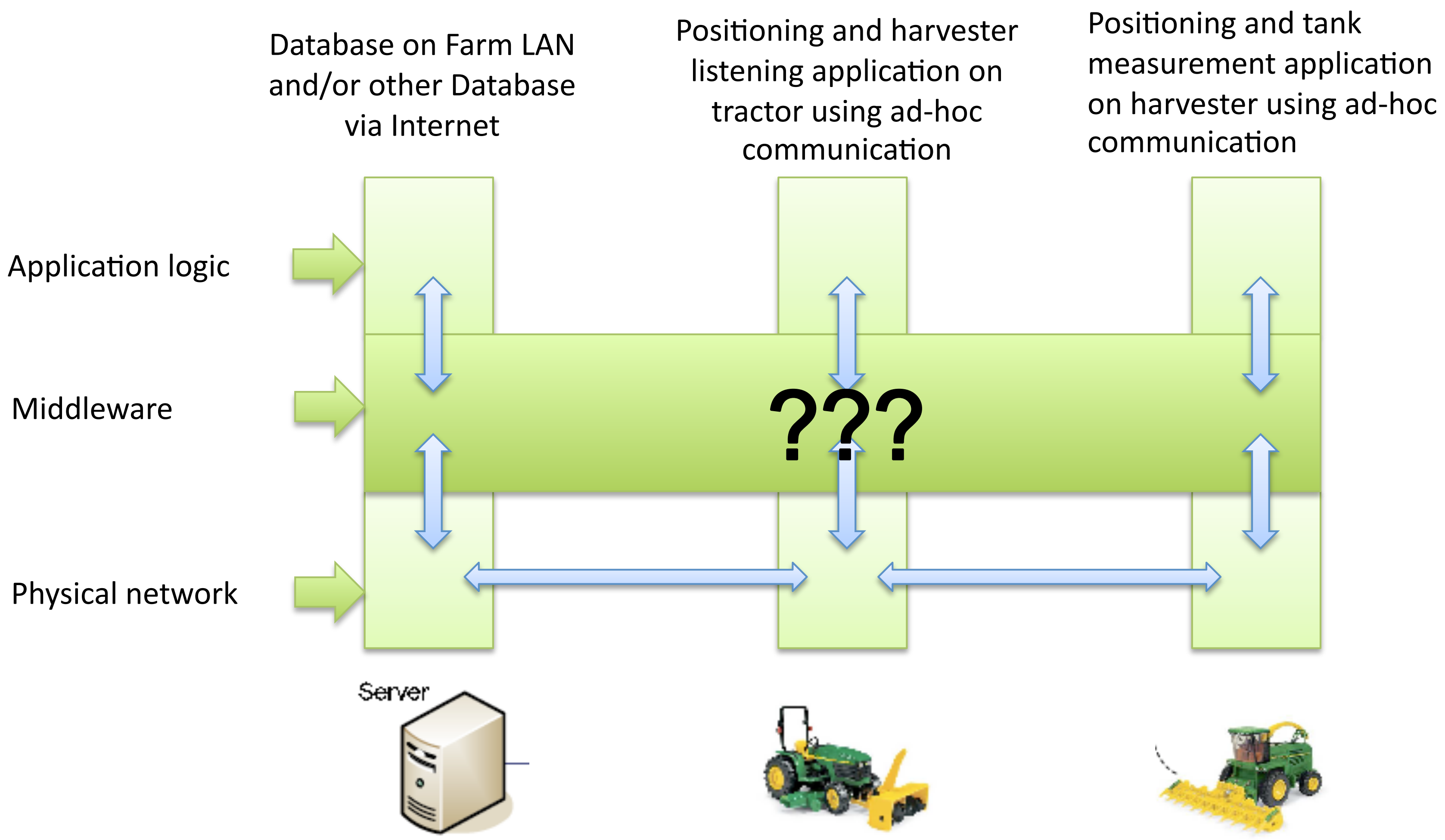
- Application must handle network issues
- Difficult and time-consuming
- Low interoperability and wasted potential

A possible solution



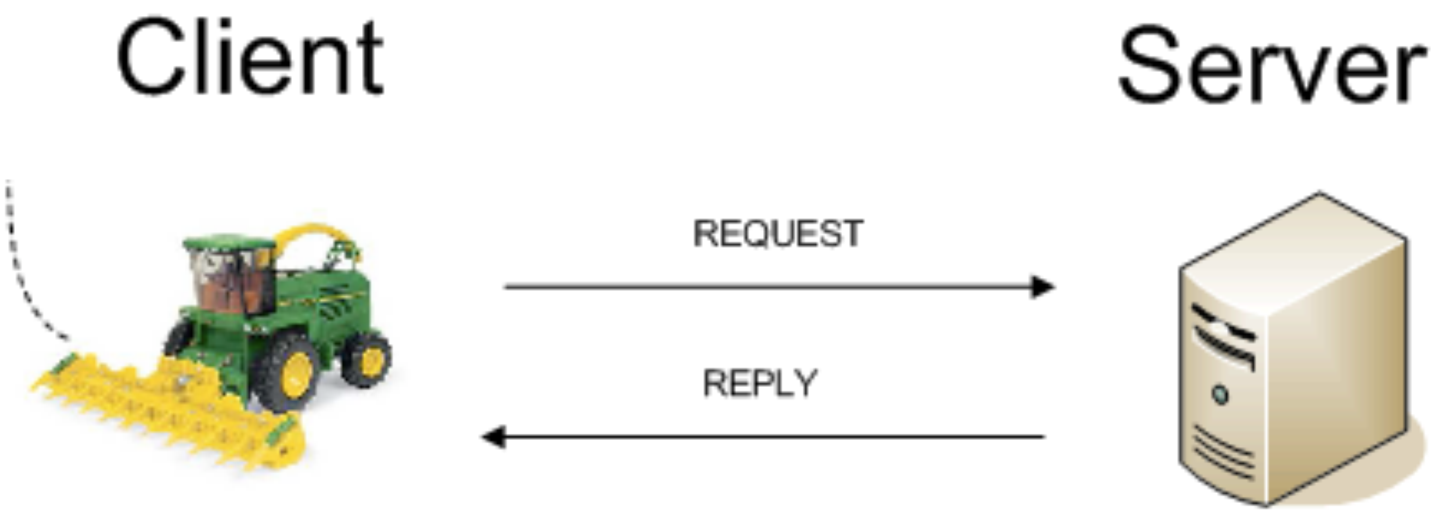
- Middleware handles network issues
- Faster development time
- Higher interoperability and better use of potential

A possible solution



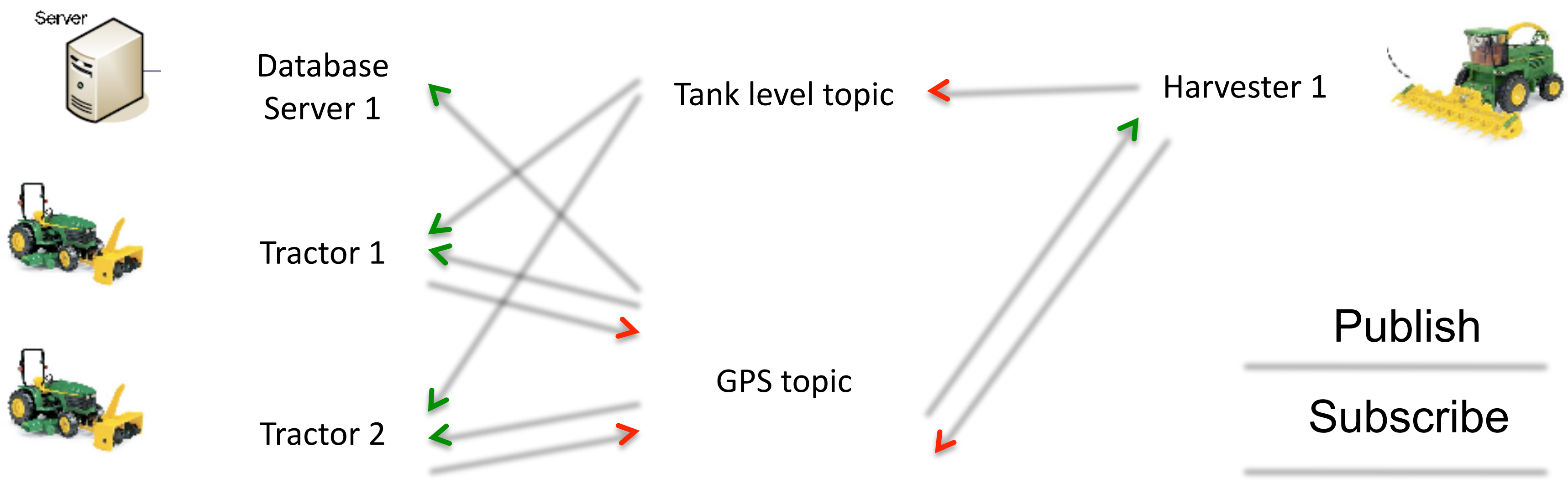
- Middleware handles network issues
- Faster development time
- Higher interoperability and better use of potential

Client-Server Paradigm



- Tight coupling between client and server to due to connection oriented nature
  - Connection will be established and then communication can proceed; Not optimal for mobile work units as application then must react individually to broken connections!
- *Problem: Servers must always be available to clients at a known network address and given time*

Abstract view of the Publish-Subscribe Paradigm

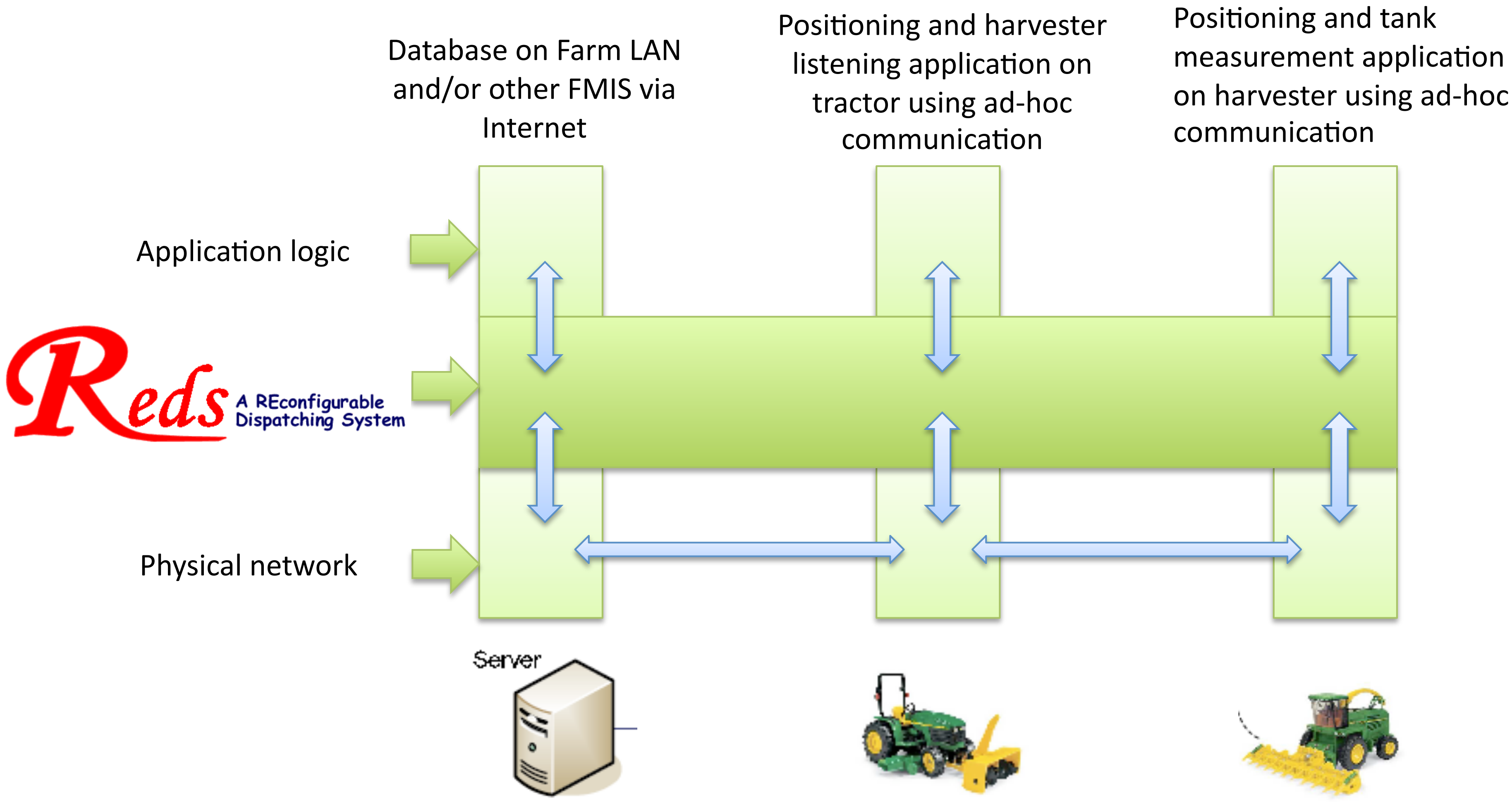


- Applications publish information that interested nodes can subscribe to

- Underlying functionality transparently caches information and routes it to brokers that forward it to subscribing nodes as they become visible in the network topology.

- Decouples the sender of information from the receiver by adding an extra layer of abstraction, thereby eliminating client-server coupling

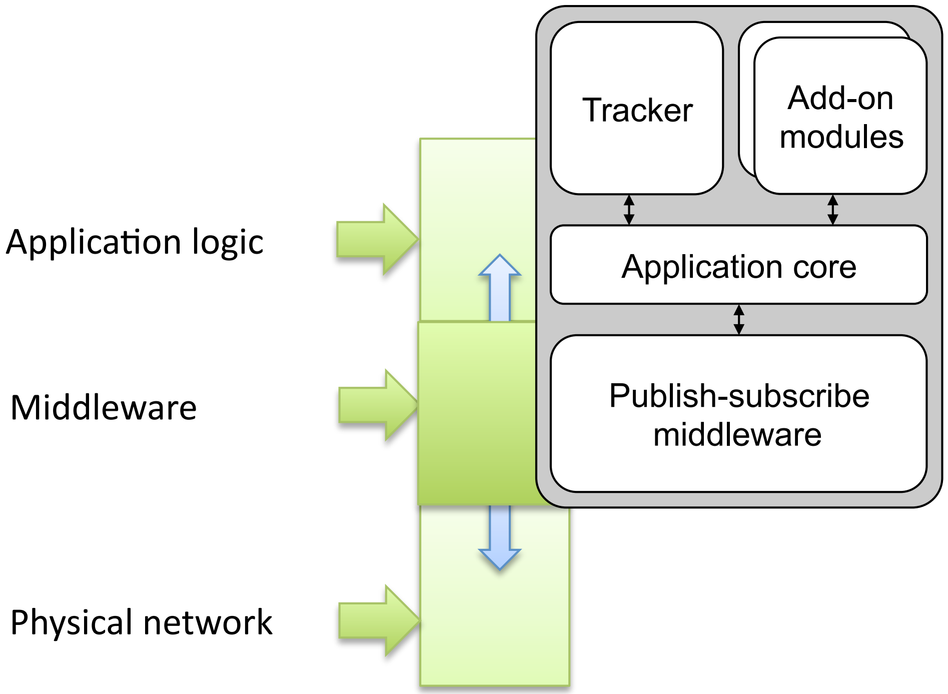
Basis for our Middleware



- One of several academic publish-subscribe prototypes
- Open system, active development and research

Result

- MoVeTracker Application



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EXPERIENCE WITH MOVETRACKER FOR OPTIMIZATION OF MAIZE AND GRASS HARVEST

Allan Leck Jensen, Faculty of Agricultural Sciences, University of Aarhus, Denmark

Jerker Hammarberg, The Alexandra Institute Ltd., Denmark

Raphael Dobers, The Alexandra Institute Ltd., Denmark


6750


Valmet

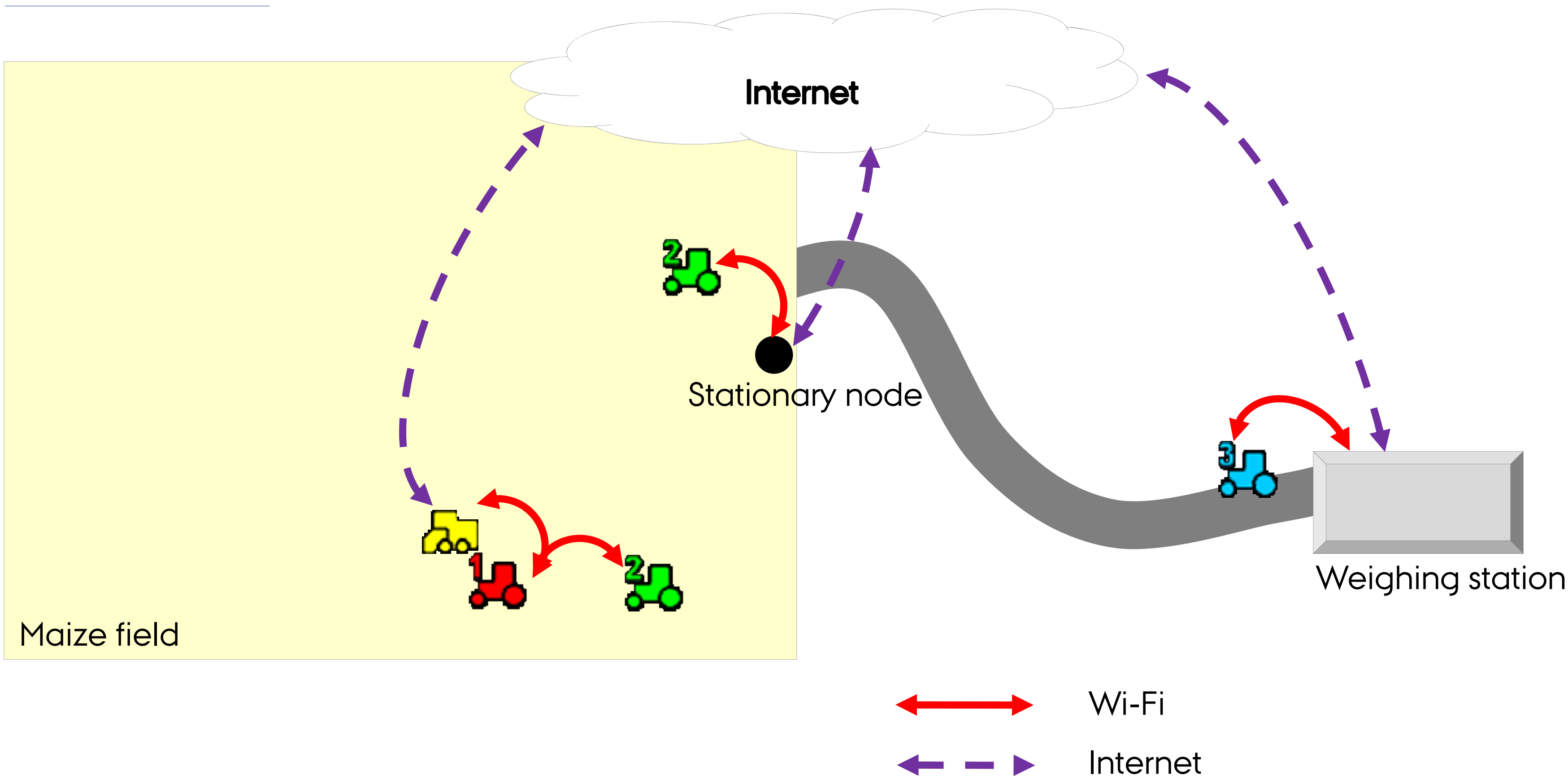

SNULLER
538


13


Fyldniveau
100%
Tid til skift
0
minutter
Indstillinger
Afslut

14

NETWORK ARCHITECTURE (AD-HOC)



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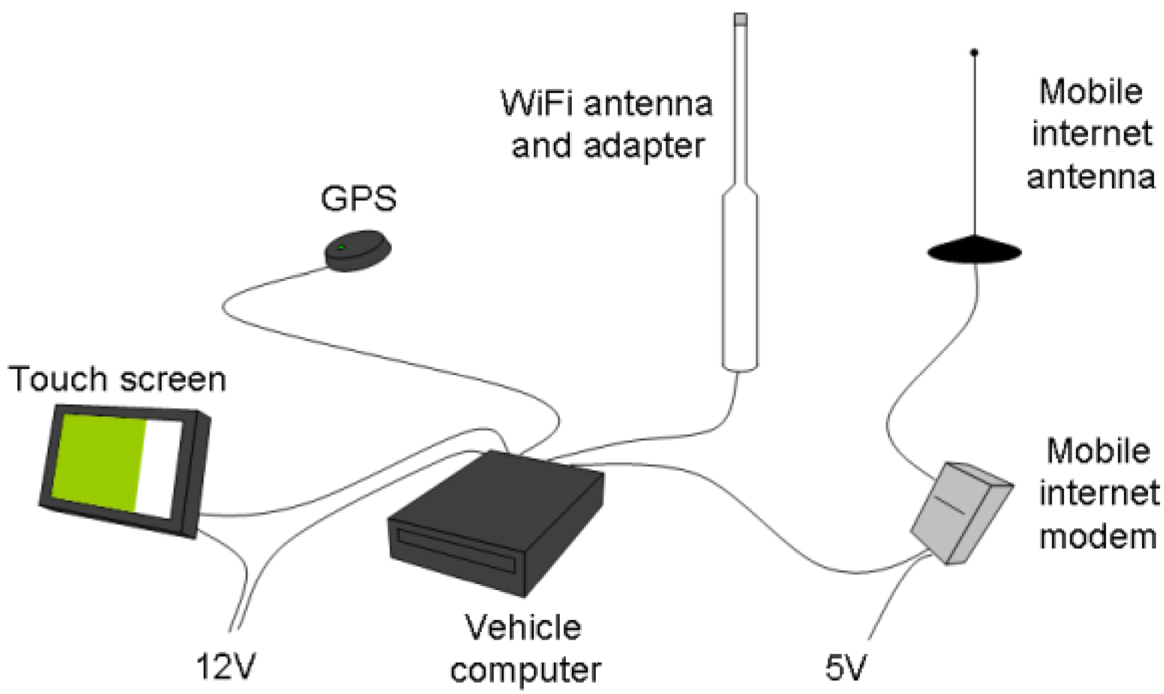
HARDWARE

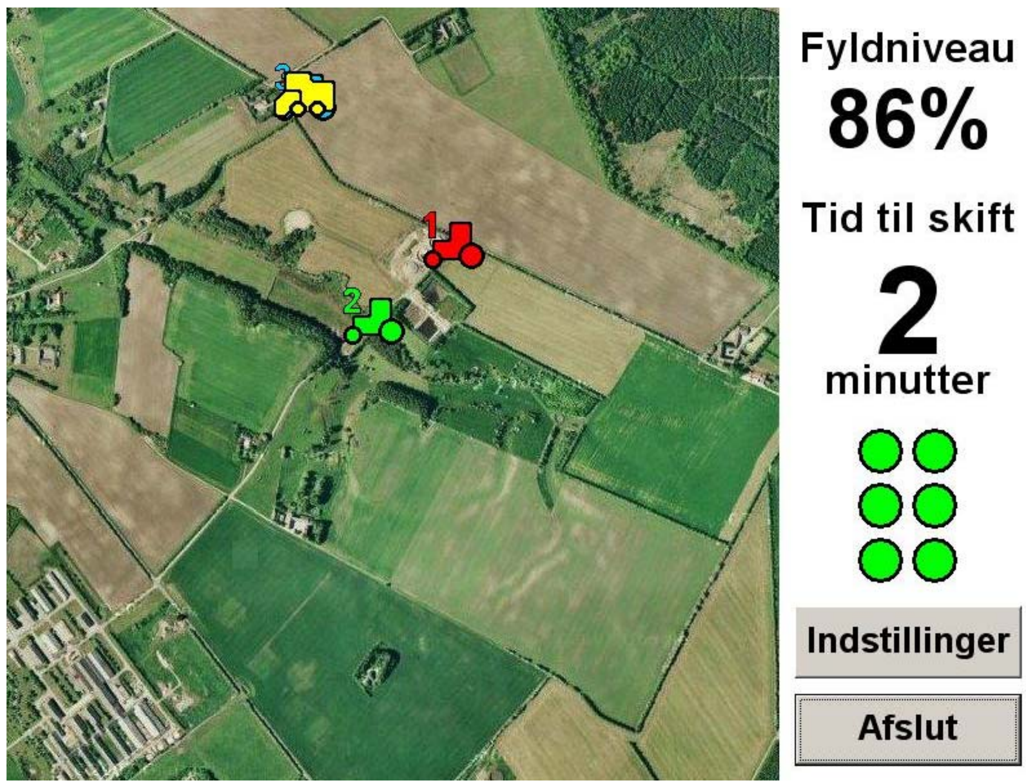
Node	Computer	Wi-Fi	Internet	GPS
Harvester	Vehicle + screen	Yes	Mobile	Yes
Carrier 1, 2, 3	Vehicle + screen	Yes	No	Yes
Stationary, field	Laptop	Yes	Mobile	Yes
Stationary, weighing station	Laptop	Yes	LAN	Yes

HARDWARE

› Hardware equipment for harvester



SOFTWARE – HARVEST APPLICATION



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PUBLISH-SUBSCRIBE

Node	Publish	Subscribe
Harvester	GPS, Fill level	GPS, Fill level
Carrier 1, 2, 3	GPS	GPS, Fill level

