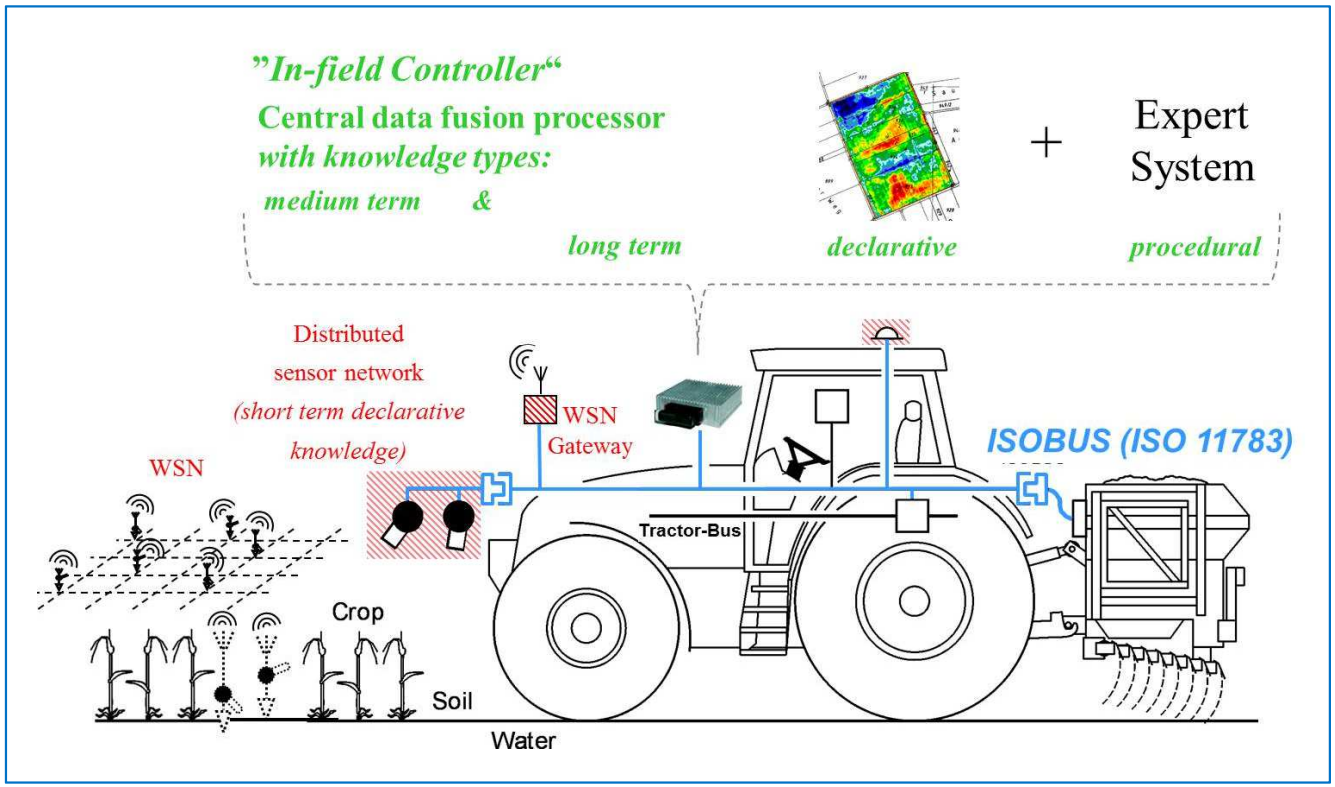
Multisensor data fusion ISOBUS-solution for a sensor based fertilizer application system



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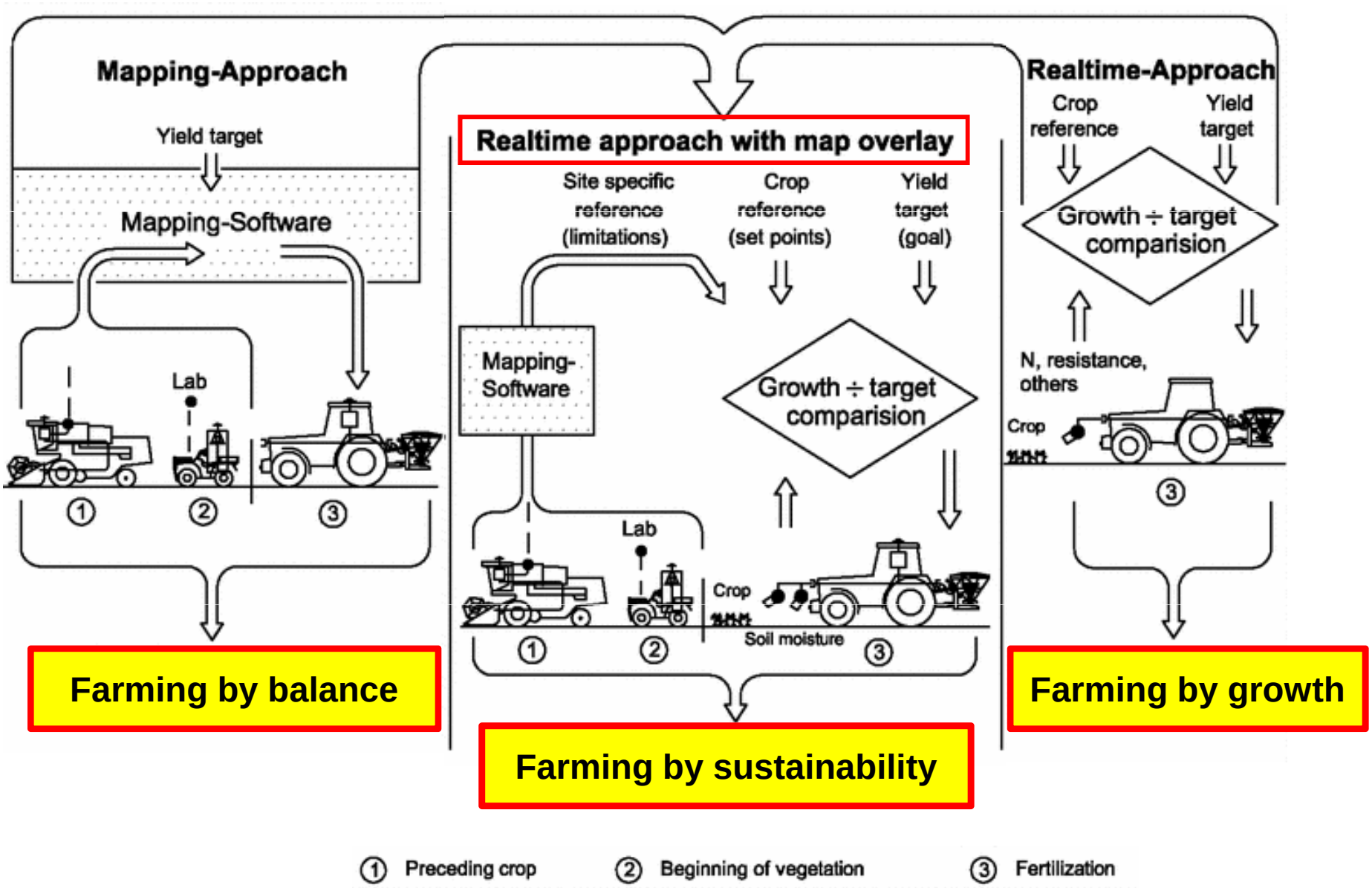
Agenda