EXPERIMENT 1: MAIZE, AUTUMN 2008

- Results:
  - Unstable harvest application
  - Wi-Fi range is too low for connection between moving units (< 500m) (this case: few units, long distances)
  - Overhead data communication for mobile internet bandwidth
  - REDS is an immature research prototype (bugs, instability)
  - Windows XP unstable
  - User feedback:
    - Show driving direction
    - Show driving traces to visualize harvested areas
    - Improved fill level estimation

ADJUSTED TECHNICAL SET-UP

- Network: No Wi-Fi, only mobile internet
- Operative system: Linux instead of Windows XP
- Harddisks: Solid-state instead of mechanical

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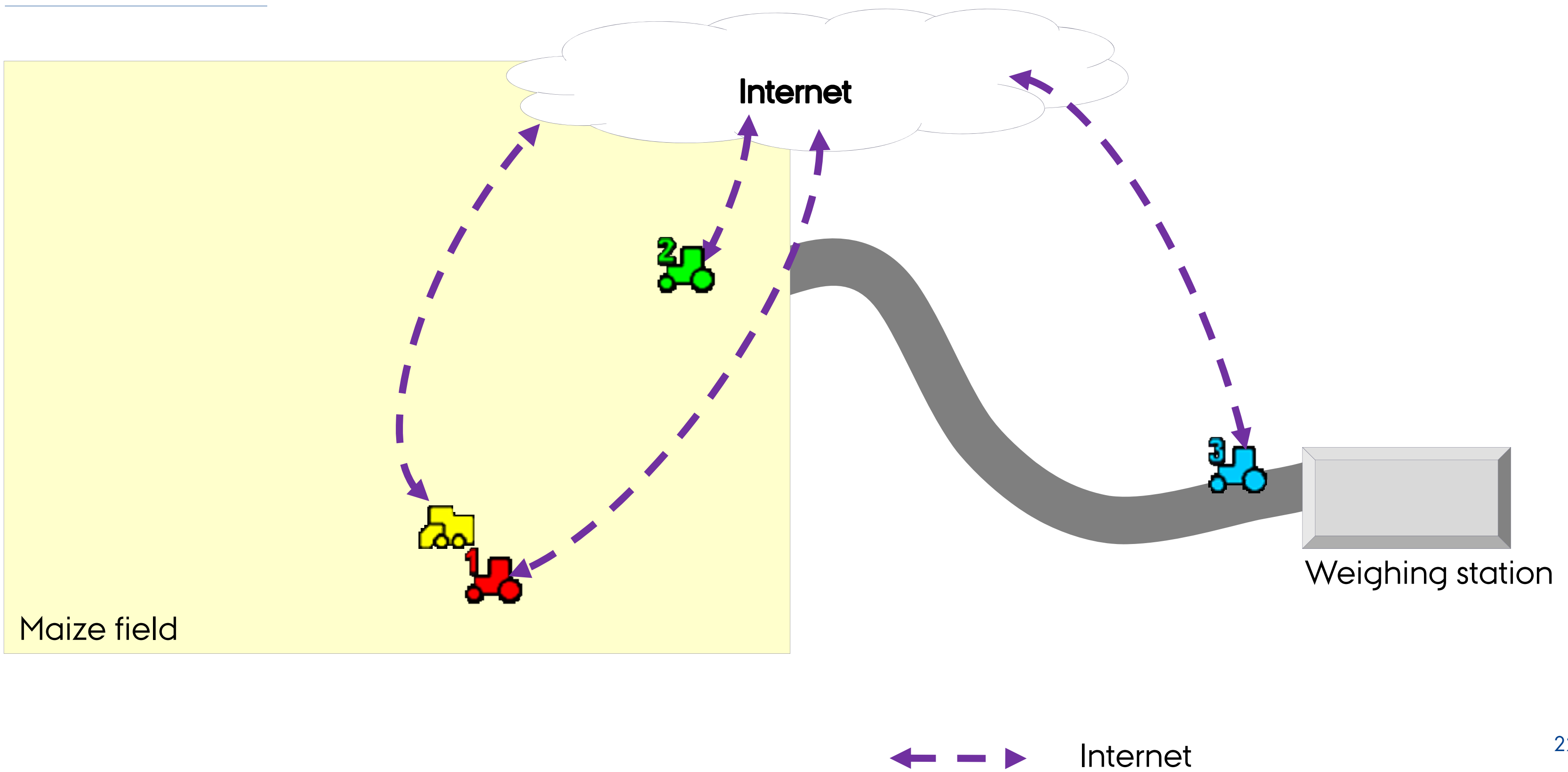
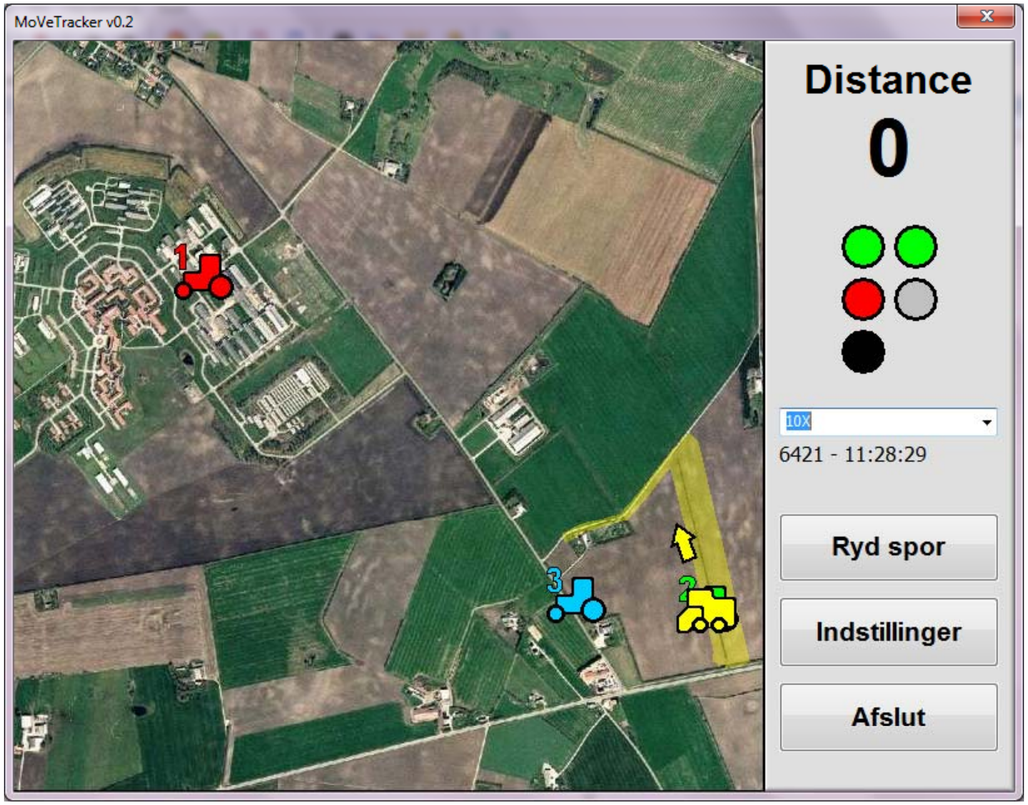
NEW NETWORK ARCHITECTURE



HARVEST APPLICATION VERSION 2



EXPERIMENT 2: GRASS, SPRING 2009

- Results:
  - Stable harvest application
  - Not possible to demonstrate time savings
  - Satisfied users:
    - Drivers of carriers: ”It was easy to find the fastest route to the harvester”
    - Driver of harvester: ”I could see when I had time to maintain the harvester”
    - More information wanted: Field and crop info, weather forecast, wet spots, stones etc.

FUTURE FOR MOVETRACKER

- Commercial (generic) product for multiple business areas, like
  - Taxi
  - Emergency
  - Road maintenance

DEMONSTRATION

demo

FIRST CONTACT

JEPO TECH

Supplied some monitors – touch

But I did not understand the purpose of the system

FIRST IMPRESSION

JEPO TECH

INVITATION TO A FIELD DEMO

EXELENT IDEE for:

Agricultural Contractors and big farms.

OTHER MARKETS

THE USERS/COSTUMERS

JEPO TECH

I ASKED SOME POSSIBLE USERS/COSTUMERS

AGRICULTURE: Agricultural Contractors

LARGE INVESTMENT TO ALL OUR MACHINES

PUBLIC ORGANISATION:

THIS IS VERY INTERESTING, DO IT FUNCTIONS SAFE ALL PLACES?

FIRST OBSTRACLE

JEPO TECH

NOT READY FOR SALE

HOW MUCH WORK NEED TO BE DONE?

AGRICULTURE:

MAPS, FOTOS,
And
A CHEAPER VERSION.

PUBLIC ORGANISATION:

STABIL COMMUNICATION IN CITIES, MAPS AND SOME USER DEFINIED OBTIONS

AGRICULTURE

JEPO TECH

2 DIFFERENT VERSIONS

ONE WAY VISION

TWO WAY VISION

BRANDED the **system**:

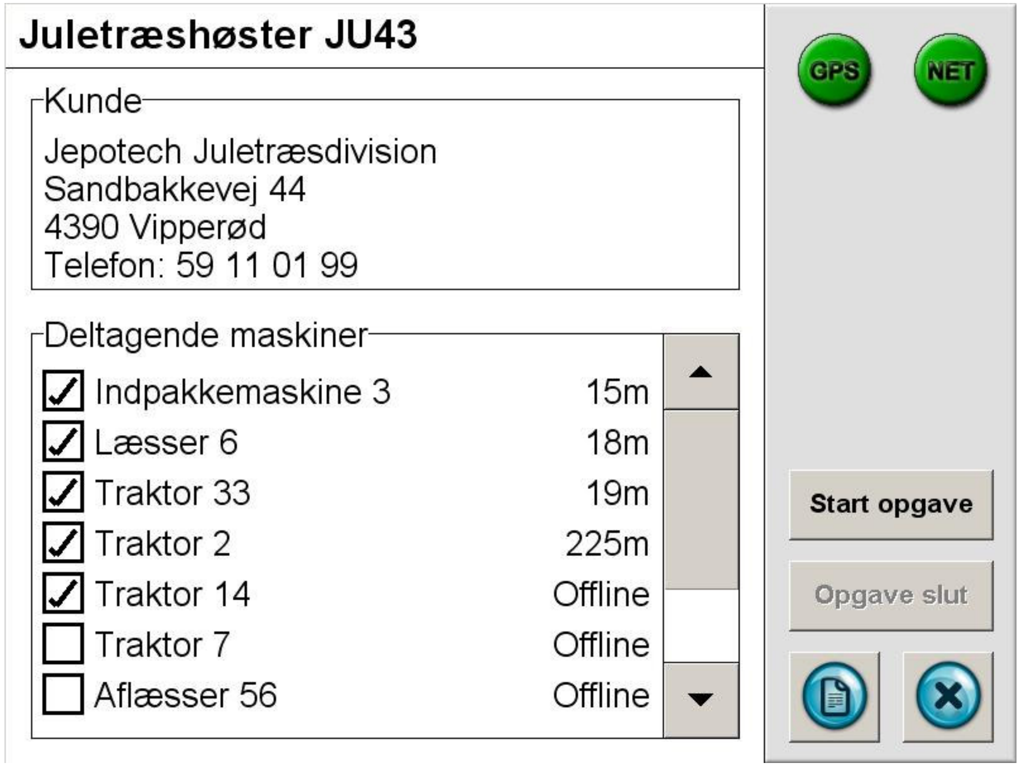
MoVeTracker™

MoVeTracker™

ONE WAY VISION

JEPO TECH

Only PC in one machine:
Used as datacollector, to make workrapport



THE QUISTION

JEPO TECH

How many projekts stays in the drawer???????

Nordunet Agro
Mobile Internet Services for Online Support of Agricultural Machinery:

Data management in automation assisted tractor-implement combination

Pasi Suomi
MTT Agrifood Research Finland, Plant Production Research
Crop Production Technology (Croptech)
pasi.suomi@mtt.fi

10.6.2010
Nordunet Agro Seminar, Helsinki, Finland

Reliable, accurate and intelligent automation systems in farming are needed so that:

- *Data from the mobile internet services are possible to use to control systems in implements*
- *Situational awareness for driver can be guaranteed (not extra stress)*
- *Data is profitable to transfer from field to FMIS*

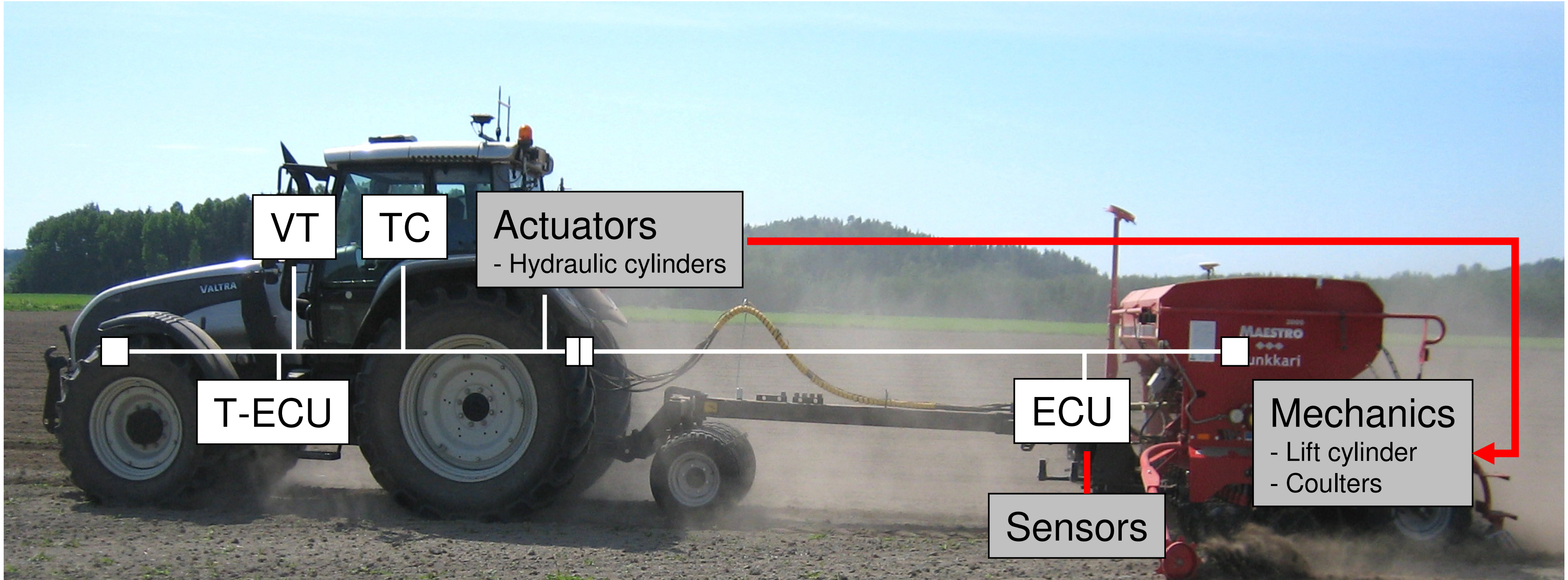
Case: Automatic working depth control in seed drills: Requirements for sensor, actuator and mechanical components

Pasi Suomi[1), Frederick Teye[1), Timo Oksanen[2)
1) MTT Agrifood Research Finland, Plant Production Research
2) TKK Helsinki University of Technology, Department of Automation and Systems Technology

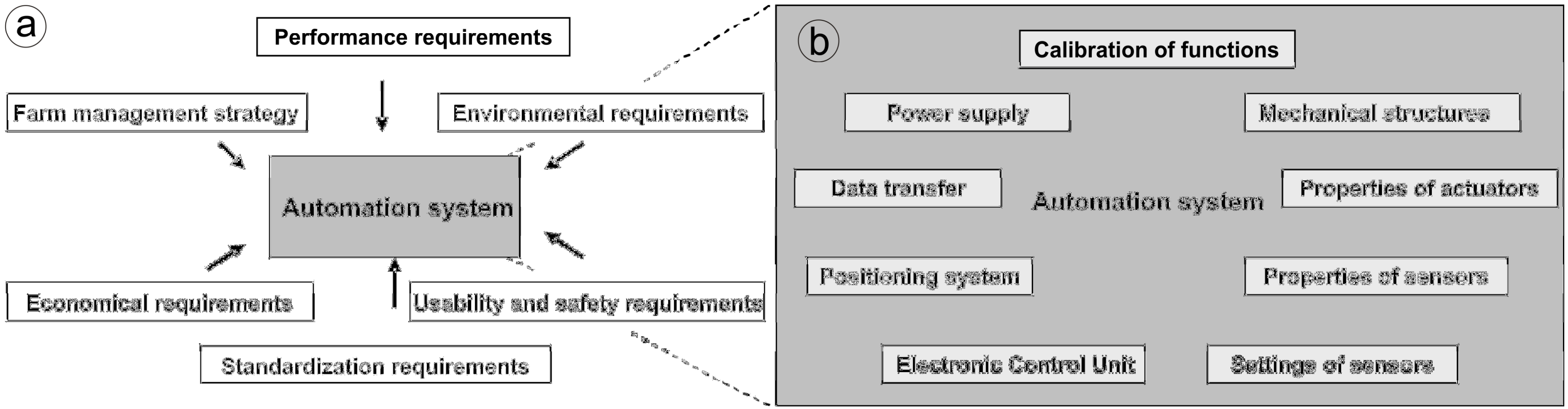
- The aim of this paper was to assess the accuracy of an automatic working depth control system for a seed drill.
- In addition, the requirements of sensors, actuators and mechanical components needed to achieve this accuracy are evaluated.
- To meet these objectives an automatic working depth control for a drill was developed.
  - Which maintains its working depth within the set value when the soil conditions change in the field (more accurate realisation of field tasks)
  - VRA-control using offline (map) or online measurements (soil moisture)
  - To reduce machine drivers' workload during driving
  - General depth control system for different drillers

Case: Automatic working depth control in seed drills: Requirements for sensor, actuator and mechanical components

- Automatic working depth control for drills, which utilizes tractor's hydraulic valves via standardized ISO 11783 network with an ISO 11783 (ISOBUS) class 3 tractor
- For the automatic working depth control for the case driller
  - Reliable measuring system needed to be implement
  - Development of a working depth model for driller ECU was required
  - Finally development of a prototype driller ECU was needed



Accuracy of automation in agricultural implements



Requirements of automations systems — **Factors that affect the accuracy of automation system**

Every measurement value, y, from a sensor under a specific test condition is given as: $$y = m + B + e$$

where, m is the general mean (expected), B is the laboratory component of bias under repeatability conditions, and e is the random error occurring in every measurement (ISO 5725).

The overall performance of the working depth control is the cumulative sum of the accuracies of the individual sensors.

The accuracy of the drilling depth estimated from the depth control system was about ± 0.2 mm during the calibrations.

Working depth model

$$WD = \overline{M}_i - \overline{C}_i + I + H \quad (2)$$

where,

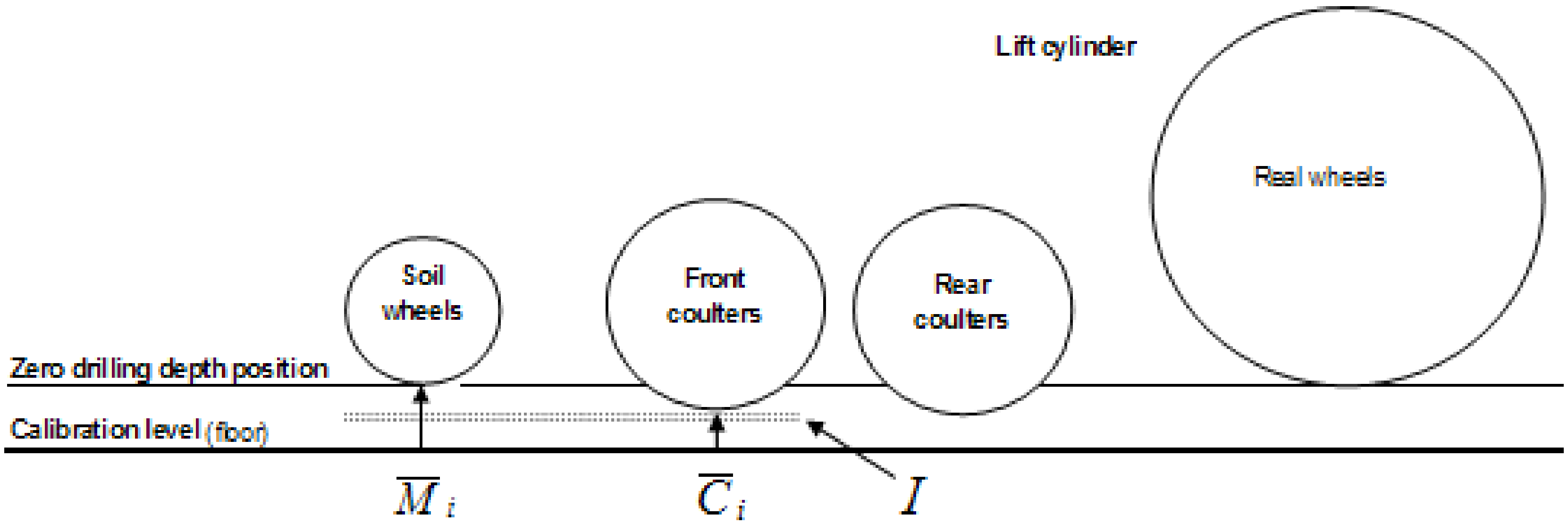
WD = working depth in mm.

$\overline{M}_i$ = average measurements of soil wheels from the calibration level in mm.

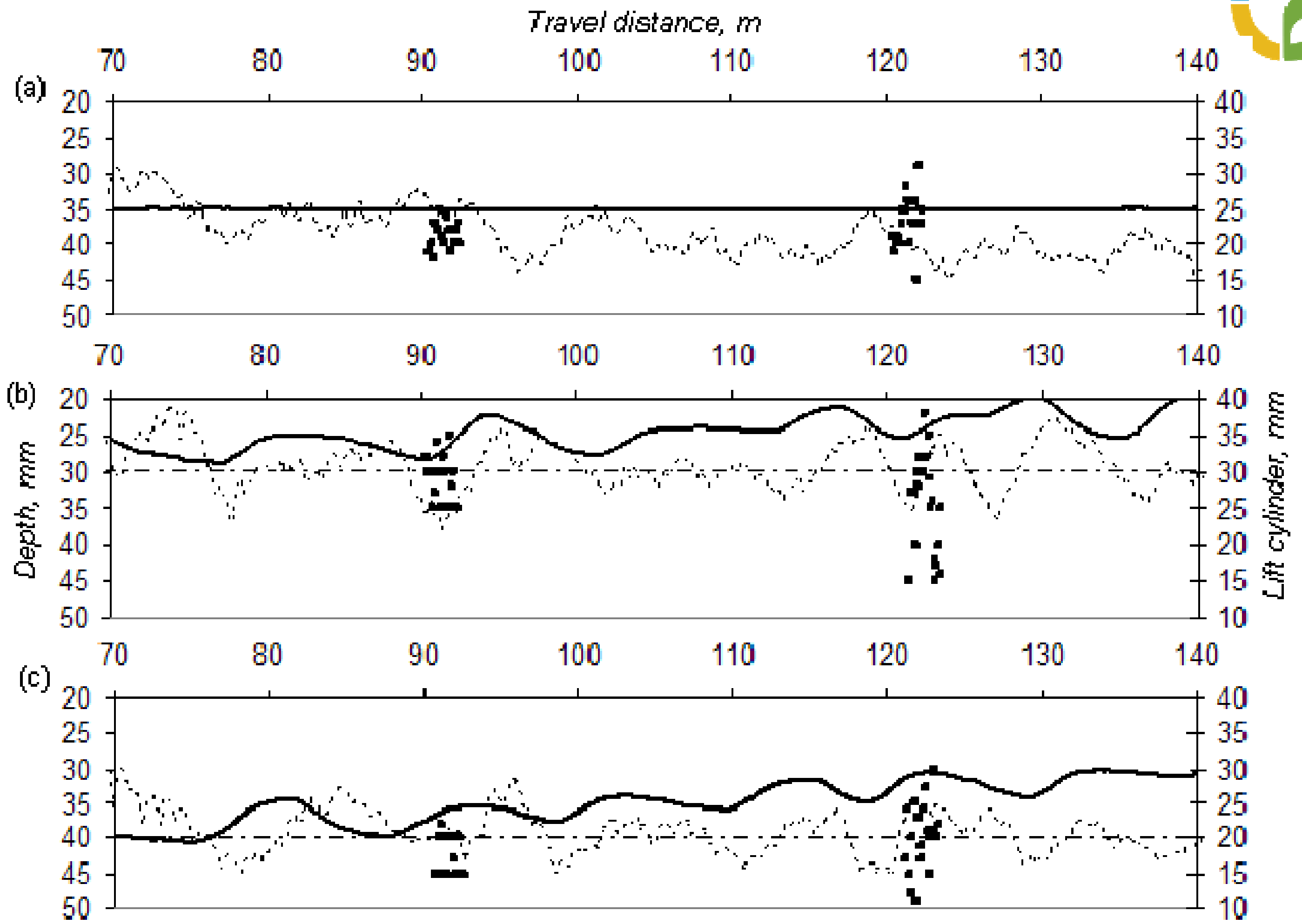
$\overline{C}_i$ = average measurements of coulters from the calibration level in mm.

I = inclination correction factor between the measuring wheel and the coulter in mm.

H = correction factor for systematic error in mm.