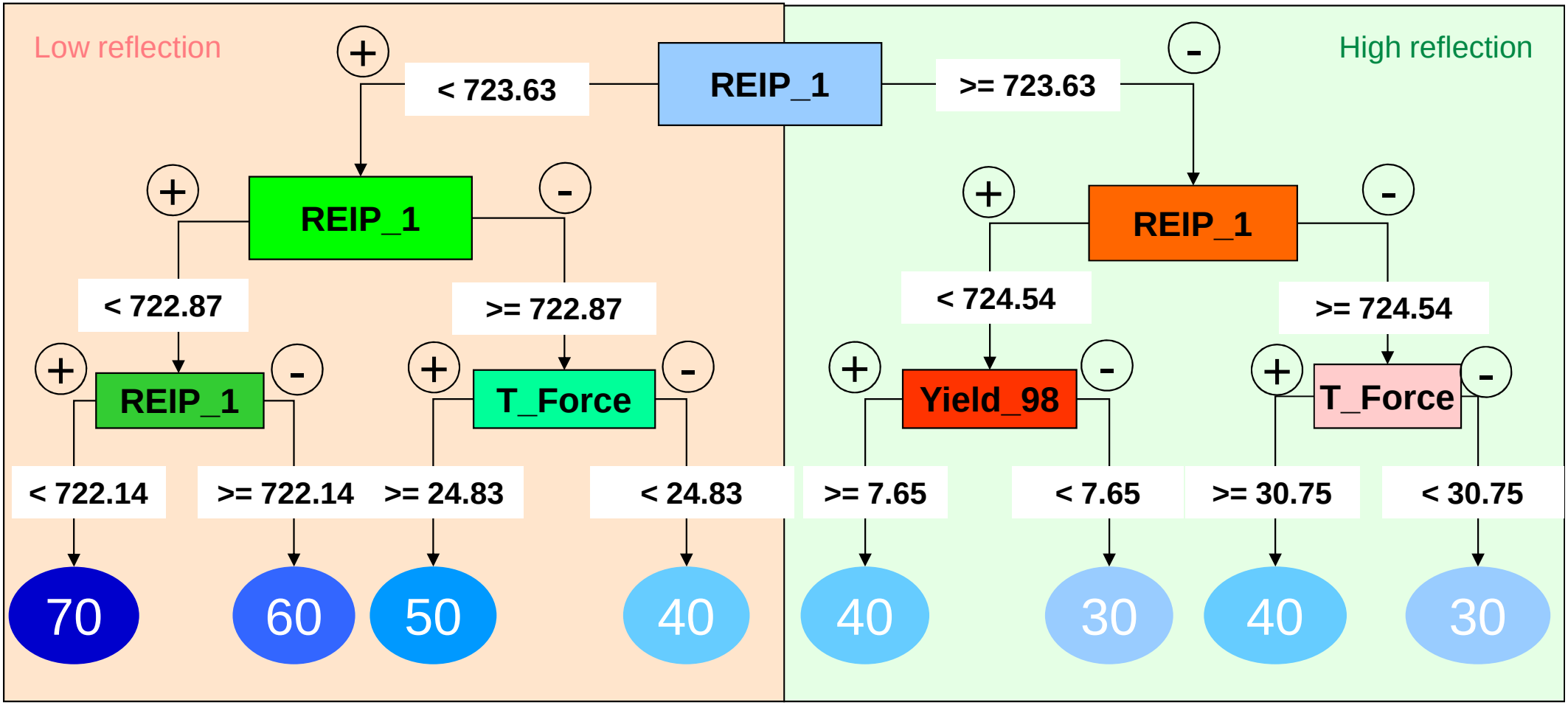
1. Real-time approach with map overlay
2. Objectives
3. Material and methods
   - MSDF (Multisensor Data Fusion) Framework
4. Results
   - Functional model, process model and derivation of MSDF algorithm
   - System architecture and MSDF ISOBUS solution
5. Discussion
6. Summary

System approaches – Process control for mobile application systems



Decision tree for site-specific fertilisation

Nitrogen application, 2nd dressing, by WEIGERT 2005 – established through Data Mining



Required N-fertilisation amount [kg/ha]

(+) Increasing value

(-) Decreasing value

REIP_1	Red Edge Inflection Point after 1st dressing = Present growing situation
T-Force	Soil resistance measured in draft control during tillage → Soil type
Yield_98	Yield map from 1998 → Fertility

Objectives

Thus, three objectives that build upon each other were pursued:

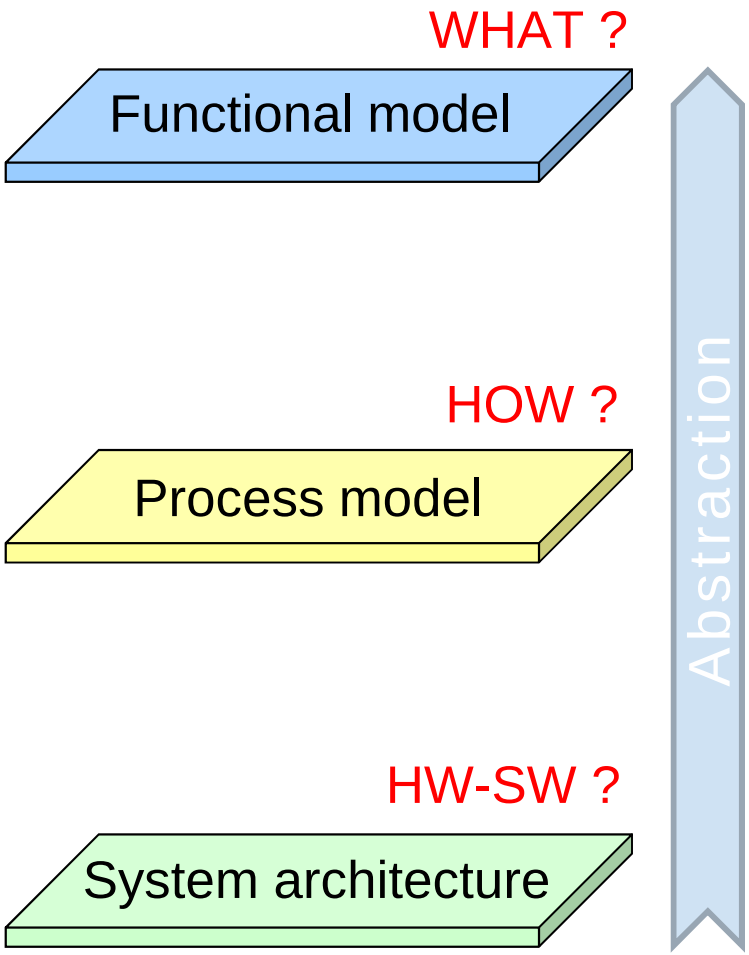
(1) **Derivation of an analysis and design method** for a real-time process control based on **MSDF** in an **Agricultural BUS system**.

(2) **Proof of feasibility** (of the proposed method), facilitation of understanding and **analysis** regarding the **ISOBUS standard** on the basis of the specific use case of a real-time process control for a sensor based fertilizer application system for intensive N fertilization according to the "**Real-time approach with map overlay**" system approach.

(3) **Implementation** of the theoretically derived **MSDF solution** as a **software simulation**.

Material and Methods – MSDF Framework

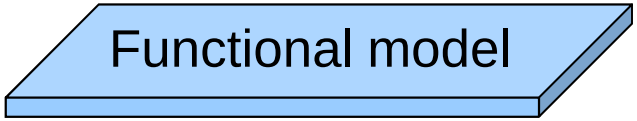
How to analyze, specify and design Multisensor Data Fusion systems?



Results – Functional & process model, MSDF algorithm

How to analyze, specify and design Multisensor Data Fusion systems?

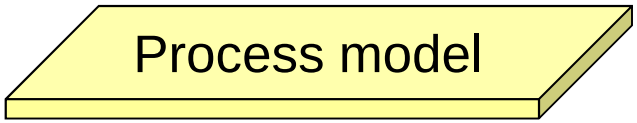
WHAT ?



Revised JDL data fusion model
(1998) (JDL = Joint Directors of Laboratories)

<-> Situation Assessment
(Level 2 Processing)

HOW ?



Fusion algorithm

(Rule based)
Expert System

Canonical problem solving form **IX**

Richard T. Antony
"Principles of Data Fusion Automation" (1995)

HW-SW ?