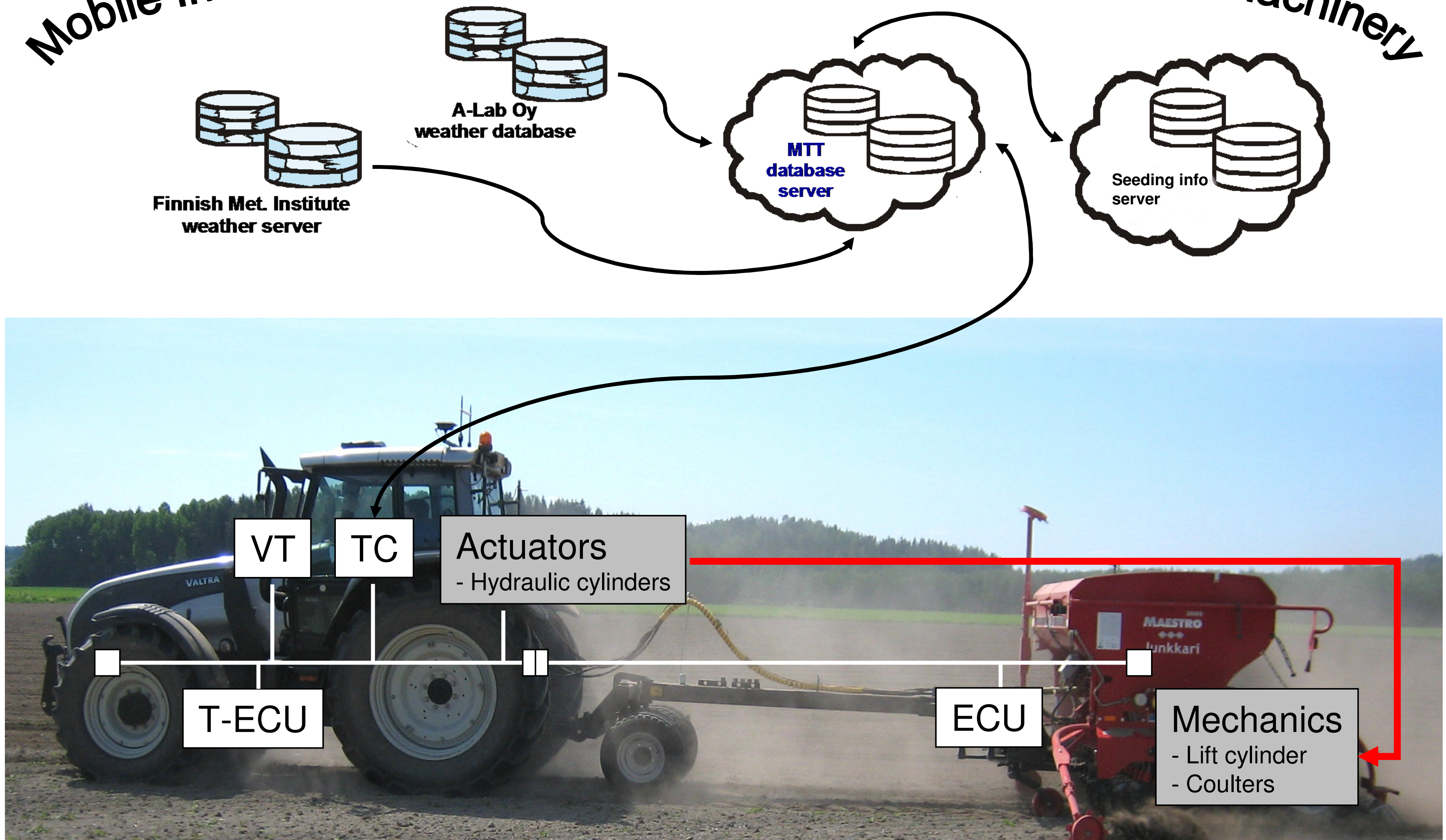


Results of test for the depth control system



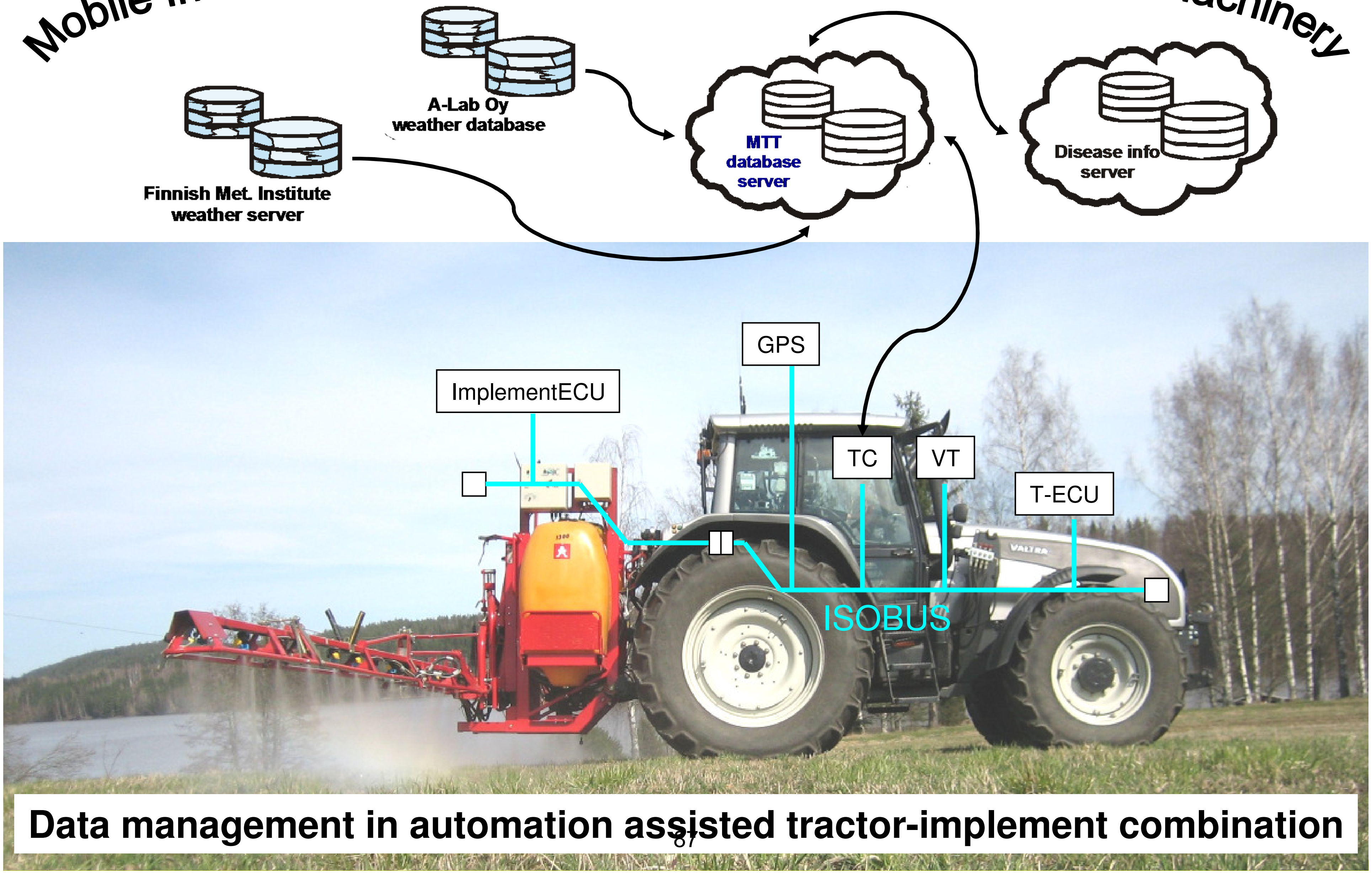
- (a) results of the manual test run
- (b) and (c) results from test runs 30 mm and 40 mm
- Solid line describes position of the lift cylinder
- Dot lines describe working depth estimated by the model
- Square plots represent real depths of seeds

Mobile Internet Services for Online Support of Agricultural Machinery



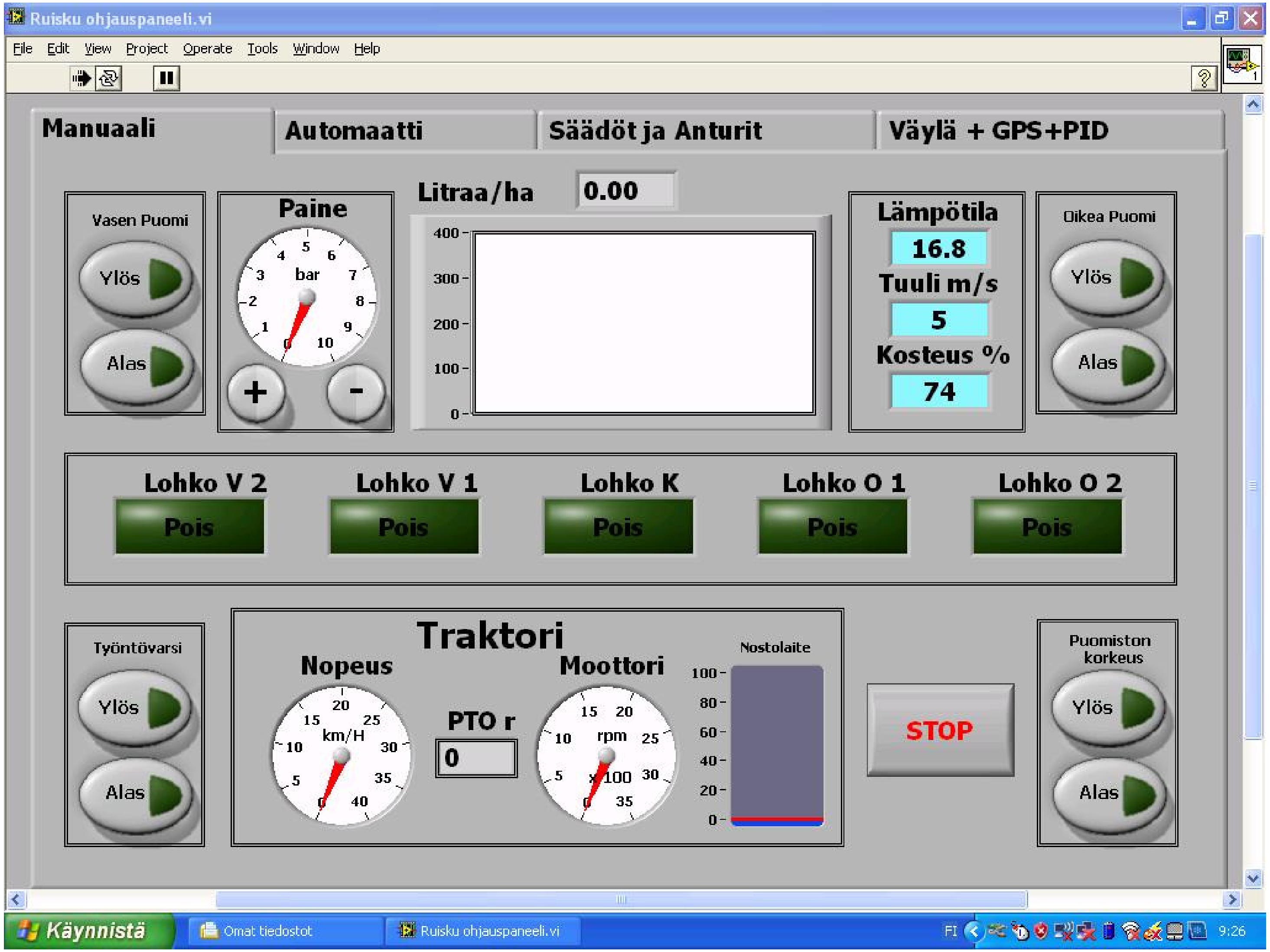
Data management in automation assisted tractor-implement combination

Mobile Internet Services for Online Support of Agricultural Machinery



Data management in automation assisted tractor-implement combination

Example prototype
Task Controller (TC) interface:



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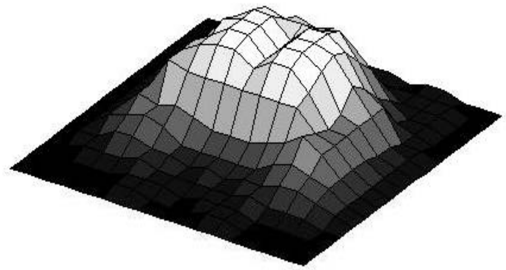

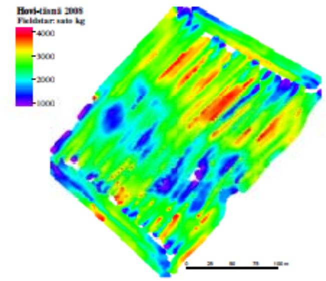

Nordunet3 - A Nordic Internet Research Program

Site Specific Information in Farm Machinery Operations

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10.6.2010, NORDUnet Agro, Helsinki, Suomi

CONTENT

- Introduction
- Wireless communication and GIS
- Map generation processes
- Examples of real-time spatial analysis
- Conclusions

Farming process needs spatial information from machine:

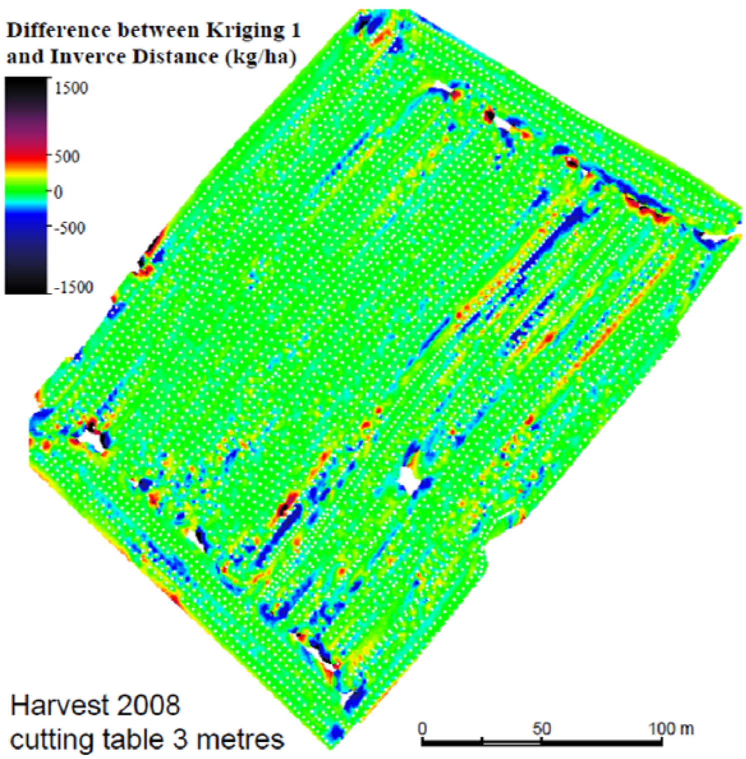
- To evaluate the success of the farming process
- To generate new tasks
- Determine development needs
- Real-time task management and logistics

INTRODUCTION

Spatial data reliability with current methods?

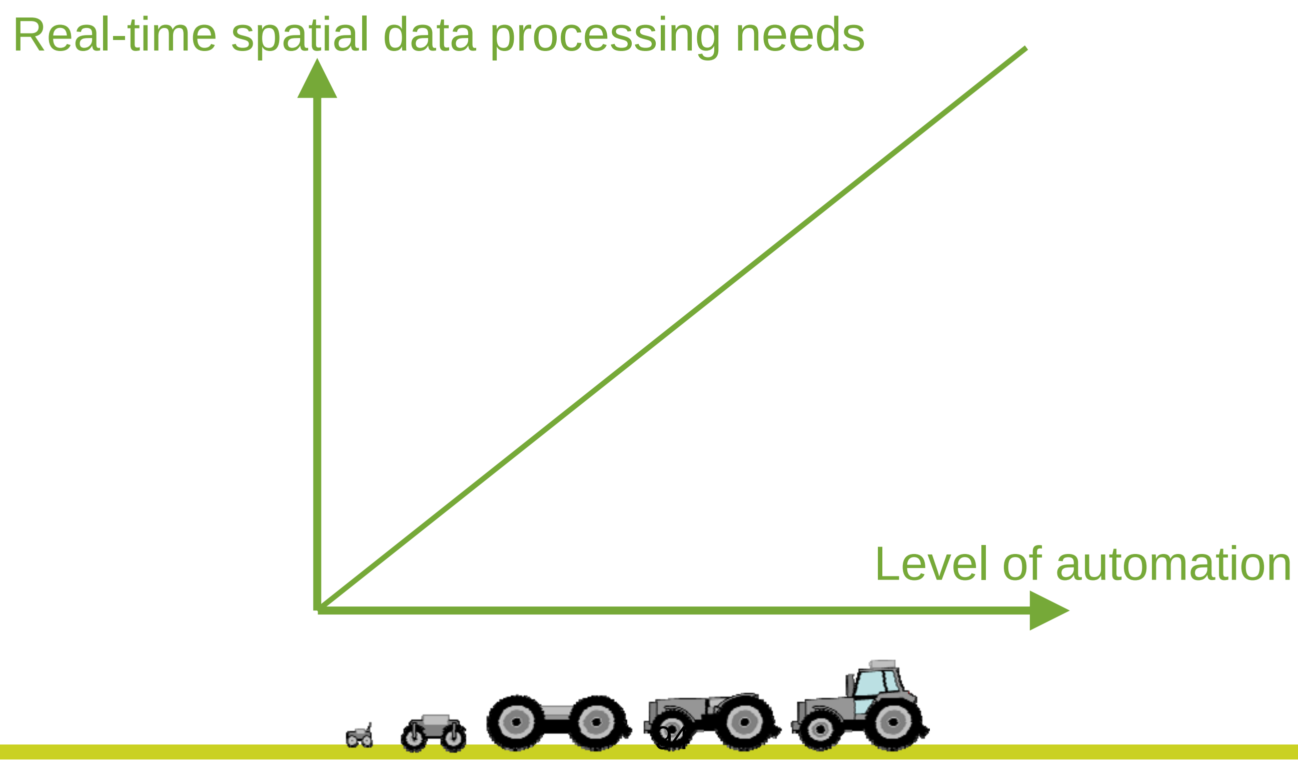
- Yield data error: 14% (excl. positioning error) (Blackmore and More 1999)
- Urea fertilisation error: 38.5% variation (Lawrence and Yule 2007)

- Single harvest; different interpolation methods:
  - Kriging 2: 4.6%
  - Kriging 3: 15.5%
  - Minimum curvature: 5.0%
  - 10m grid: 22.2% (vs 0.5m)
  - Inverse distance: 4.7%



INTRODUCTION

- Map generation processes are not ready
- Increasing level of automation needs more accurate spatial information and it might need it in real time
- How much data, how often?

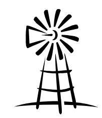
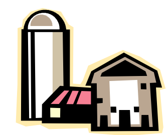


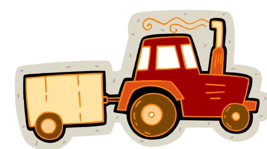
EXPLOITING WIRELESS COMMUNICATION AND GIS

During the task execution, the working unit could communicate with:



- **Customer, supervisor, operator**
  - Task status, further plan
- **Infrastructure**
  - Task status, task updates, logistics
- **Different working units**
  - Task updates and dynamic planning
- **Similar working units**
  - Task updates and dynamic planning

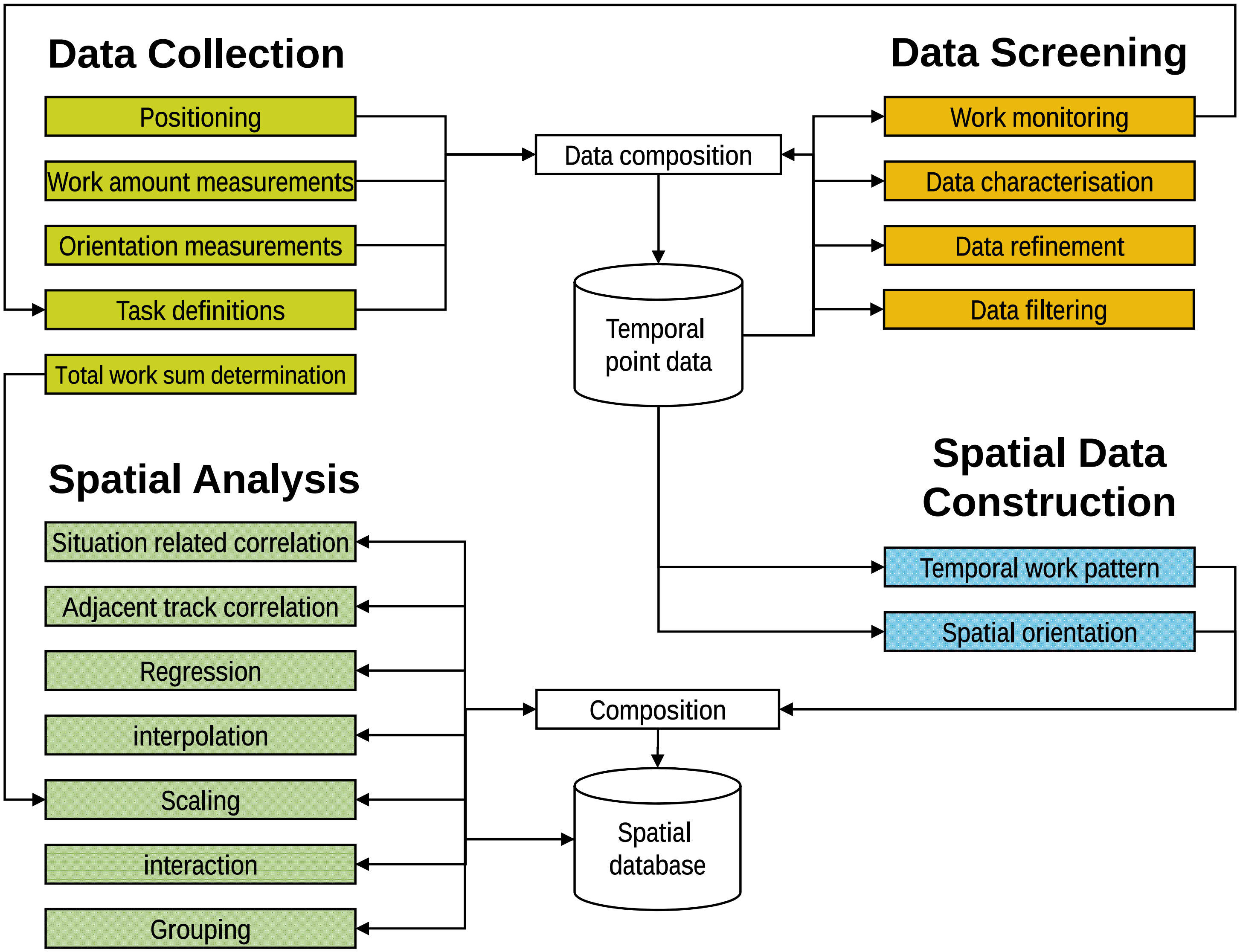


= What have I done, what is my plan?