ISOBUS (ISO 11783)
compliant system architecture

Results – System architecture and MSDF ISOBUS solution

According to Hall and Llinas (2001) three alternatives for data fusion system architectures can be distinguished:

(1) **Direct fusion** of (sensor) data, — **Raw data level**

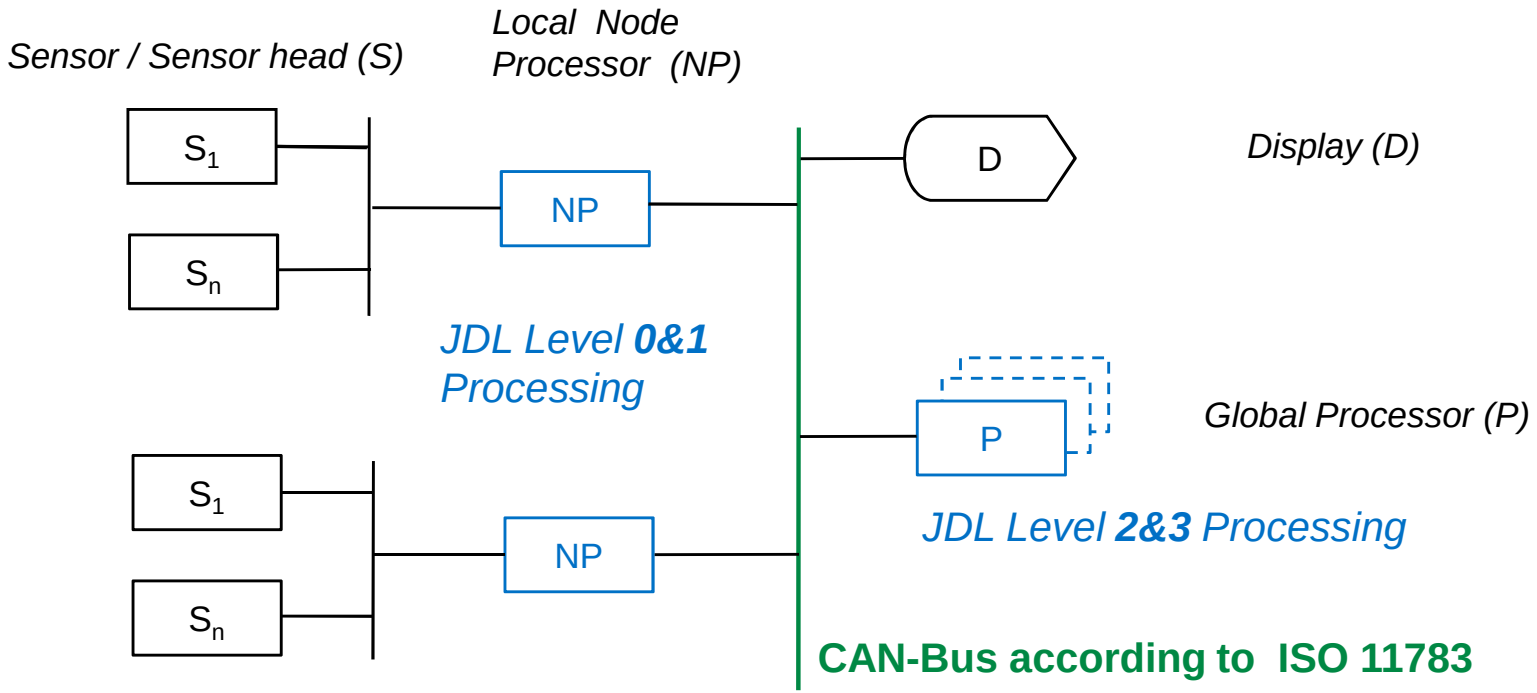
(2) Representation of (sensor) data via feature vectors with subsequent **fusion of feature vectors** — **Feature/State level**

(3) Processing of each sensor to achieve **high level inferences or decisions**, which are subsequently combined. — **Decision level**

Due to **non-commensurate information** sources (see also results of functional model) there is **no fusion at raw data level** possible, but fusion **at feature/state or decision level** is demanded.