MAIN PROCESSES FOR MAP GENERATION: (Working unit)

- Data collection
  - Gather all the required inputs
  - Set requirements for the following processes
- Data screening
  - Analyse the measurements
- Spatial data construction
  - Develop informative spatial data
- Spatial analysis
  - Study work using topological, geometric, or geographic properties
  - Set requirements for the earlier processes

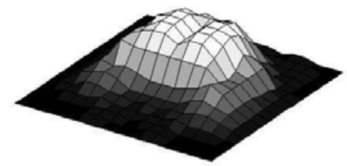
SPATIAL INFORMATION FLOW AND DATA PROCESSES FOR THE PLAN EXECUTION (Framework):



EXAMPLES OF REAL-TIME SPATIAL ANALYSIS:

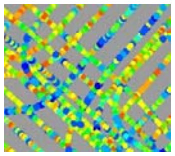
Situation related correlation

- Combines spatial autocorrelation with specific circumstances
- Work pattern correction according to local wind speed and direction



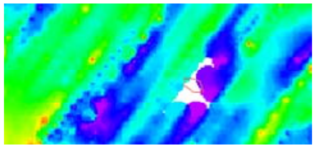
Adjacent track correlation

- Compares neighbouring driving lines
- Smoothes the neighbouring yield moisture and amount



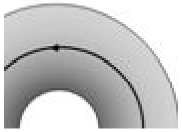
Regression

- Captures local, field-wide or global spatial dependencies
- Detects local exception like a pole detouring



Interpolation

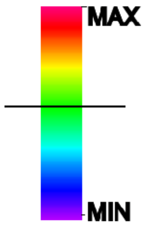
- Produces continuous map layer by estimating values according to chosen methods
- Represents the thickening resulted from non-differential gear implement



EXAMPLES OF REAL TIME SPATIAL ANALYSIS:

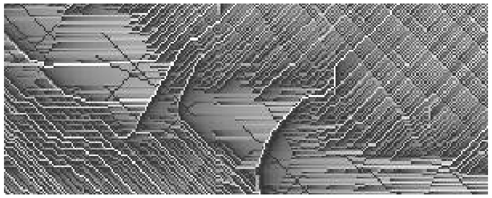
Scaling

- Scales the map according to the actual input/output sum
- Scales the average yield so that it corresponds to a weighted yield/ha



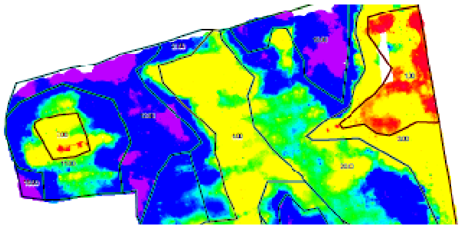
Interaction

- Exploits other spatial information to adjust values
- Adjusts the manure levels by using a water flow model and forecast



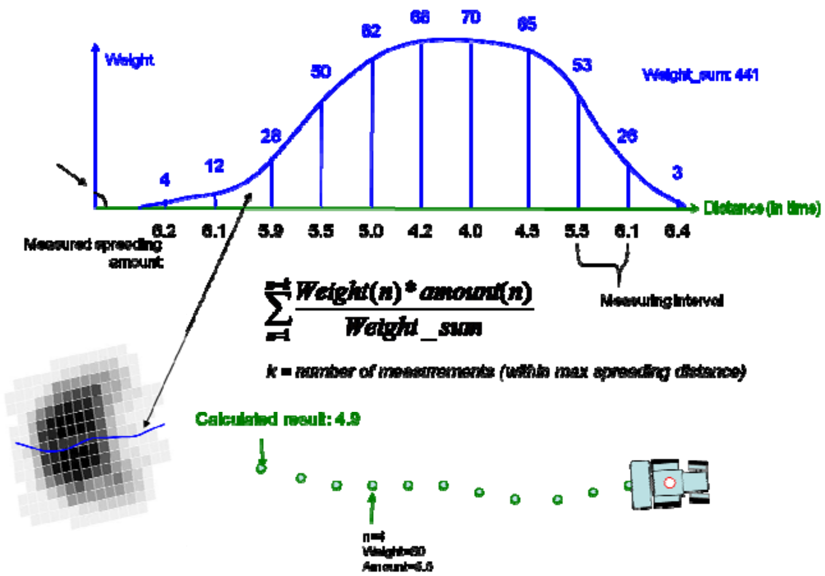
Grouping

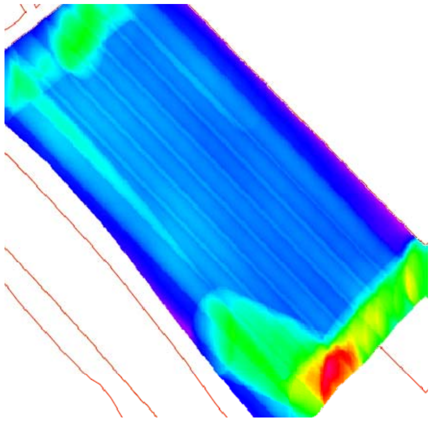
- Produces a map for a specific use by means of clustering, classification, characterization and aggregation methods
- Determines new management zones



CONCLUSIONS

- Map generation is not faultless
- The need of real-time data handling is increasing together with automation
- Several authors could need the real-time data
- All the possible spatial data handling processes can be needed to be done in real-time





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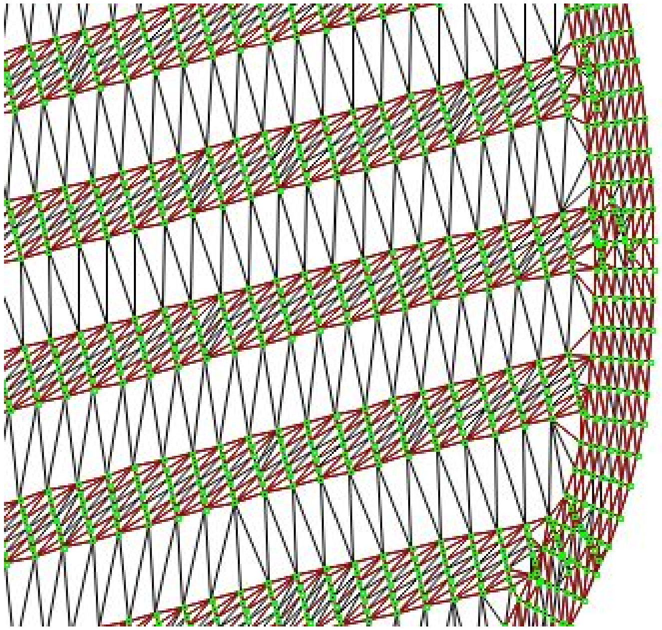

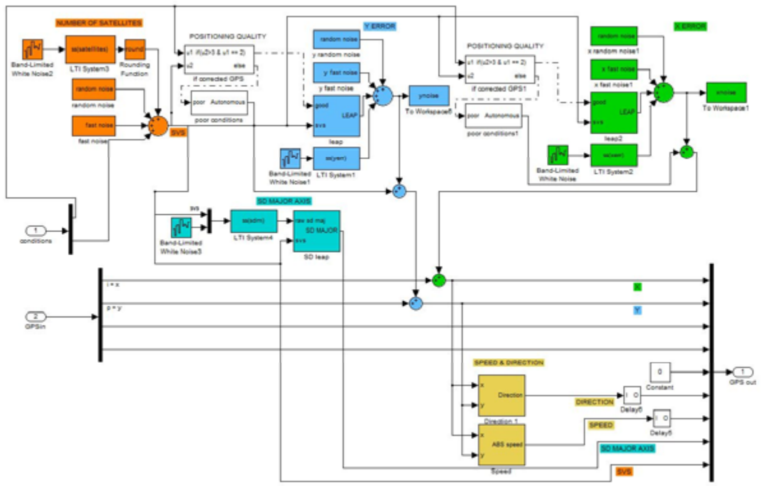

A platform for the optimization and automation of autonomous vehicles in field operations

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Faculty of agricultural sciences

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For presentation at

Nordunet Agri Seminar

Helesinki, Finland

June 10th, 2010

Outline

- Objectives
- a tool for automatic route planning
- A discrete event based simulator
- Optimization (in progress)

Objectives

- Optimize and mechanise the operation of AVs in field operations.

✓ Develop a tool able to: (1) provide all possible driving courses of a field as a function of direction and driving style, (2) able to operate any field regardless of its complexity, .

✓ Develop a simulator able to provide real time information (such as effective and non-effective working distance, overlapped or missed area, time, etc) of each driving course.

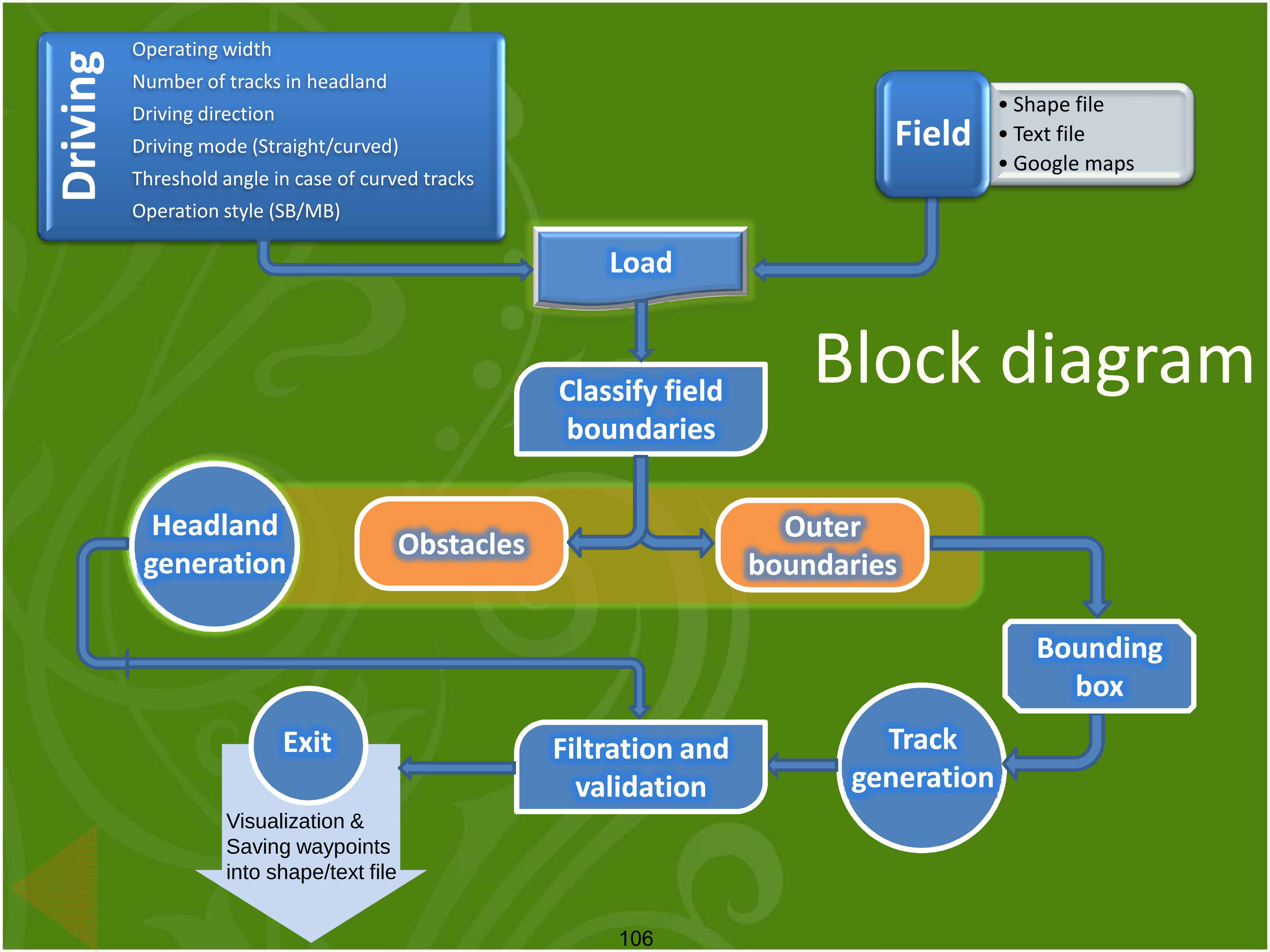
✓ Develop an optimization tool to select optimum driving course.

✓ Provide way points of optimum driving course to AV in the form of shape or KML files.

1/3

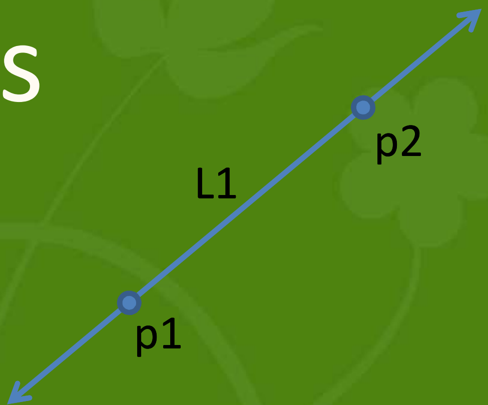
On-line field track gernation tool

- Block diagam
- Simulation results
- Conclusions



Driving
Operating width
Number of tracks in headland
Driving direction
Driving mode (Straight/curved)
Threshold angle in case of curved tracks
Operation style (SB/MB)
Field
• Shape file
• Text file
• Google maps
Load
Block diagram
Classify field boundaries
Headland generation
Obstacles
Outer boundaries
Bounding box
Track generation
Filtration and validation
Exit
Visualization & Saving waypoints into shape/text file

Basic operators

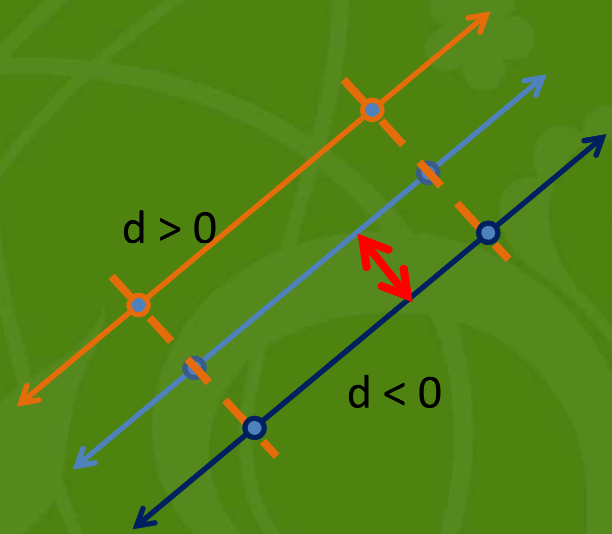


Create line

- L = line(p1,p2)

Parallel line

- L2 = pLine(L1, d), d ∈ R



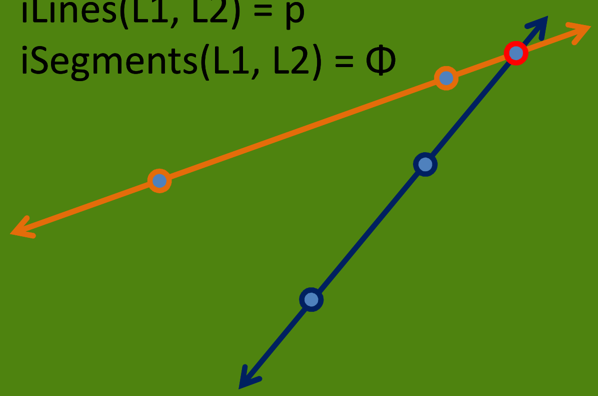
Intersect lines

- P = iLines(L1, L2)
- P = iSegments(L1, L2)

lineAngle

- Θ=lineAngle(L1, L2)

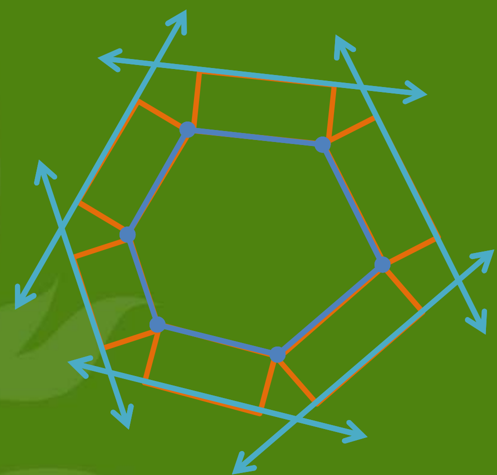
iLines(L1, L2) = p
iSegments(L1, L2) = Φ



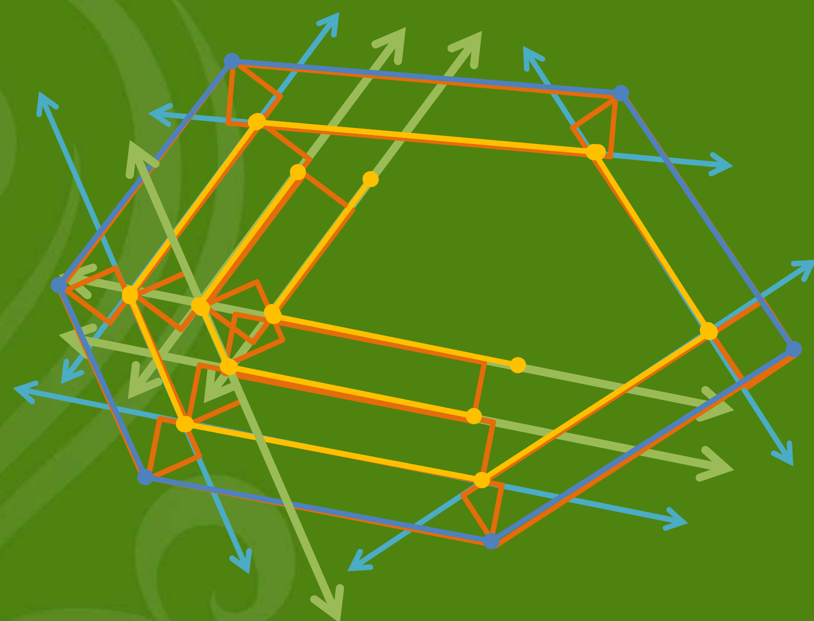
Headland track generation

- Headland
  - Boundaries (d<0)
  - Obstacles (d>0)
  - Smoothing

```
For i = 1 : n-1
  L(i) = line(p(i),p(i+1))
End
For i = 1 : n-1
  pL(i) = pLine(L(i), d)
End
For i = 1 : n-1
  p1(i) = iLiness(pL(i), pL(i+1))
End
```



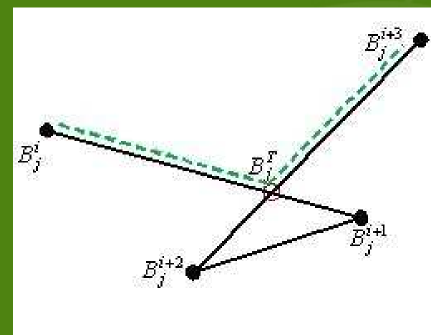
Closed polygon in clock-wise direction

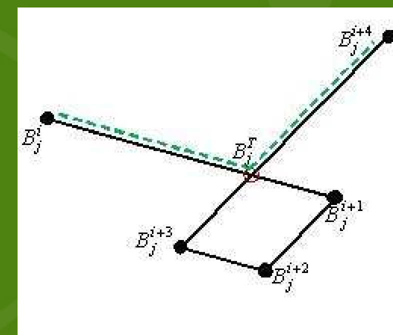


Smoothing

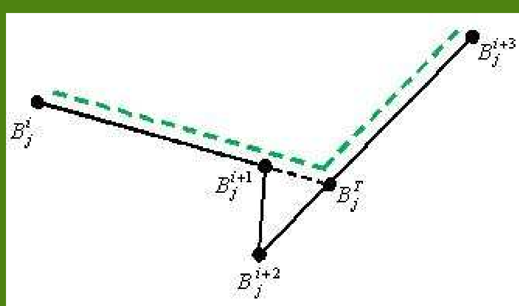
Type-1 smoothing Filter

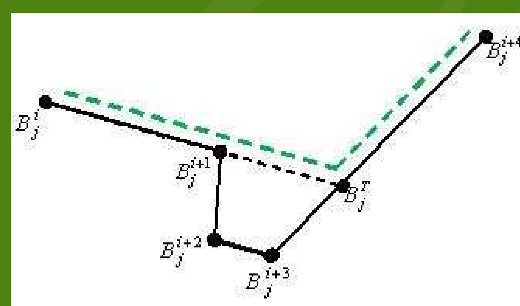
Dissolving segment(s) connecting two intersected segments

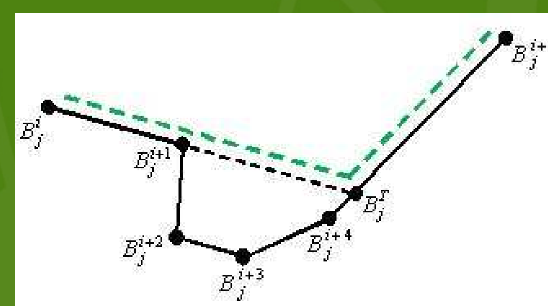




Type-2 Smoothing Filter



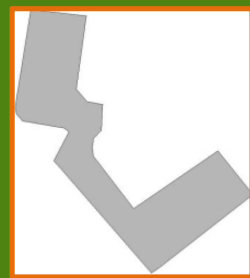


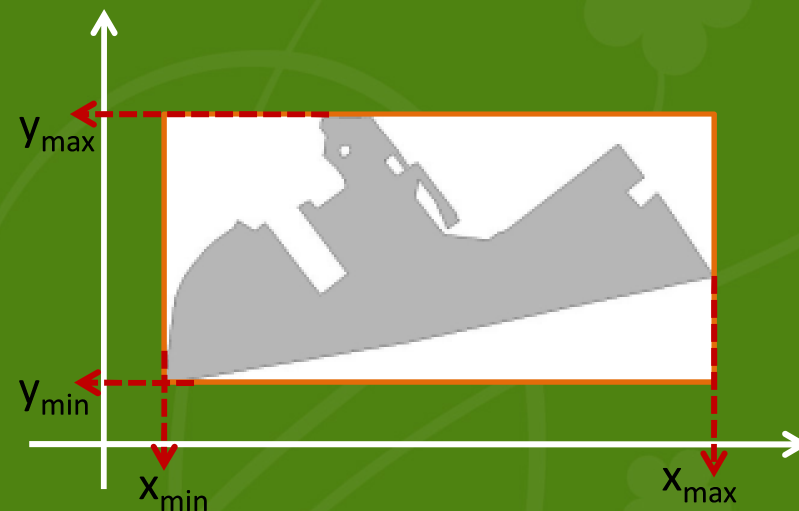


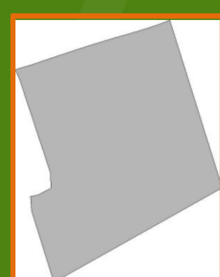
Dissolving segment(s) between a segment and a line intersected at distance less than or equal a certain threshold value

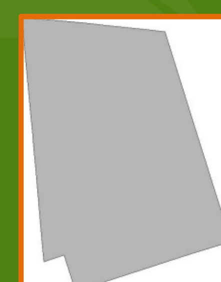
Minmum bounding box (MBB)

MBB is the box with the smallest area containing all points of the field outer boundary

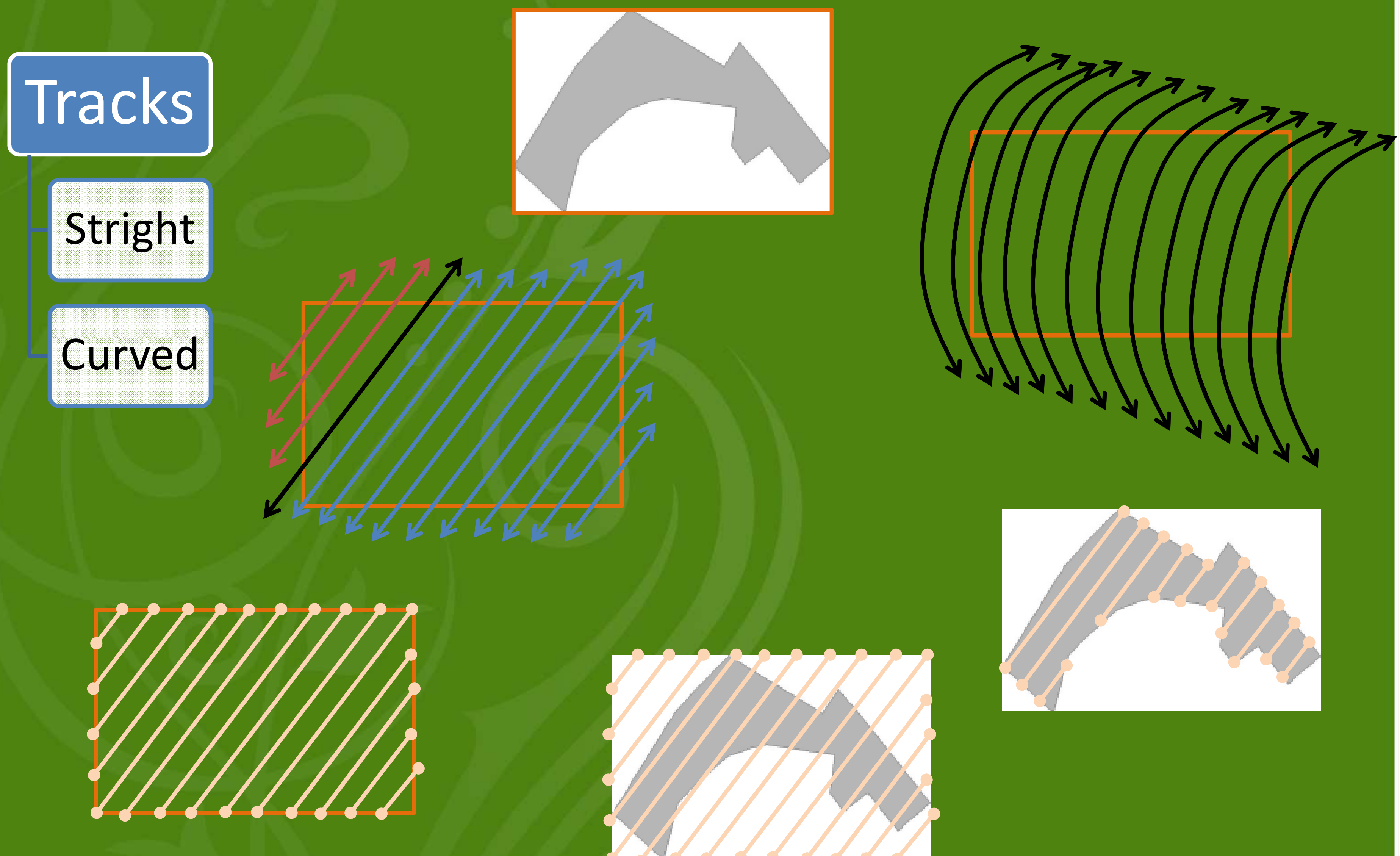






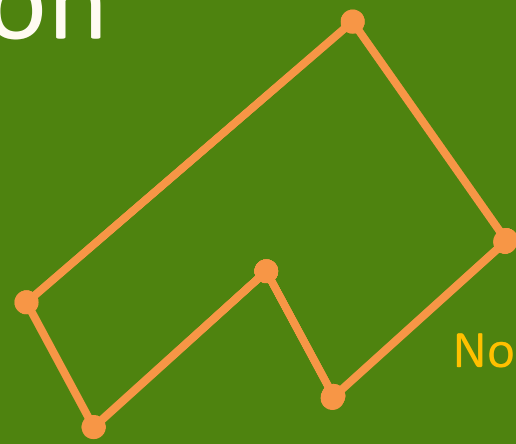


Track generation

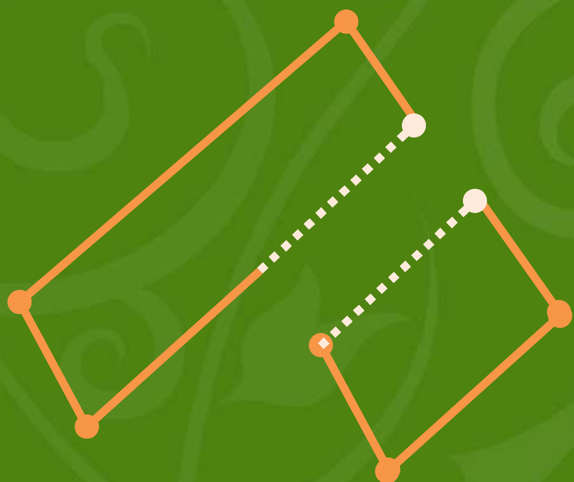


Operation style: Multi/single-block operation

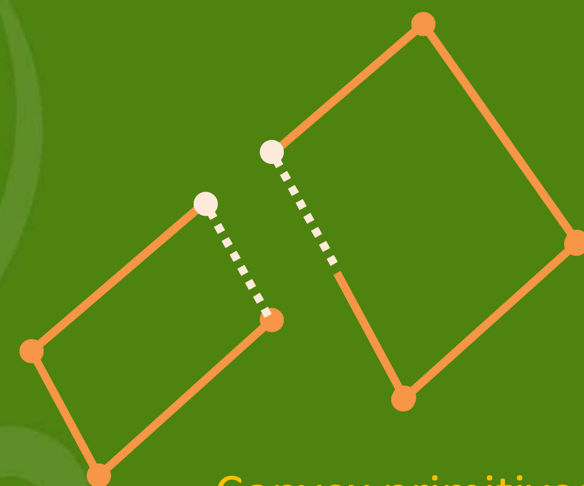
MBO: For converting a non-convex field into its convex primitives