Results – System architecture and MSDF ISOBUS solution

System architecture type **“Distributed Sensor/Fusion”** out of the collection of representative MSDF architectures according to Waltz and Llinas (1990) enables the implementation of the “Real-time approach with map overlay” in a mobile Agricultural BUS-System.



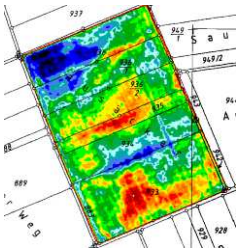
Results – MSDF ISOBUS solution

”In-field Controller“

Central data fusion processor

with knowledge types:

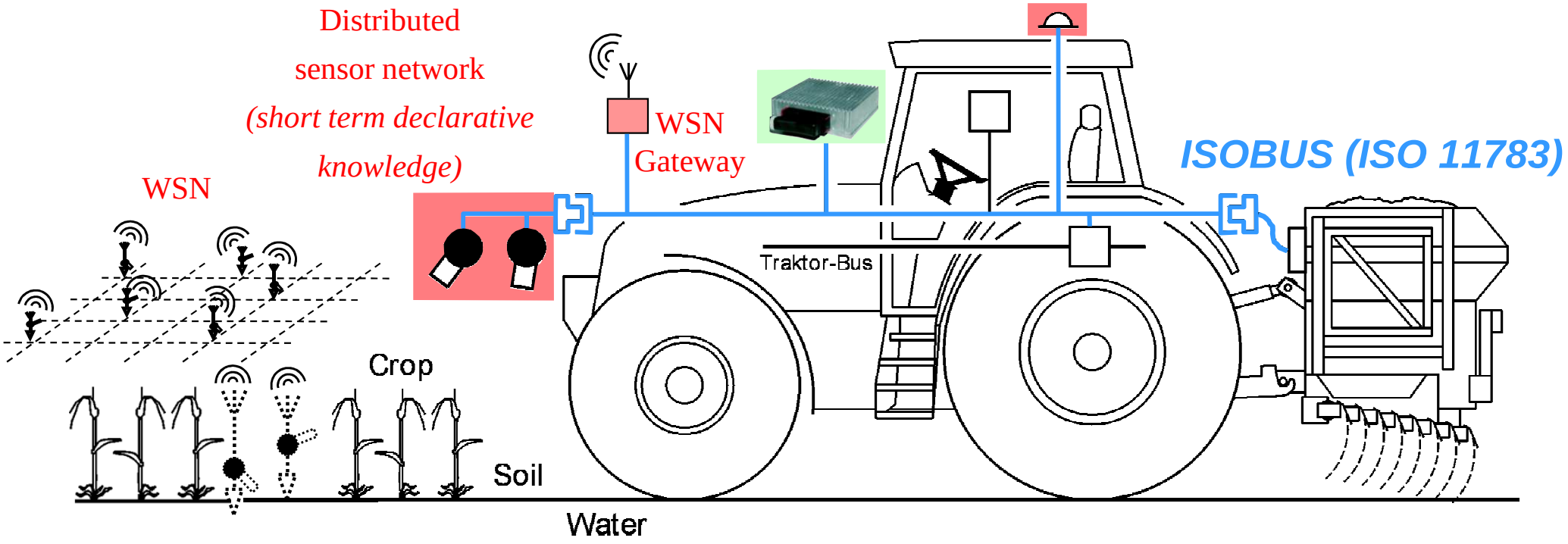