Non-convex



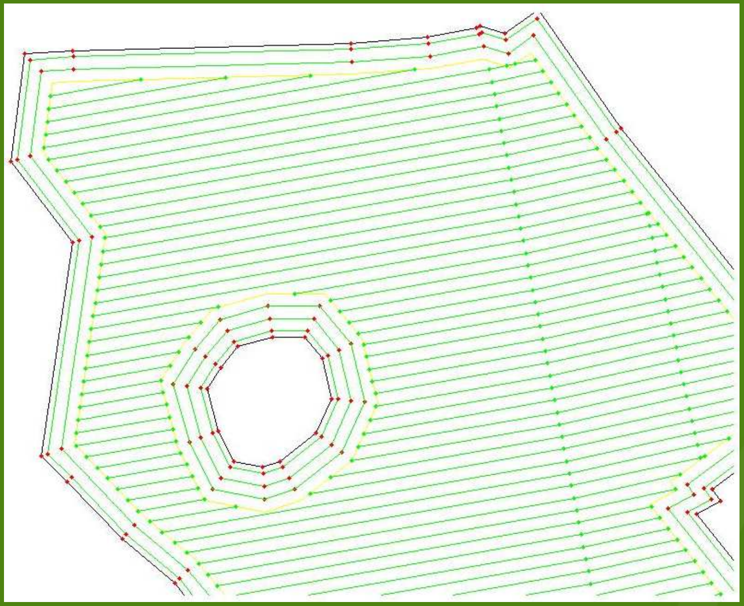
Convex primitives (1)

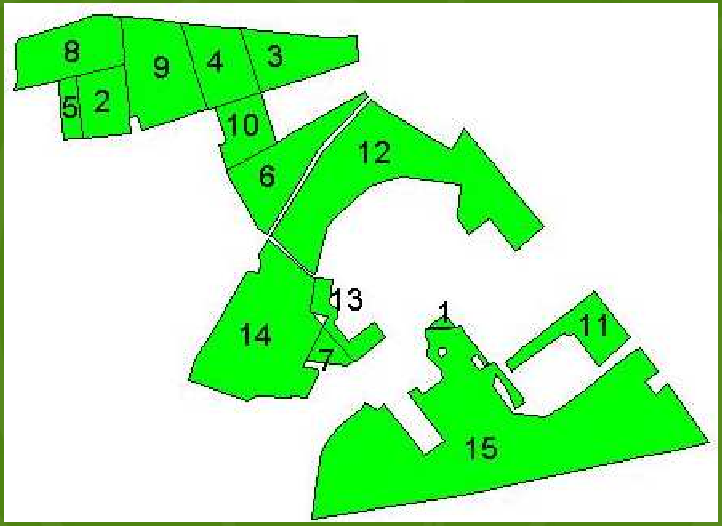


Convex primitives (2)

Results

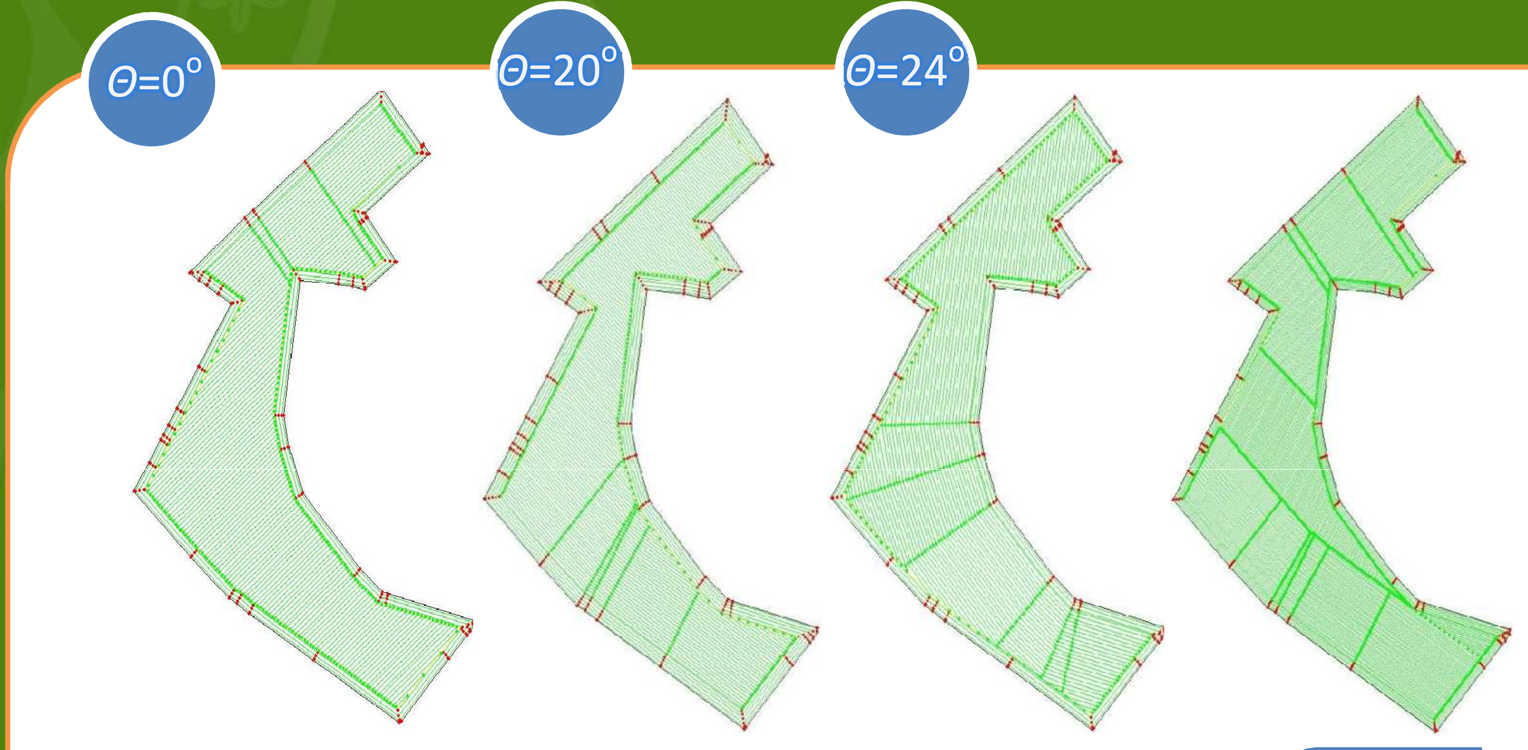
Satellite image of 15 fields, Foulum Research Center, Denmark

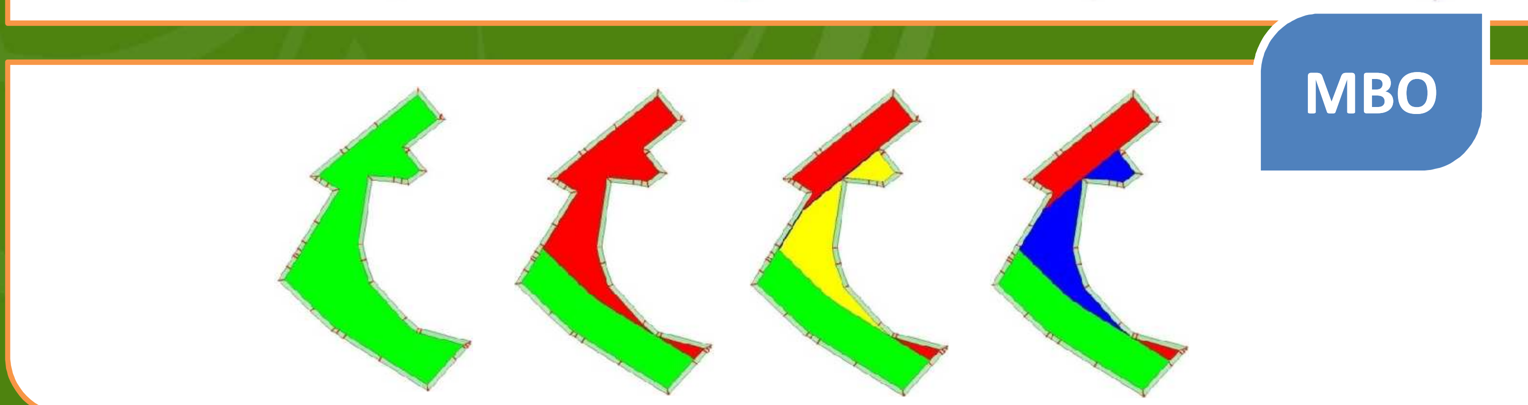




A close view of field 15 for 3 headland tracks and 3 obstacle-headland tracks for a machine of 2 m operating width

Results

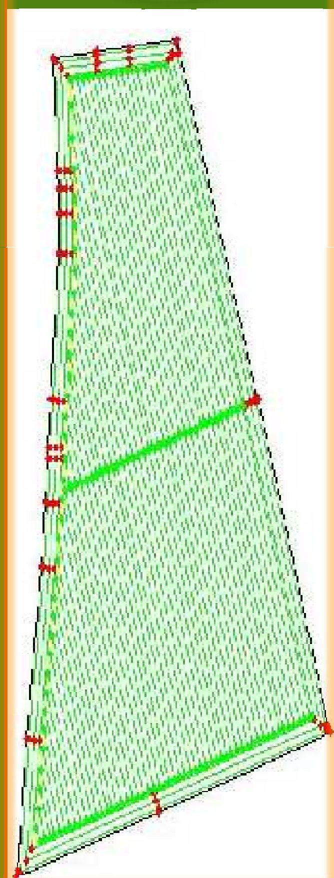


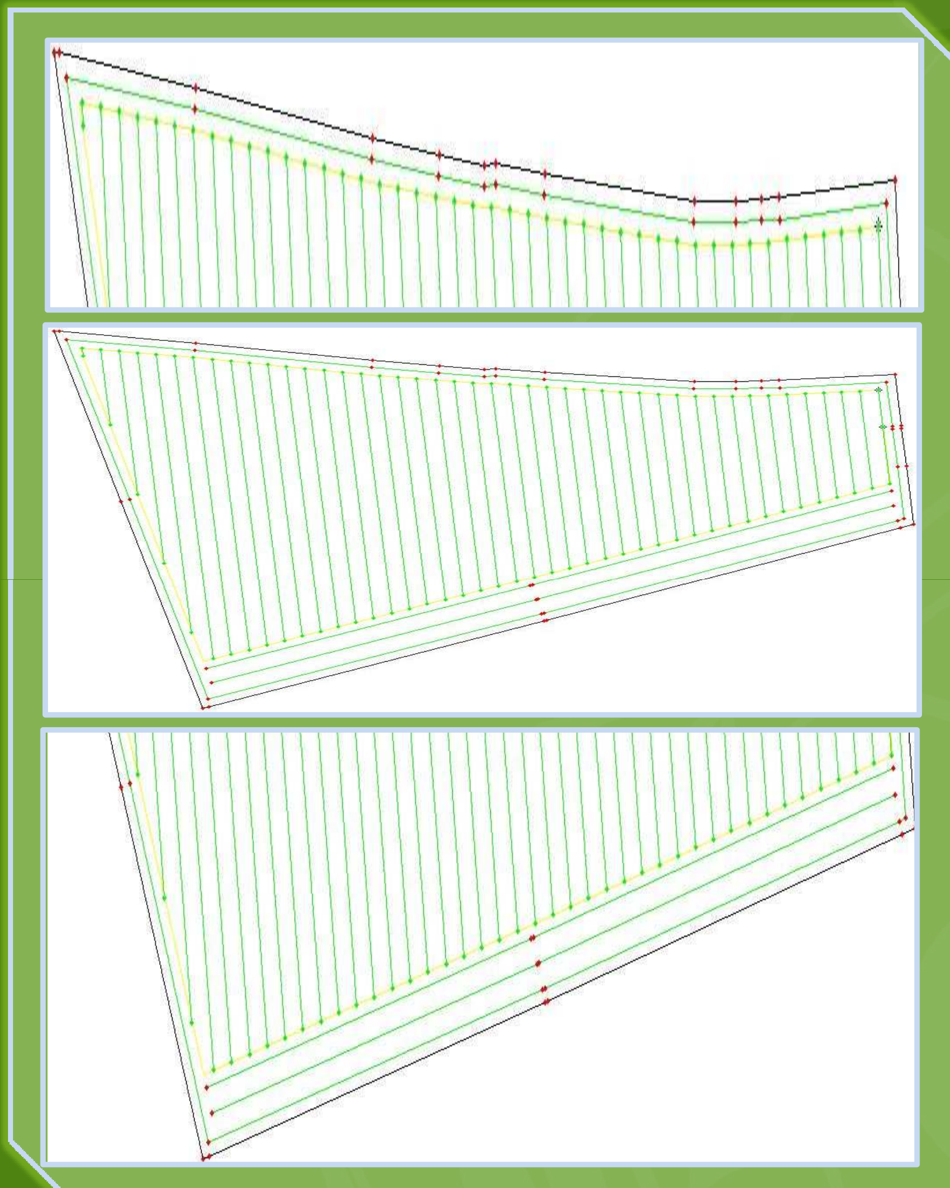


Results

Stright

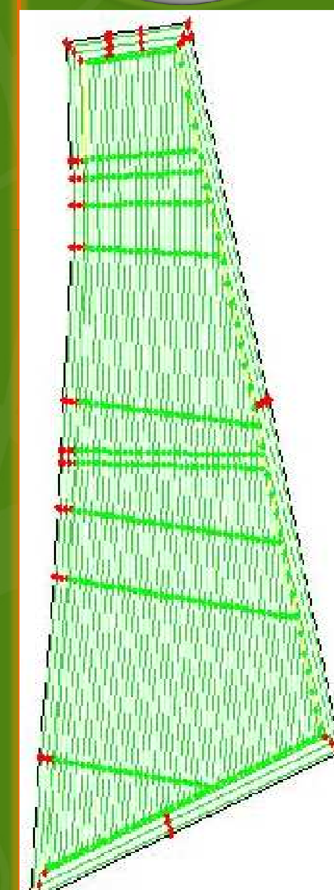
$(\theta=0^{o})$





Curved

$(\theta>0^{o})$



Unequal operation of headlands: one headland pass to north and three to south side of the field

Discussion and conclusions

Features

- Fast algorithms
- Online/offline operation
- Low computational requirements

Completness

- Operate any field regardless of its complexity

Integration

- Can be integrated with a simulator for optimization
- Can be Integrated with AV control system for providing waypoints for direct navigation

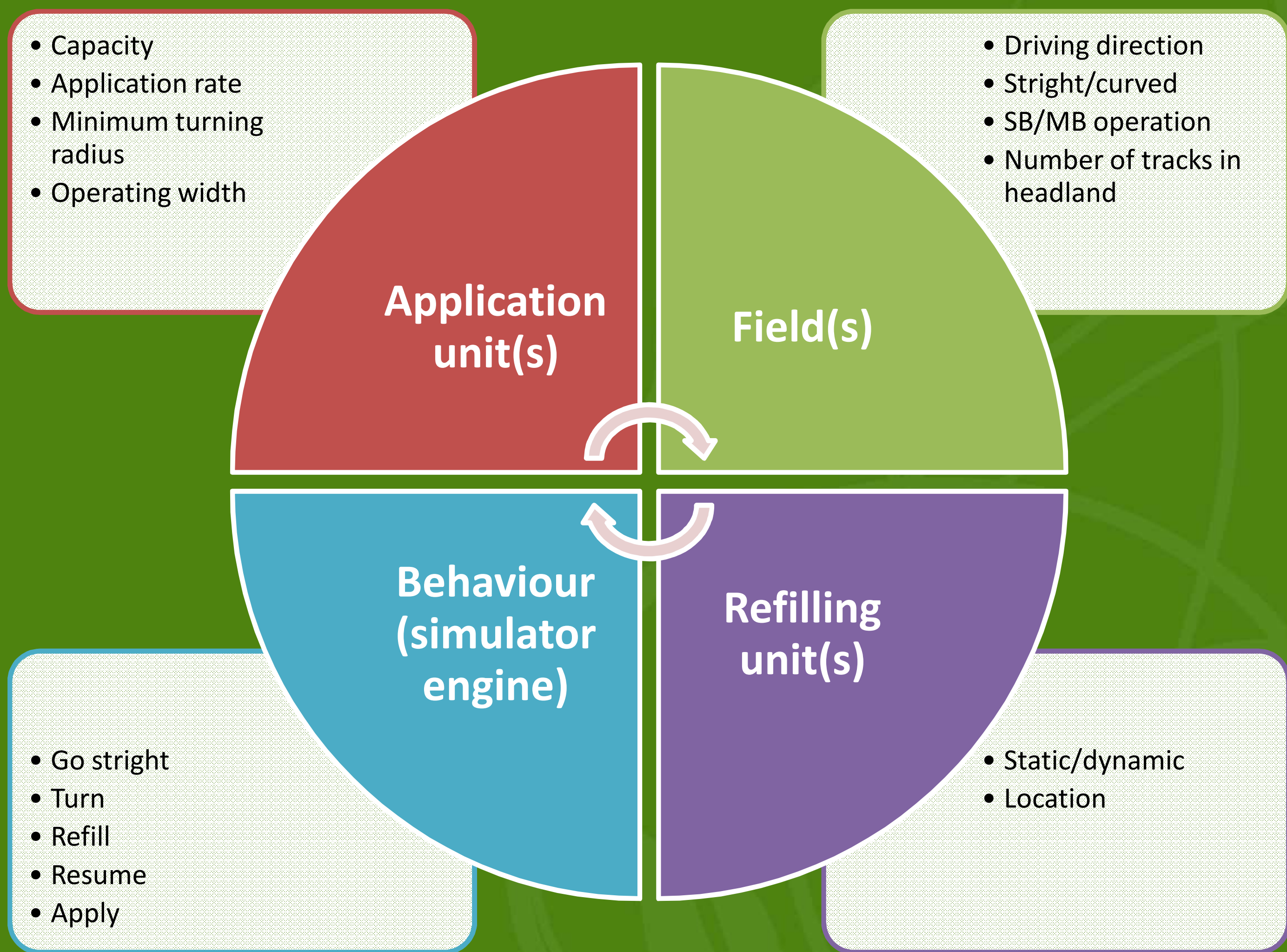
2/3

Simulator

"A plat form for the optimization/management/coordination of multi-machinery and traffic system for field operation"

- Structure
- Setup
- Simulation example
- Discussions

Structure

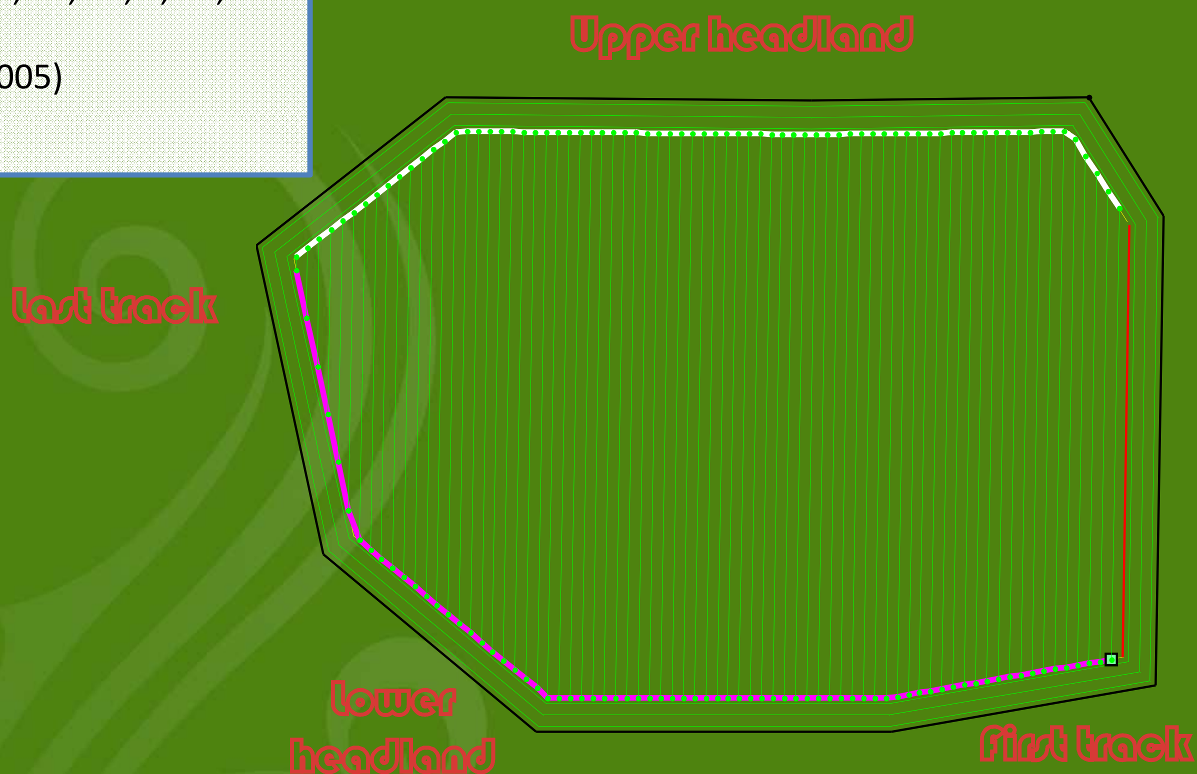


Capacity
Application rate
Minimum turning radius
Operating width
Driving direction
Stright/curved
SB/MB operation
Number of tracks in headland
Application unit(s)
Field(s)
Behaviour (simulator engine)
Refilling unit(s)
Go stright
Turn
Refill
Resume
Apply
Static/dynamic
Location

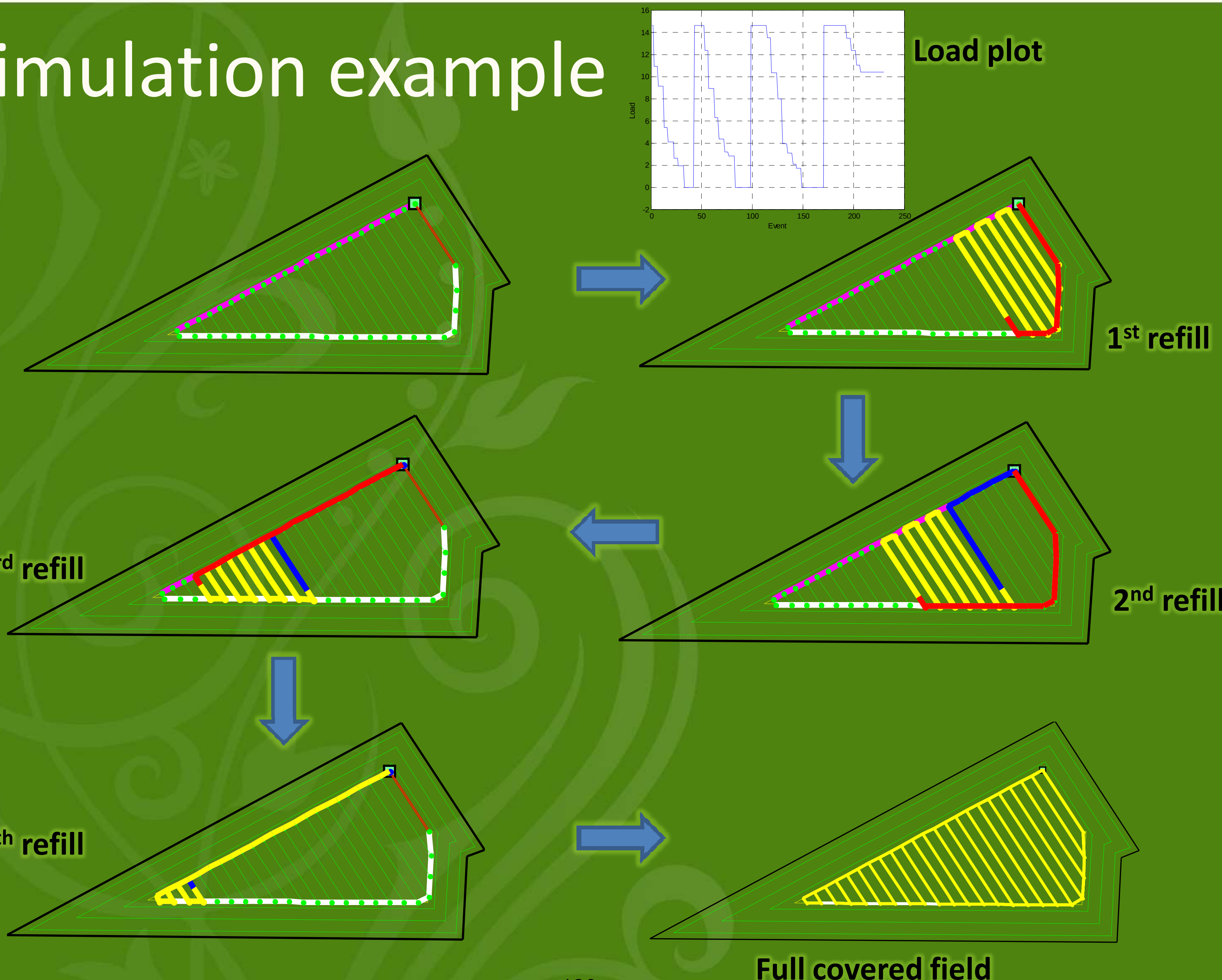
Setup

Instantiation of a field and two vehicles

- tf = Field('f1', 'from a file', 10, 3, 3);
- tf.plotField
- pos = tf.getTrack(tf.sequence(1)).lower;
- v1 = Vehicle('v1', 'application unit', 1, pos, 20, 10, 5, 10, 14.6);
- v2 = Vehicle('v2', 'refilling unit', 1, pos, 20, 10, 5, 10, 14.6);
- sim = MicroSimB(tf, [], v1, v2, [], -1, 0.005)
- Sim.run



Simulation example



Conclusions

Outputs

- Non-working distance
- Effiecent distance
- Overlapped area
- Number of refills
- Operation time
- etc

Integration

- Easy to integrate with optimization tool for optimization/management of multi-machinery for field field operation

What else?

- Covering headlands (in progress)

3/3

Optimization of driving direction and sequence of tracks for field operation

Using a multi-layered integer valued GA tool

- Quick overview
- An example

Flowchart of 3 layered GA optimization tool

Inputs
- Field boundaries
- Operating width
- Number of tracks in headland

Driving direction optimizer (layer1)
- Minimize non-effective distance, time, overlapped area, etc.
- Return optimum course driving direction

Divide parallel tracks into blocks
- This reduction speeds up the operation of GA

Optimize sequence of blocks (layer2)

Optimize sequence of tracks in each block (layer3)
- Combine in one sequence string
- exit

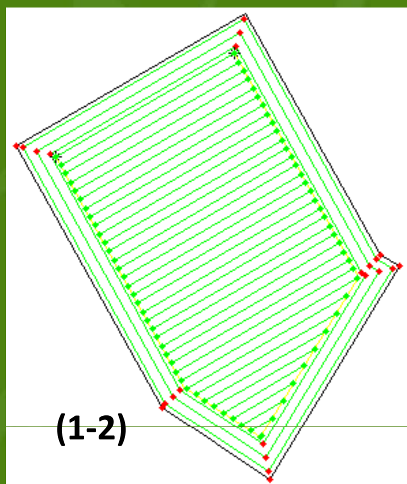
Driving direction

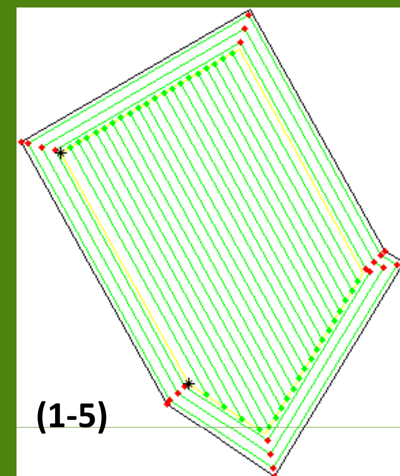
- For simplicity, a driving direction is defined as the line connecting vertices *i* and *j* where *i*, *j* Є{1,2,...,*n*], n is the number of vertices of field inner boundaries
- Possible driving directions = (n-1)+(n-2)+...+1
- A solution is obtained in few secons.

Track sequence optimization

- For a field of *t* tracks, *t*! different sequences are exist.
- A normal 64 bit PC can only optimize the sequence up to 12 tracks (12! Combinations) and a solution could be obtained after some hours.
- To speed up this process and to allow unlimitted number of tracks divide tracks into blocks of odd number of tracks lees than 12 and use a two-layered GA to optimize sequence of blocks and sequence of tracks in each block.
- A solution could be obtained after few minutes.
- The less number of tracks in each block, a faster solution coubd be obtained.

An example





Possible driving direction	Number of rows	Rows Length (m)	Nonworking distance (m/h)	Overlapped missed area (m^2/h)
(1-2)	36	5831.59	876.13	842.12
(1-3)	35	5742.31	1039.87	38.55
(1-4)	24	5746.43	775.69	75.62
(1-5)	20	5536.50	496.49	-1813.70
(2-3)	21	5771.36	506.82	300.06
(2-4)	29	5739.41	941.61	12.47
(2-5)	32	5739.37	1010.16	12.11
(3-4)	33	5823.21	895.78	766.67
(3-5)	35	5753.88	851.42	142.67
(4-5)	30	5693.25	871.42	-402.97

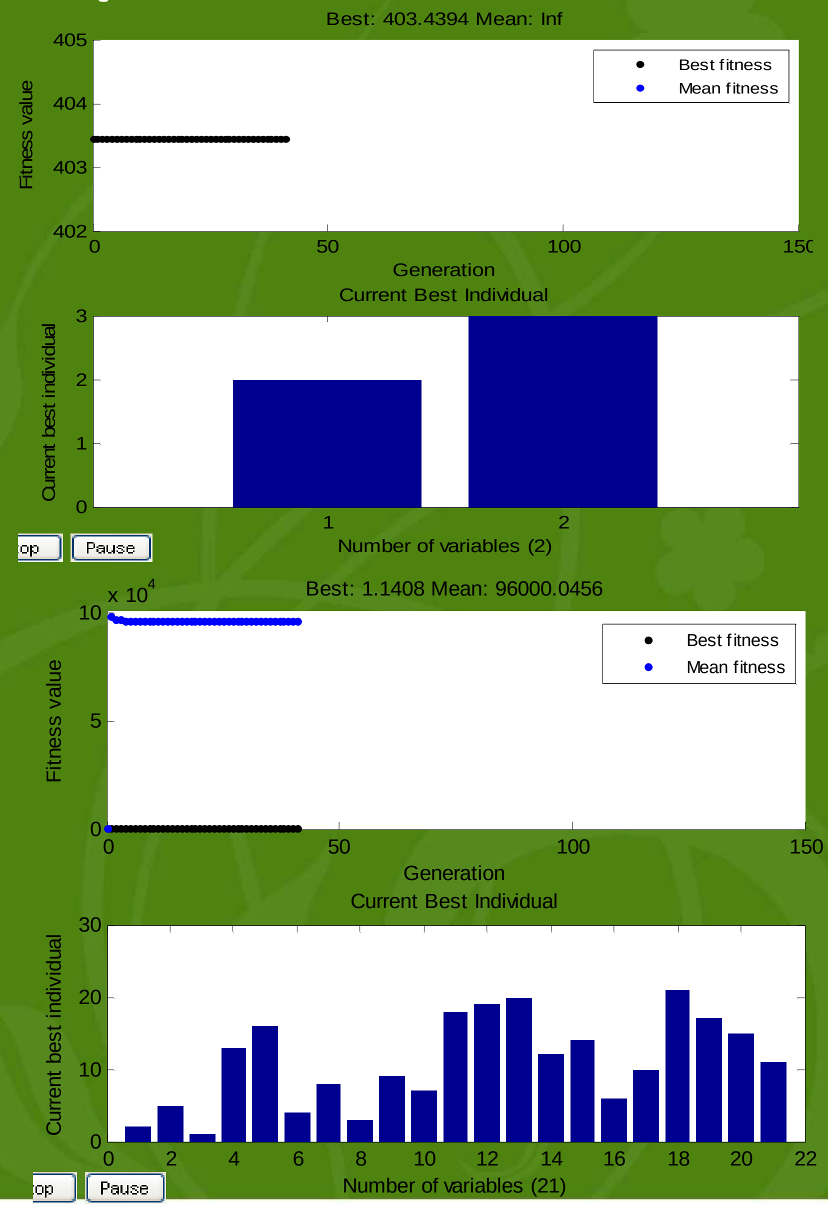
An example

Driving direction

- The optimum driving direction to minimize non-working distance and overlapping area is to drive parallel to edge [2 3].
- Solution is obtained in 6.79 s.

Track sequence optimization

- The optima course obtained in the optimization layer by driving along side [2 3] has t = 21 tracks.
- For 21 tracks, 21! = 51090942171709440000 possible sequences (i.e., different arrangements or permutations) are exist.
- For a tractor with a speed of 10 km/h in tracks, 2.5 km/h in Omega turning and 5 km/h in PI turning.
- The optimum sequence of tracks, in order to minimize field total operation time, if found to be: Seq = [2 5 1 13 16 4 8 3 9 7 18 19 20 12 14 6 10 21 17 15 11].
- Solution is obtained in 314.52 s.
- Minimum field operations time is 1.14 h.



Thanks for your attention…

Questions

A platform for the optimization and automation of autonomous vehicles in field operations

June 2010

Examples of agricultural ICT utilising web server based electronic control units (WebECU)

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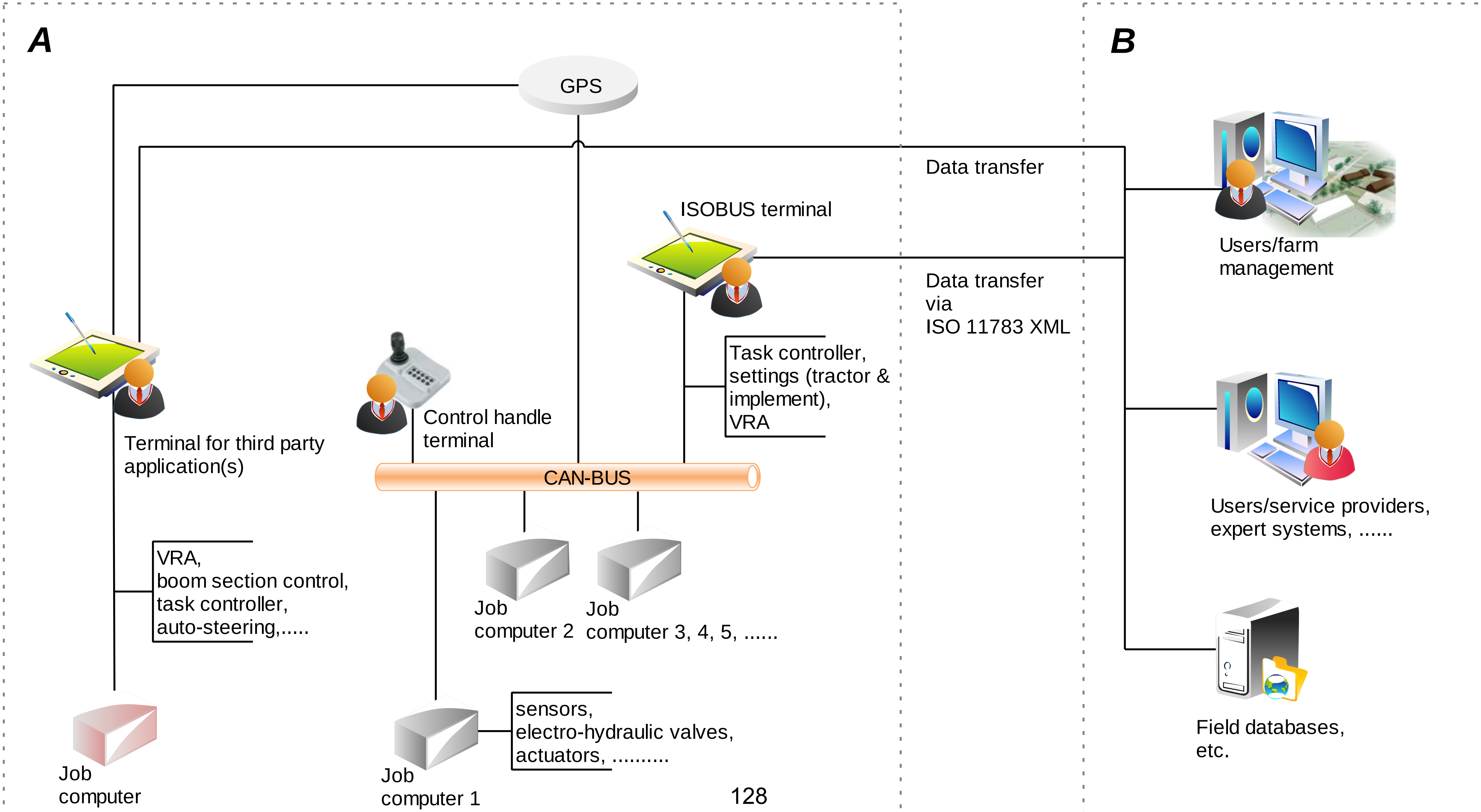
Jens Overgaard, Højvang

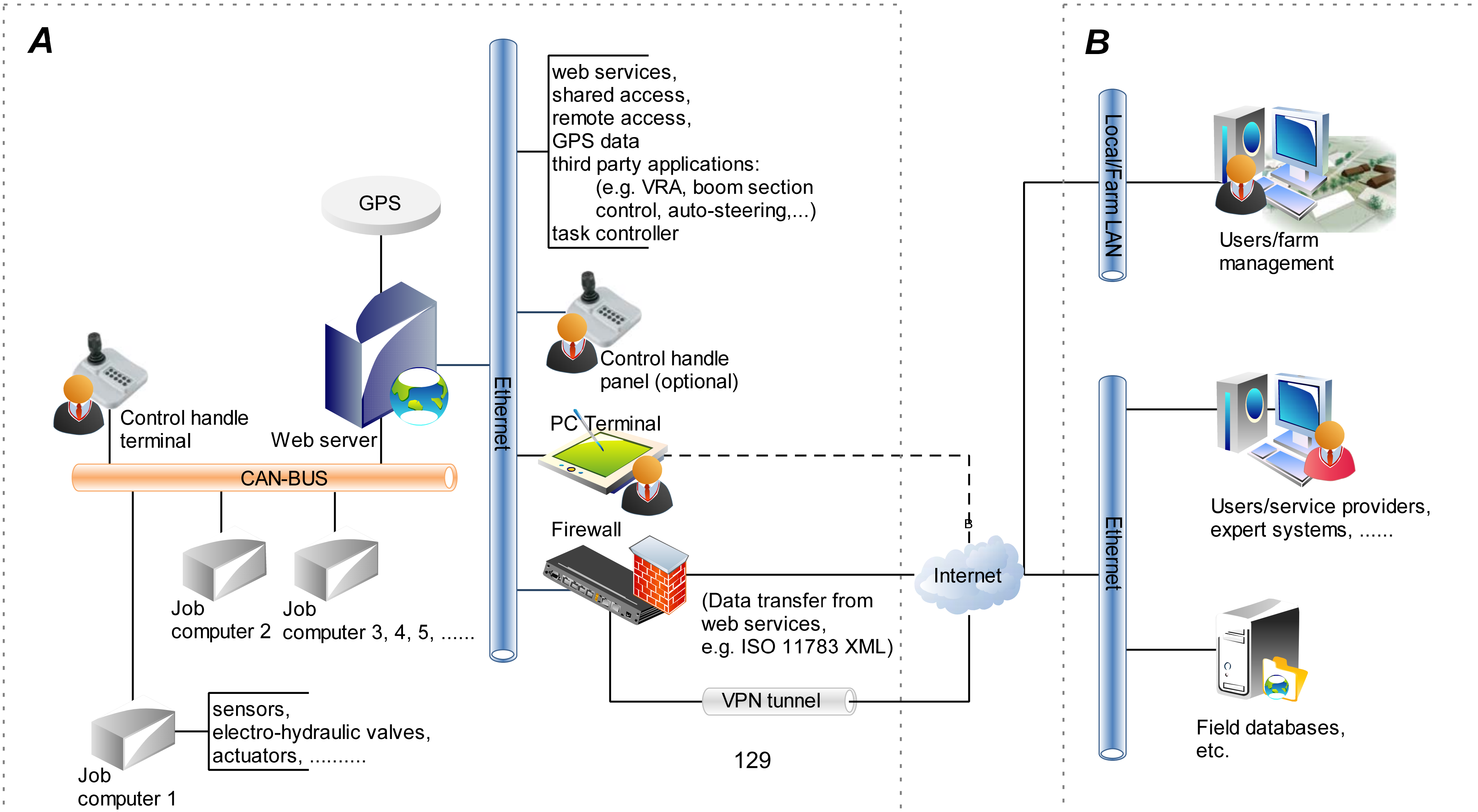
Henrik Lund Jensen, Lykketronic A/S

Morten Allerød, SAMSON AGRO A/S

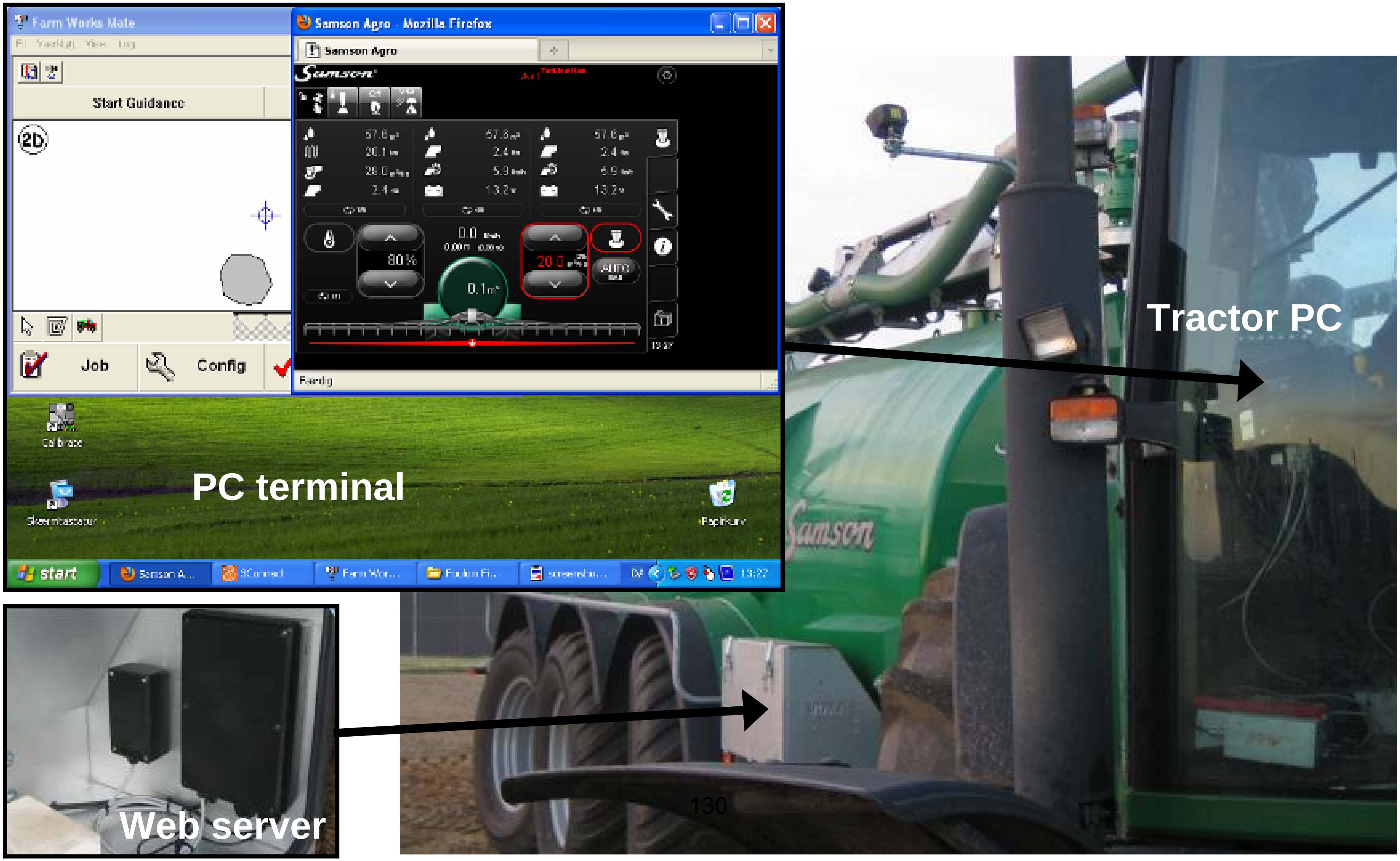
Project background



WebECU architecture tested in project



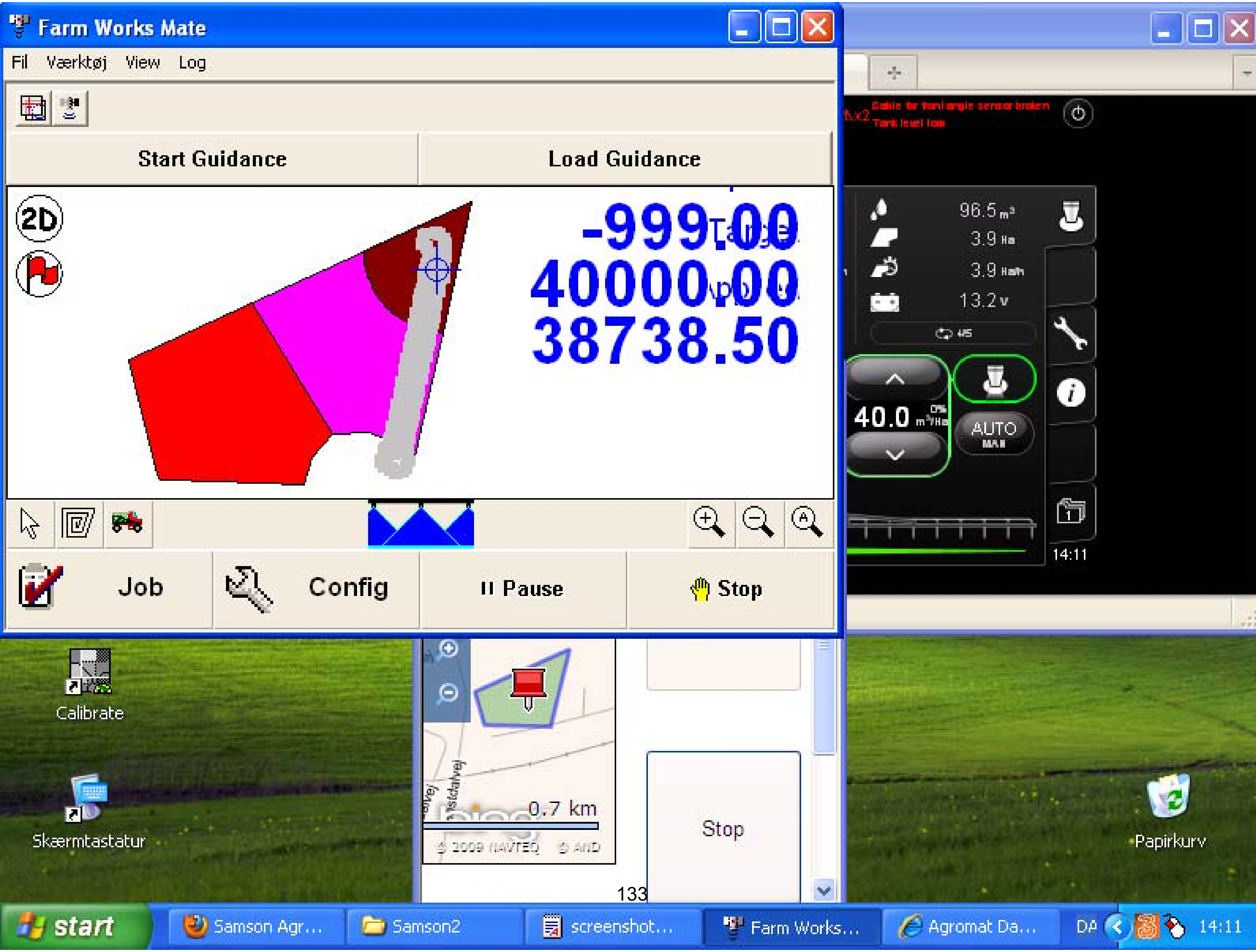
Evaluation of Samson SlurryMaster 7000, SiteMate (TCP/IP), and eDag, December 12th 2009



Samson®
On
Off
1643.3 m3
86.6 km
9.6 m3/Ha
88.7 Ha
D 0:03:46 h:m:s
S 1:56:04 h:m:s
TOT 1:59:50 h:m:s
1643.3 m3
88.7 Ha
15.4 Ha/h
7777.7 V
1/5
2/5
4/5
80%
6.5 Km/h
0.00 m (7.50 m)
2.6 m3/Ha
MAN
AUTO
21.2 m3
1/1
1
14:47

System characteristics

- Linux server,
- CAN-BUS communication between control handles and Web server,
- standard PC as virtual terminal (touch screen, Firefox™ internet browser),
- variable rate control, machine control, third party software on same terminal,
- open choice of PC terminal,
- ISO11783-10 data transfer between the web server and management information databases,
- standard wireless and mobile Internet communication,
- 3rd part software applications on the PC terminal
- full leverage of standard PC architecture and web server technology.


Farm Works Mate
Fil
Værktøj
View
Log
Start Guidance
Load Guidance
2D
-999.00
40000.00
38738.50
Job
Config
Pause
Stop
Tank level low
96.5
3.9
3.9
13.2 v
40.0
AUTO
14:11
Calibrate
Skærmtastatur
Papirkurv
0.7 km
Stop
start
Samson Agr…
Samson2
screenshot…
Farm Works…
Agromat Da…
DA
14:11

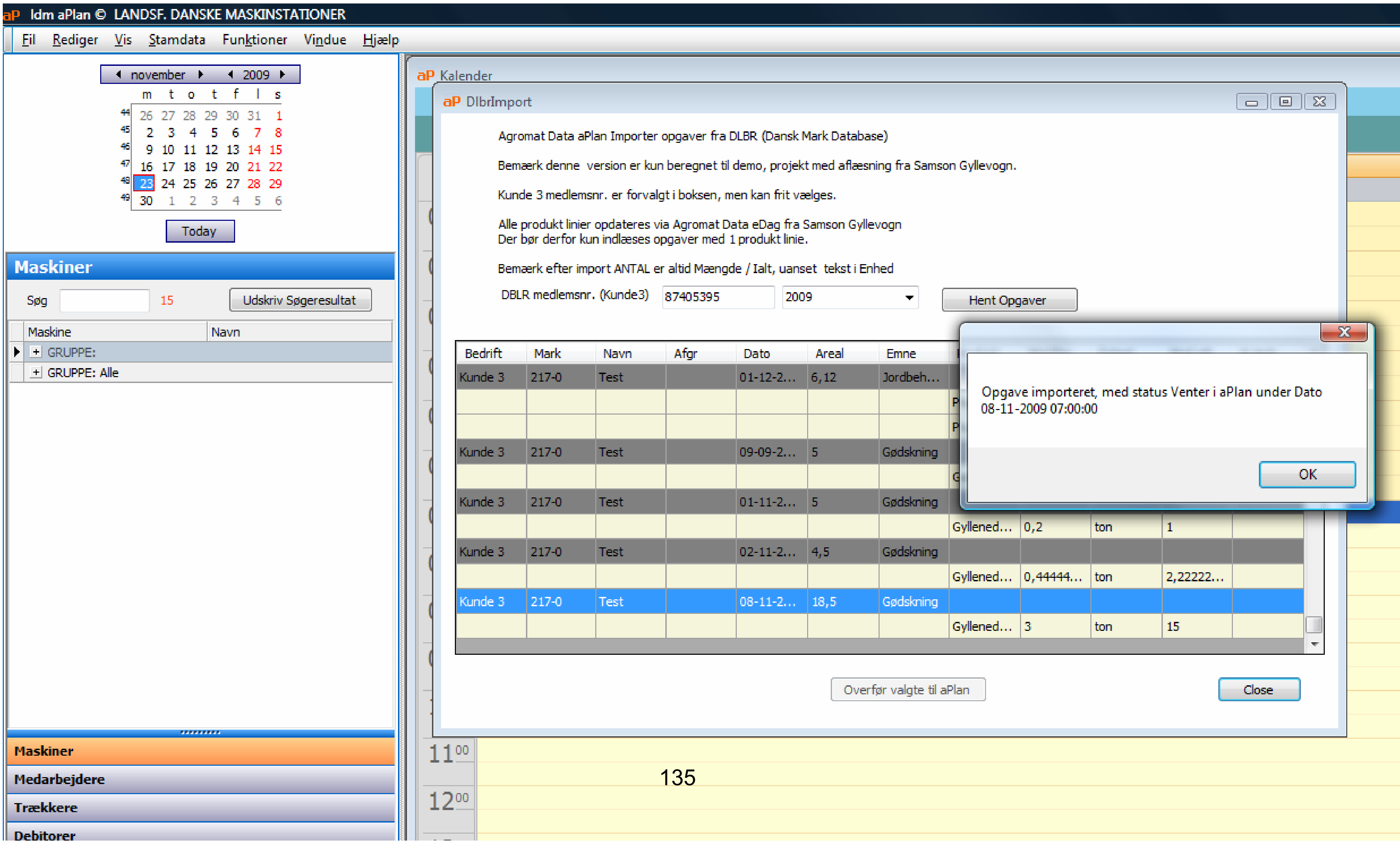
Summary of demonstrated 3rd part applications

- Variable rate application
- Auto-section control
- Task handling and automatic accounting (no geo-data)
- Traceability
- ”Google maps”, route, observations, info by email using existing web services
- Remote service

Not investigated:

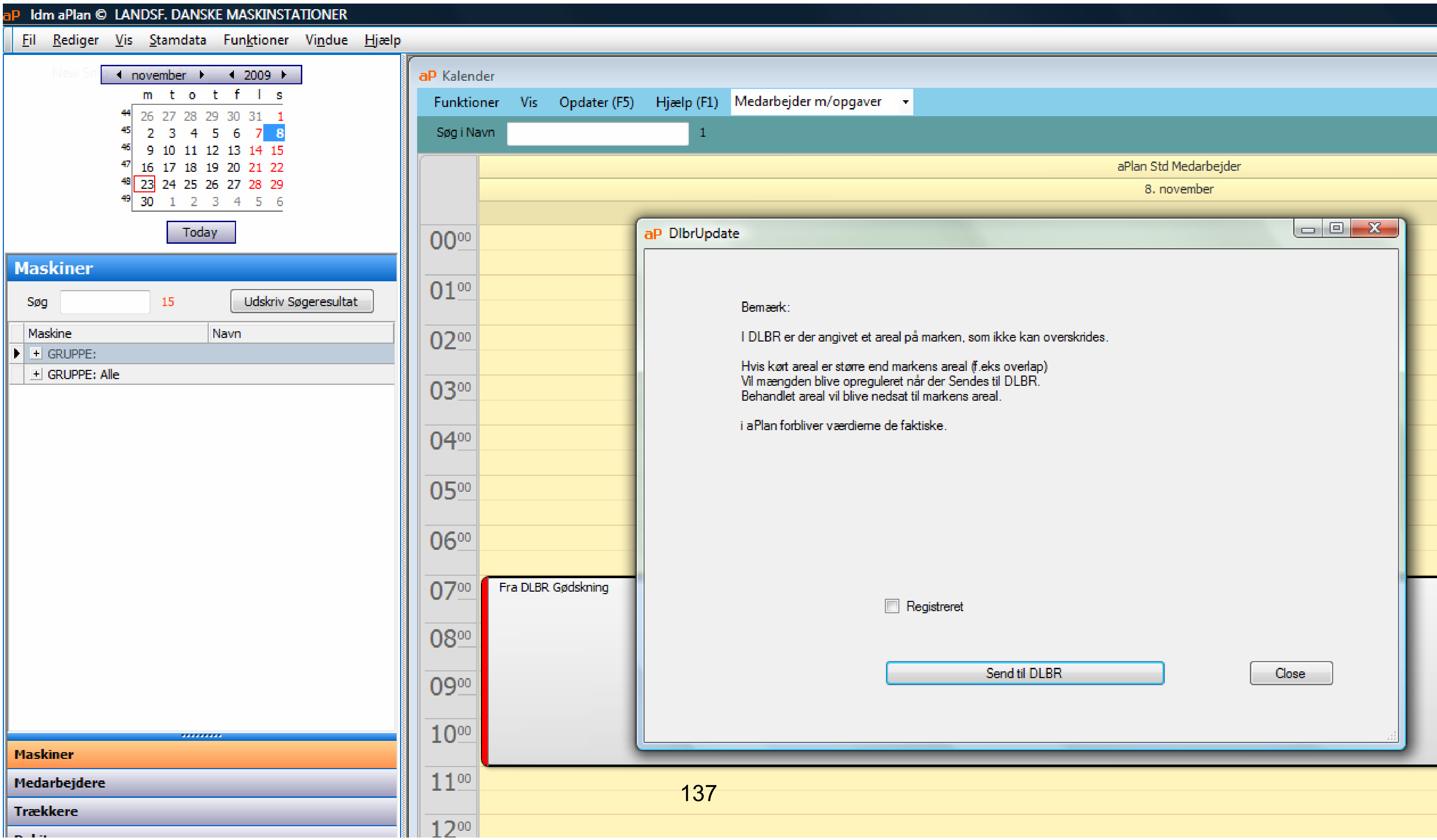
- Fleet management
- Surveillance cameras.
- Simulator
- ……………….

Task controller (aPlan™), office

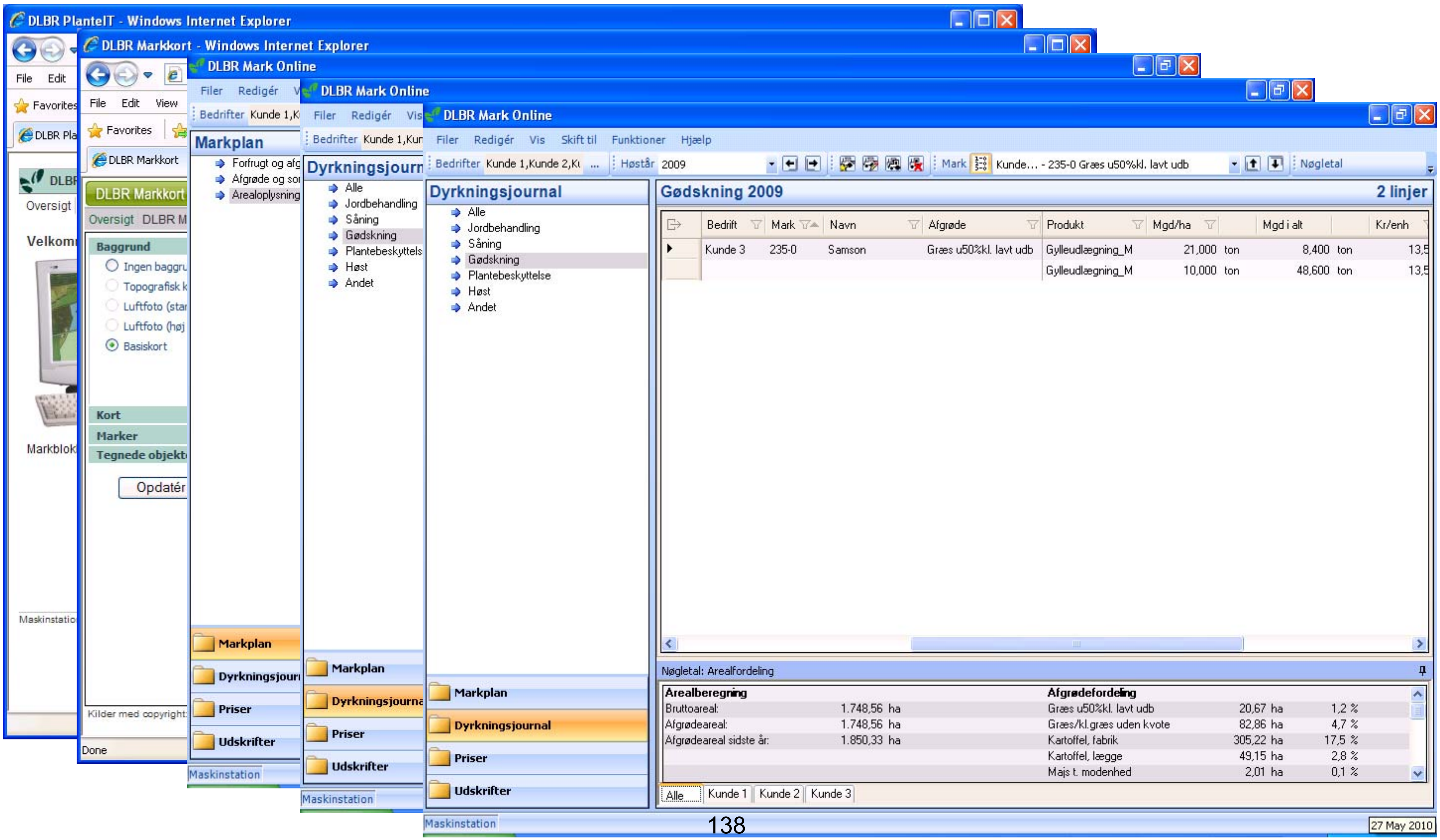


Task controller (aPlan™), tractor PC

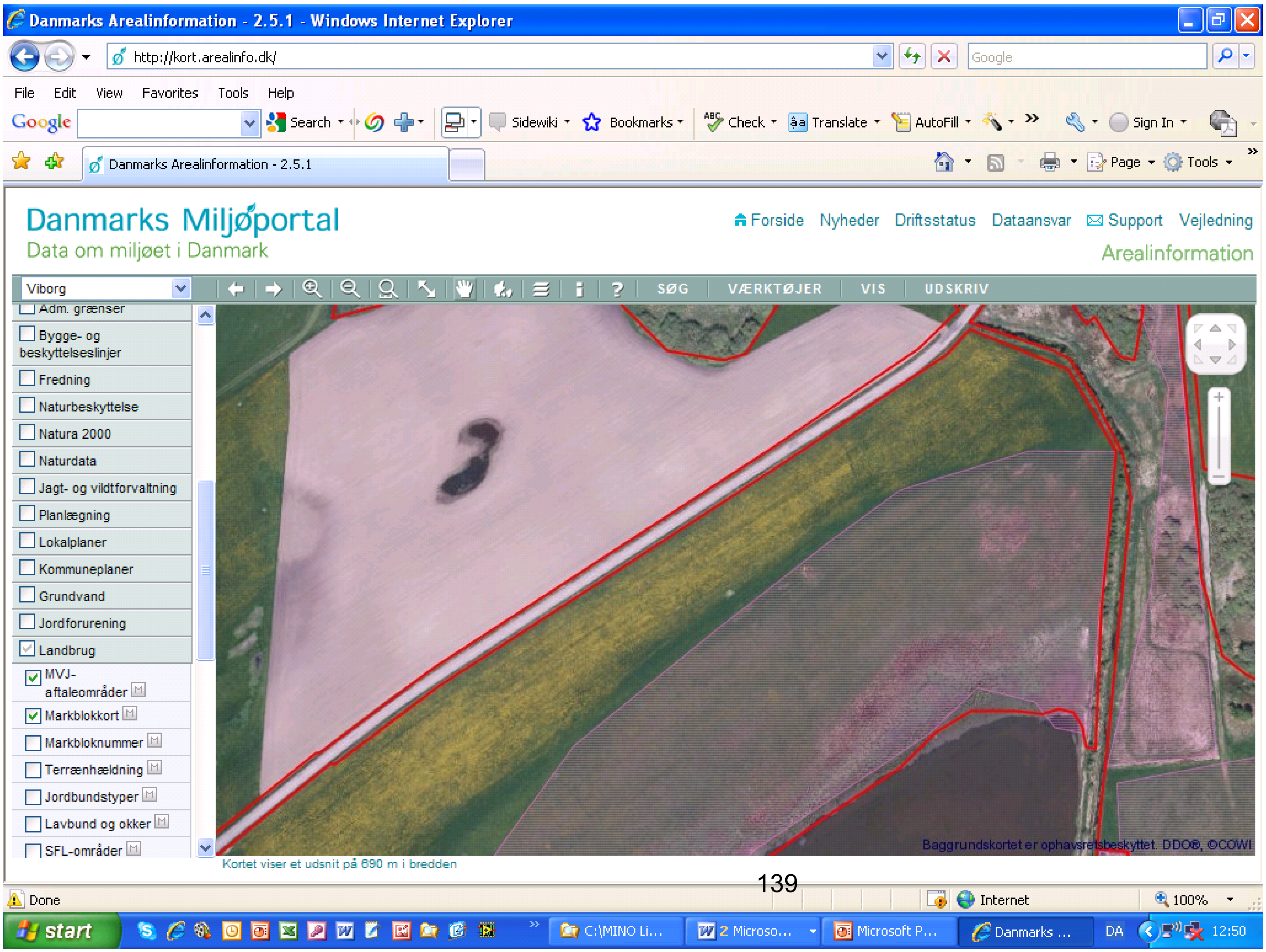
Accounting and traceability (eDag™ & aPlan™), office



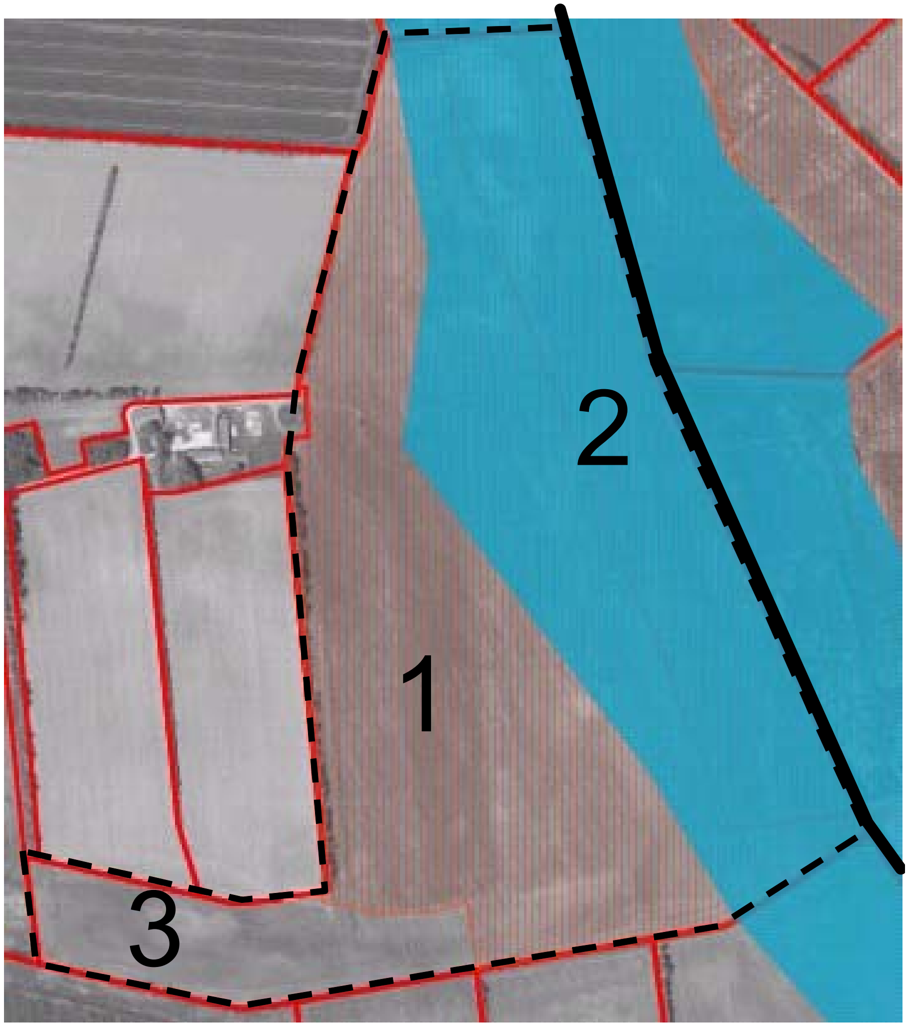
FMIS (Mark-Online™), office



GIS web services for protection of environmental sensitive areas



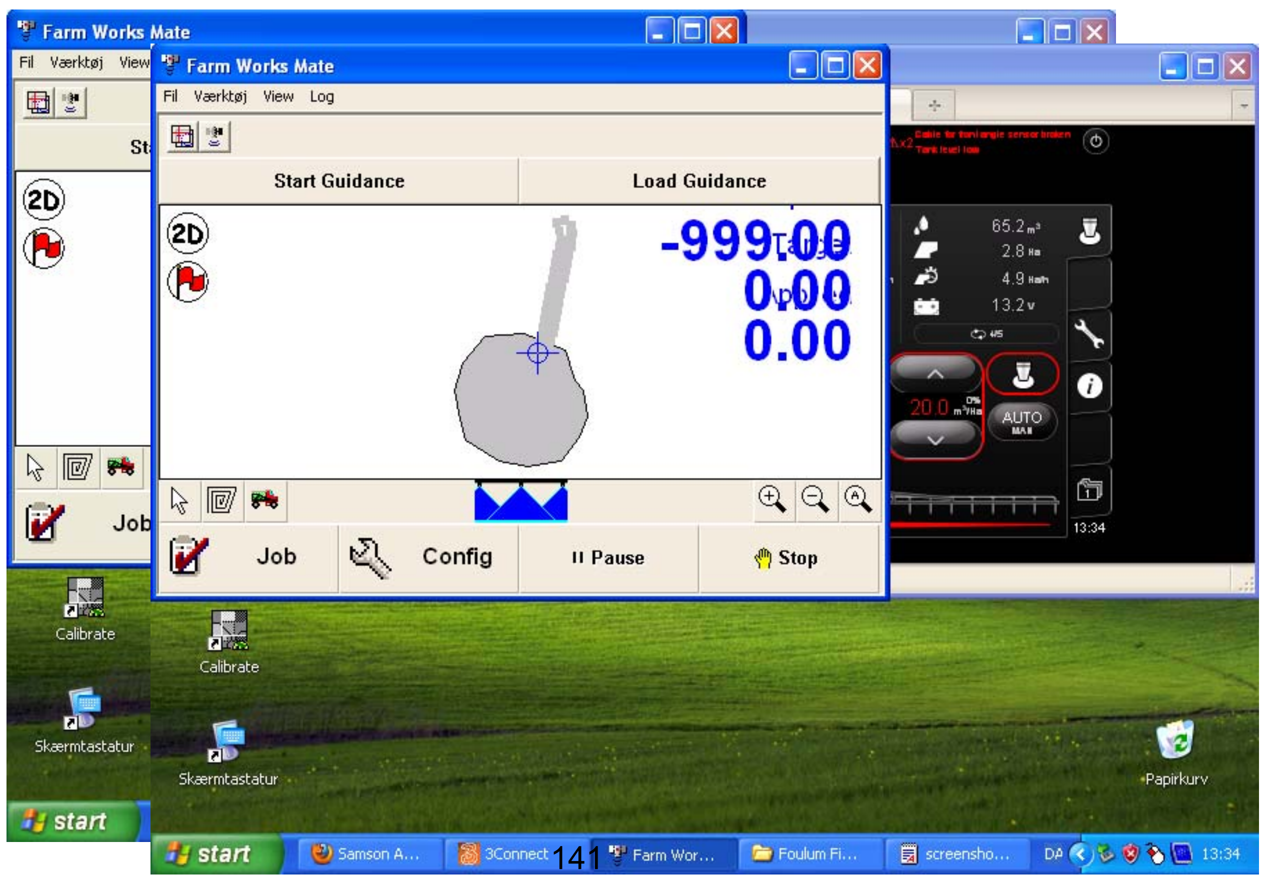
GIS web services for protection of environmental sensitive areas



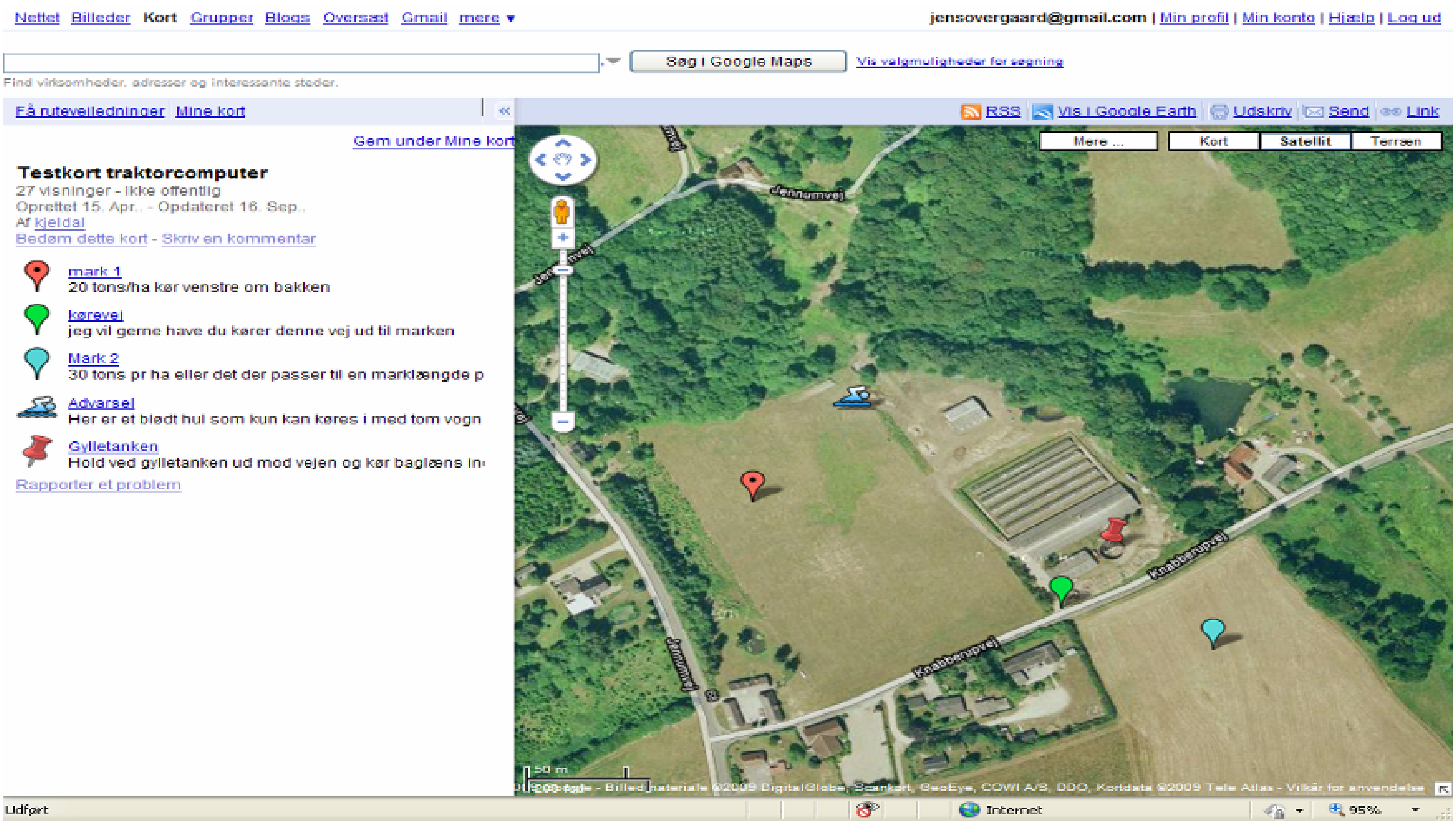
Area 1: SFL-area
Area 2: Wet area
Area 3: Field (dotted linie)

VRA and guidance (Site Mate™), tractor PC

- Download "Shp" files from on-line GIS databases
- Import to modified FarmWorks Site Mate on PC terminal
- Restrict dose rate automatically, VRA



Google map; observations, info by email using existing web services



Conclusions on WebECU’s

Specific conclusions can be pointed out for the solution using web technologies for vehicle and implement distributed electronic control system:

- **Owner benefits from all implements and all tasks on one terminal.**
- **Driver benefits from lots of new features on same terminal.**
- **Time for engineering is saved compared to a sequential development strategy.**
- **Implement manufactures benefit from browser and web servers (standards).**
- **Third parties benefit from easy integration on the terminal and easy read/edit of relevant data.**
- **The PC terminal solution is scalable according to owner and user needs/applications**

Project partners:

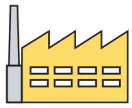
CropInfra
- Production and information management infrastructure for crop production farms

Liisa Pesonen, Pasi Suomi, Raimo Linkolehto, Frederick Teye, Jere Kaivosoja, Ari Ronkainen

MTT Vihti, Tomorrow's Farm program, 2009-2011, contact: liisa.pesonen@mtt.fi

FARMER

► Farm planning



INDUSTRY

► Exchange of basic production data in food chains

SOIL / WEATHER DATA

► Online SOILWEATHER sensor network
► Real-time soil monitoring (Soil Scouts, co-op. University of Helsinki)
► Automated measurement station for surface and sub-drainage field waters

DATABASES

► CropInfra databases
► Other collaboration servers and databases
► Information exchange between the servers
► Requirements for the database structure
► Data quality requirements

ADVISORY / GOVERNMENT

► Services
► eGovernment

REALIZATION

► Automatic documentation of field work data and upload to farm database
► Site-specific control /IECU development
► Task Controller (TC) development

► Update of farm unmanned pulling unit "APU-Module" (co-op. Aalto University)
► Site-specific grass massflow measurement
► Safety of autonomous machines

CropInfra for:
- ► *Research, testing and piloting of new system features*
- ► *Collecting system parts or features from the research and fitting them to the whole farm system*

- ► *Getting feedback for the next research steps*
- ► *Gaining expertise of needed details and the whole farm system*
- ► *Getting firm experience of practical solutions and realistic understanding of the next development steps needed for productising*

- ► *Development support to productising companies*
  - *- expertise in early productising stages*
  - *- tailored tests for performance, connectivity and inter-operability within the whole future oriented system*

Scientific research
- New concepts
- New technology
- *Research collaboration*

CropInfra
- New features in practise
- Continuously evolving
- Pilots & demonstrations
- Interface for companies

Productising support
- Expertise and experience of requirements and realisation
- Tailored tests

CropInfra serves as a research and pilot platform for many projects providing conditions to study and develop smart production environments for farms of tomorrow.

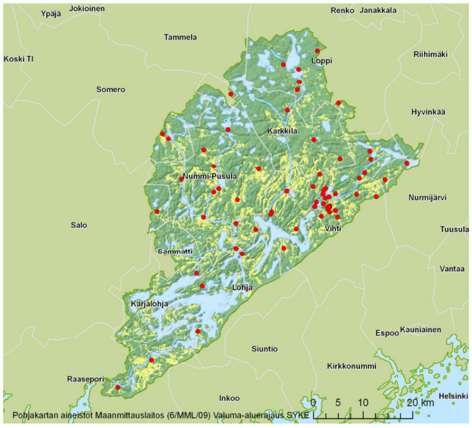
Main focus so far in implementing the infrastructure. Some smart features has been implemented.

In the future, the focus shifts to research and development on smart features in mobile work units and work environment.

SoilWeather: Wireless sensor network at Karjaanjoki river basin Finland

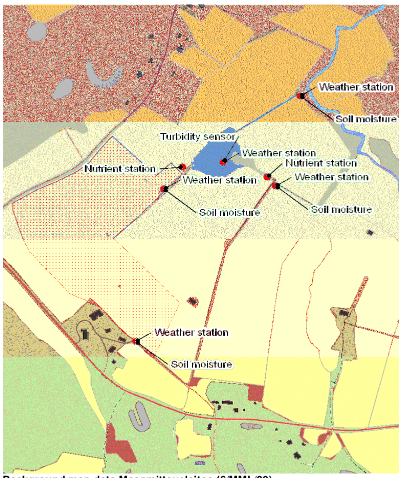
Sensor network

SoilWeather wireless sensor network (WSN) covers entire Karjaanjoki river basin (~ 2000 km²), in Southern Finland. It hosts 69 nodes that monitor local weather (54 nodes), soil moisture (30 nodes), water turbidity (18 nodes) and nitrate concentration (4 nodes). Measurement frequency varies between 15 minutes and one hour.



The data goes through a quality control (DQ) procedure every 24 hours. The QC sends an automatic warning to quality controller for unexpected observations or missing data, and labels the unexpected or clearly flawed data to the database. Sensors are maintained twice a year and according to the alarms produced by DQ procedures. Sensors measuring in the water are also regularly cleaned.

Hovi farm intensive measurement site



Background map data Maanmittauslaitos (6/MML/09)

At hovi farm, the sensors measure at field parcel level and monitor retention efficiency of constructed wetland. At Hovi, there is three Weather stations of which two have also soil moisture sensor, 2 nutrient measurement stations and one turbidity station.

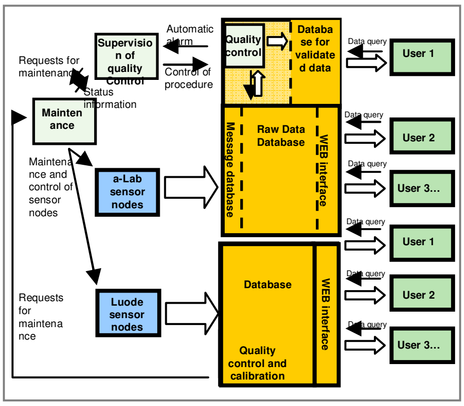
In addition, in one field parcel surface and underdrain nutrient discharge is monitired by turbidity sensor.

Hovi constructed wetland. Photo Janne Vesterinen).

Measured variable	Sensor	Accuracy	Frequency (min)
Air temperature (C)	Pt1000	0,1 C	15 / 30
Humidity (%)	AST2 Vaisala HMP50	0,1 %	15 / 30
Precipitation (mm)	Davis Rain Collector	0,1 mm	15 / 30
Wind direction (degrees)	Davis Anemometer	5 astetta	15 / 30
Wind spped (m/s)	Davis Anemometer	0,1 m/s	15 / 30
Soil moisture (%)	Decagon ECHO (capacitance)	0,1 %	15
Soil moisture (%)	FDR (Frequency Domain Reflectometry)	0,1 %	15
Water turbidity (NTU)	OBS3+	0,1 NTU	15
Water level (cm)	Keller 0.25 bar	0,1 cm	15
Water nitrate concentration (mg/l)	S::can Nitro::lyser	0,1 mg/l	60
Water turbidity (FTU)	S::can Nitro::lyser	1 FTU	60
Water level (cm)	Keller PR36	0,1 cm	60
Water temperature (C)	Luode consulting	0,1 C	60

Measurements and data transfer

SoilWeather WSN provides environemtanl information with high temporal resolution and near-real time all year round. More than 30 000 measuremetns is saved on the data server daily. The sensors are connected to cores that send data wireless through GSM network to the server. The measurement data is availlable for use almost real-time. The data from weather stations are freely available at http://maasaa.a-log.net and at http://testbed.fmi.fi



Sirpa Thessler & Hanna Huitu, MTT Plant Production Research
Background photo: A-lab weather station at Hovi (Janne Vesterinen, MTT)

www.mtt.fi

On-line field-track generation tool

Ibrahim Abd El-Hameed, Dionysis Bochtis, Michael Nørremark, & Claus G. Sørensen

Department of Biosystem Engineering, University of Aarhus, Denmark

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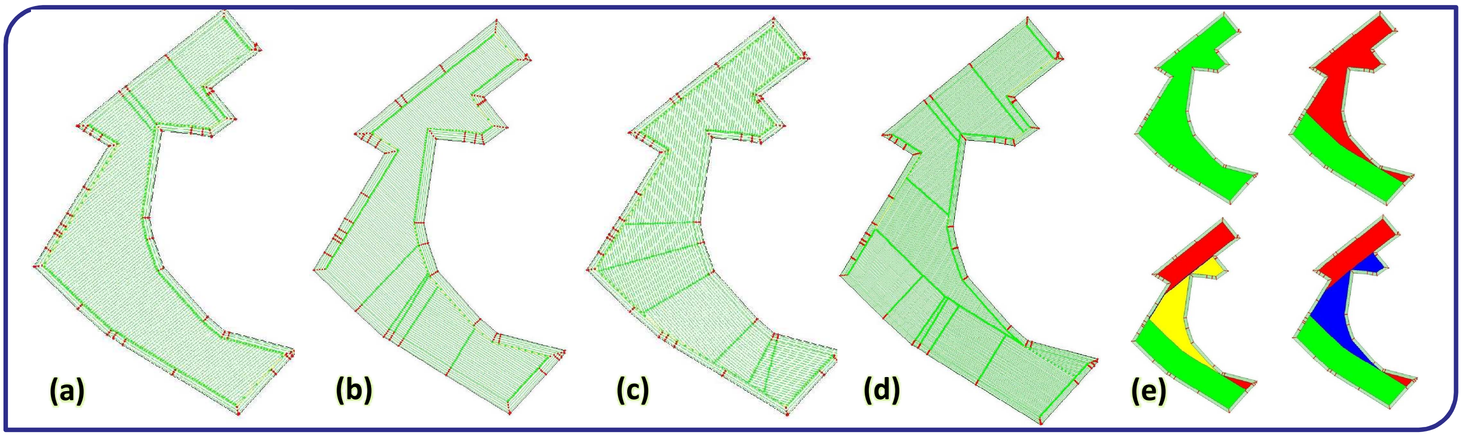
Conclusion

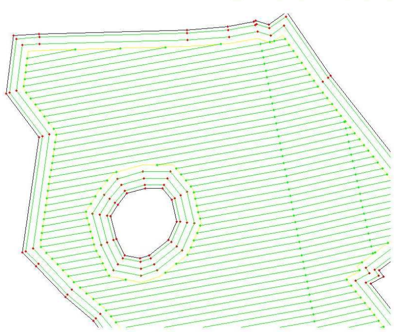
- Fast and on-line algorithm
- Deal with any field shape regardless of complexity and number of obstacles
- A platform for operational planning optimisation

Objective

- Generation of the field tracks as geometrical entities for coverage planning of an auto-steering agricultural vehicle or a field-robot



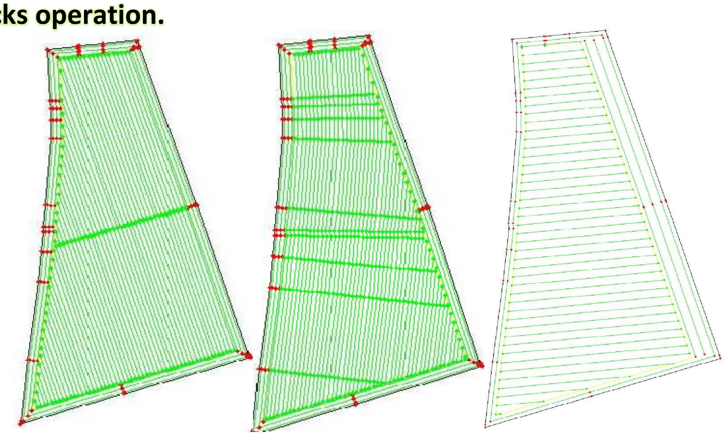
A Field for threshold angle (a) 0°, (b) 20°, (c) 24° (single block), (d) multi-blocks operation and (e) sequence of multi-blocks operation.



A close view of 3 obstacle-headland passes for a machine of 2 m operating width

Inputs

- Field boundary
- Operating width
- Driving direction (optional)
- Number of headland passes
- Threeshold angle for the curved tracks
- Multi/Single-block operation



A Field covered by straight (left), curved (middle) and unequal operation of headlands; one headland pass to its north side and three headland passes to its south

Outputs

- Geometry of tracks
- Geometry of headlands

Future Farm Foulum is a research and demonstration platform supporting national and international projects within the agricultural domain

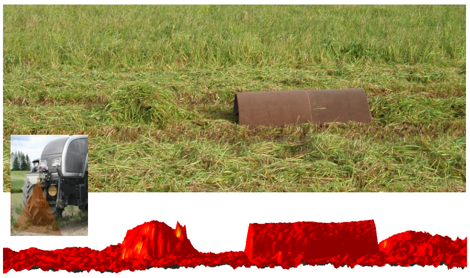
www.FutureFarmFoulum.EU

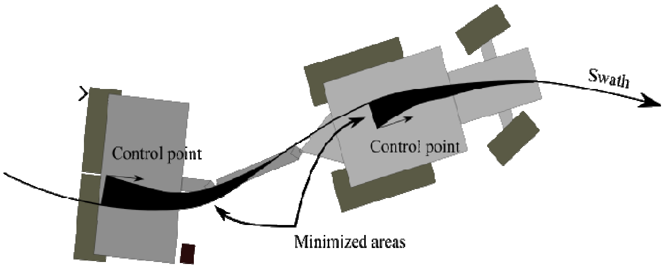
Assisting and Adapting Agricultural Machine

AGROMASSI

The central goal of AGROMASSI project is to develop assisting and adaptive features for the tractor-implement system which will reduce the operator's workload. The project aims at improving the efficiency and precision of the work process on-farm, and ensure optimum application by machines.

- The new features are classified as mechatronic automation and control, management of the driving process, management of the cultivation process and support systems for contract work.
- The intelligent system should be the operator's best friend – it should be a co-driver or a secretary when necessary.





Work Packages

WP 1: Integrated Automation and Control for Tractor-Implement Systems
WP 2: Integrated Navigation for Agricultural Machines
WP 3: Interface Design for Tractor-Implement Systems
WP 4: Appropriate Application of the Productive Inputs
WP 5: Operation Management on the Field
WP 6: Common Tasks for All Work Packages

Research partners

Aalto University School of Science and Technology
MTT Agrifood Research Finland / Plant Production Research
University of Helsinki / Department of Agricultural Sciences

Comppanies

Arctic Machine, Junkkari, Kemira, Parker-Vansco, Potila, Suonentieto, Valio, Valtra, Wapice, Vieskan Metalli

AGROMASSI is part of FIMECC/EFFIMA program.

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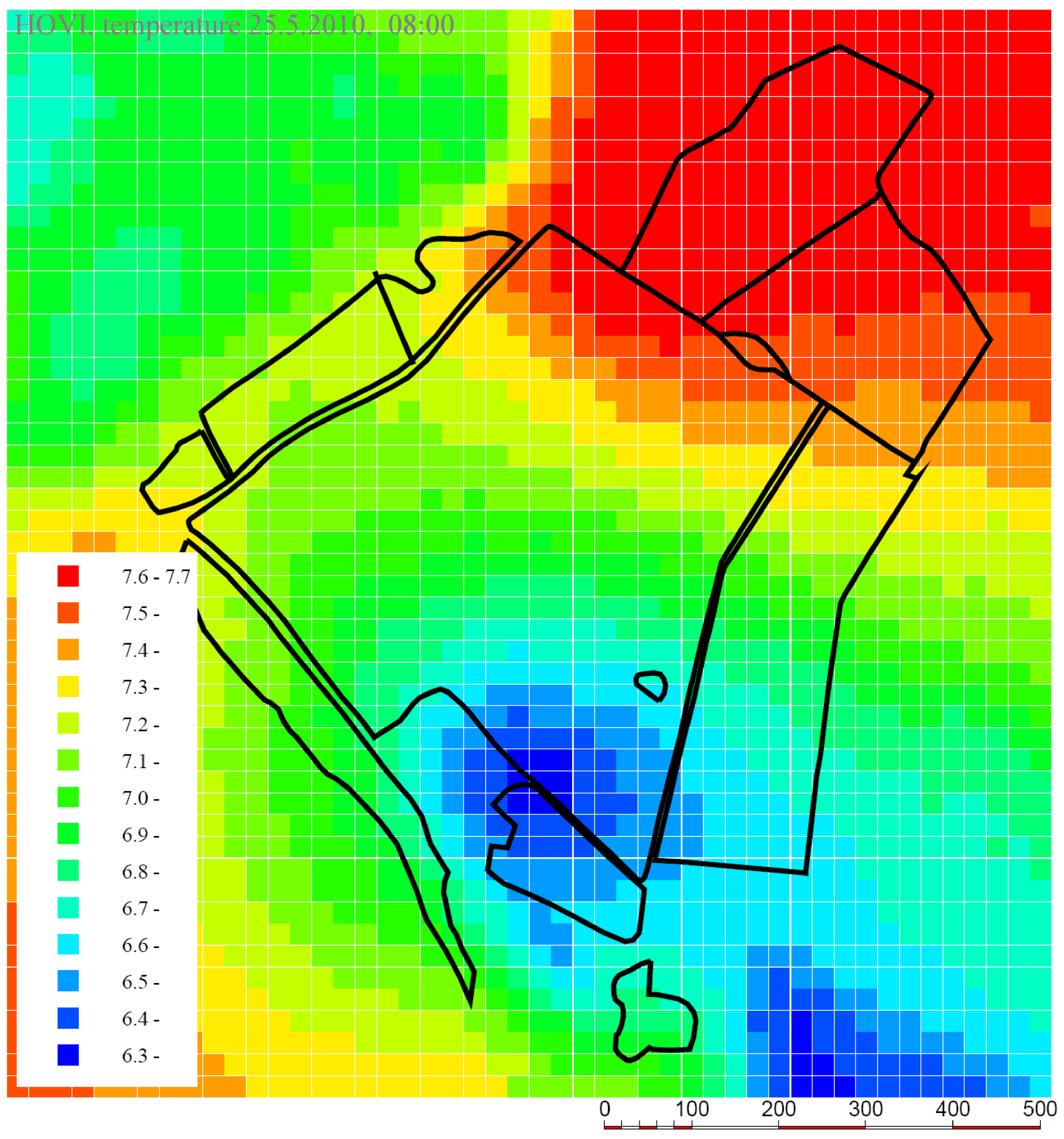
Integration of weather data in precision agriculture spraying



Background

Information of disease forecast and weather forecast in addition to environmental parameters such as wind, temperature and air humidity enables prompt application of plant-protection agents (such as pesticides and fungicides) for disease control.

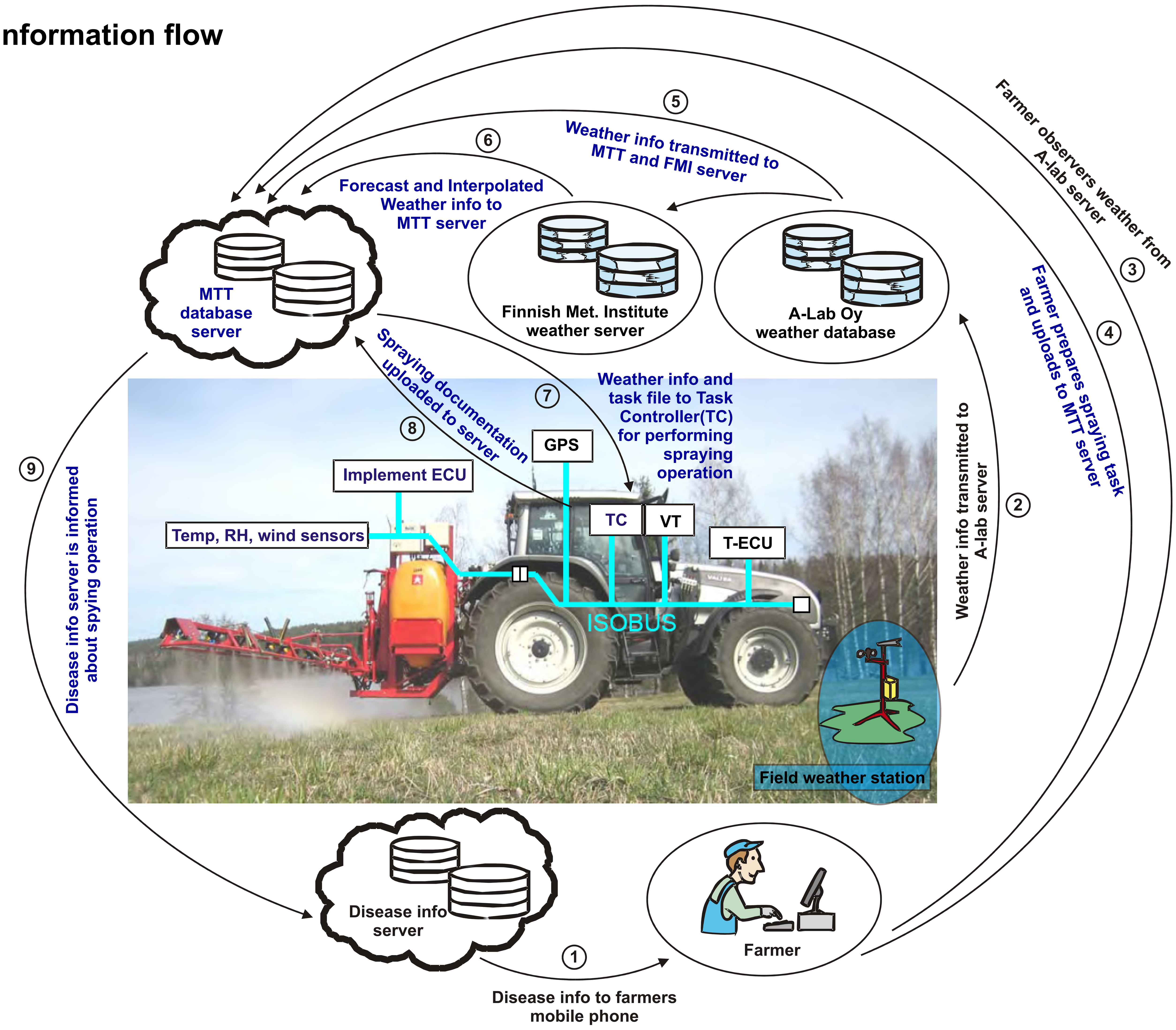
Environmental information can be obtained from the sensors installed on-board the application unit, and weather sensor network located in the vicinity were the field work is being done.

Real-time weather information enables the optimal control of the drop size of fluid and the amount released to improve the efficiency of plant-protection agent application.

Objective

The objective of the work package is to demonstrate the utilization information from SoilWeather network data, weather forecast and disease forecast information to optimise the application of plant protection agents in precision agriculture.

Information flow



Frederick Teye, Pasi Suomi, Raimo Linkolehto, Liisa Pesonen, Jere Kaivosoja
frederick.teye@mtt.fi, MTT Plant Production Research, Crop Production Technology

www.mtt.fi

FACULTY OF AGRICULTURAL SCIENCES
AARHUS UNIVERSITY

FutureFarm

PC and Web server
based vehicle and implement control

Michael Nørremark
[1]Department of Biosystems Engineering, University of Aarhus, Denmark
Michael.Norremark@djf.au.dk, Research Centre Foulum, Blichers Allé 20, DK-8830 Tjele

Objectives:

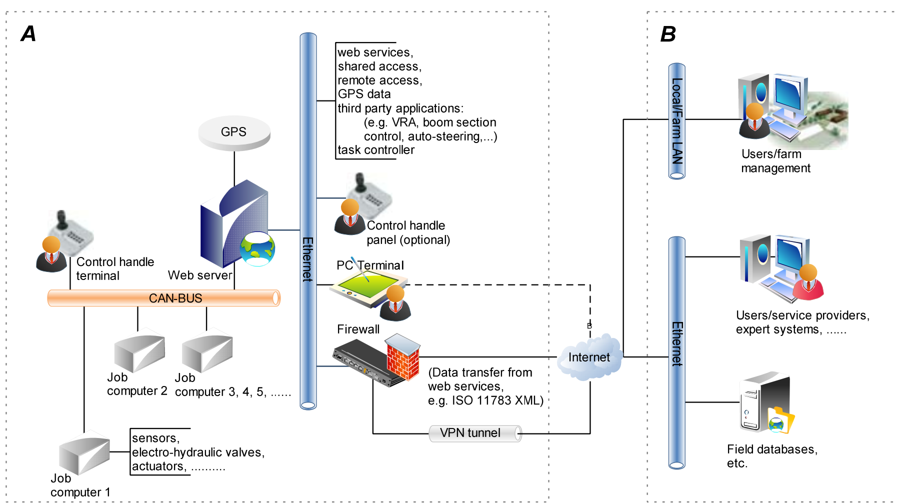
– to develop a web server technology based distributed electronic control system for agricultural vehicles and implements.

– to demonstrate the many possibilities that the system provides for e.g. users, agricultural machine manufactures, and software development companies.

(courtesy of Lykketronic A/S)

System characteristics:

- Linux server,
- CAN-BUS communication between control handles and Web server,
- standard PC as virtual terminal (touch screen, Firefox™ internet browser),
- variable rate control, machine control, third party software on same terminal,
- open choice of PC terminal,
- ISO11783-10 data transfer between the web server and management information databases,
- standard wireless and mobile Internet communication
- full leverage of standard PC architecture and web server technology.



Network diagram for the web server technology based distributed electronic control system (A) and connections to management expert and information systems (B).

Partners:

LYKKETRONIC
Samson
DME
FACULTY OF AGRICULTURAL SCIENCES
AARHUS UNIVERSITY
T&O STELECTRIC
HARDI
Agri Contact
RD
DELTA
Dansk Landbrugsrådgivning
Landscentret

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