medium term & long term



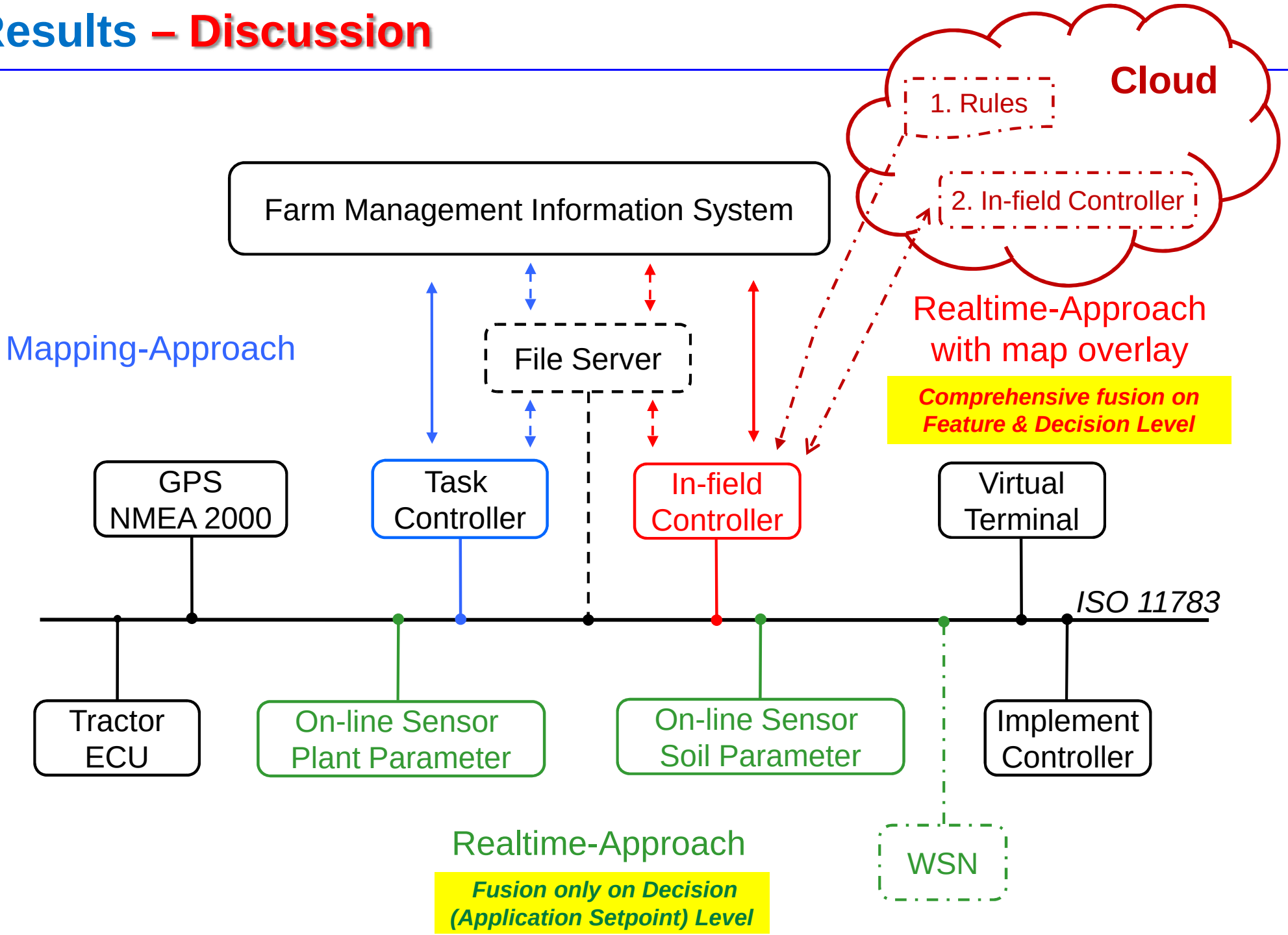
declarative

\+ Expert System

procedural



Results – Discussion



IN-FIELD CONTROLLER (Copyright 2002-2005 TUM/TIP/IKB/Ralph Ostermeier)

EM38
0.001 x mS/m
19.178
35000 30000 25000 20000 15000 10000

Yield98
1 x g/ha
8.980
12000 11000 10000 9000 8000 7000 6000

Tforce
1 x N
29.819
45000 35000 25000 15000

N1
1 x kg/ha
40
120 100 80 60 40 20 0

Limit
1 x kg/ha
11
120 100 80 60 40 20 0

Position
Field: D4
Grid-ID: 81
X: 4
Y: 6

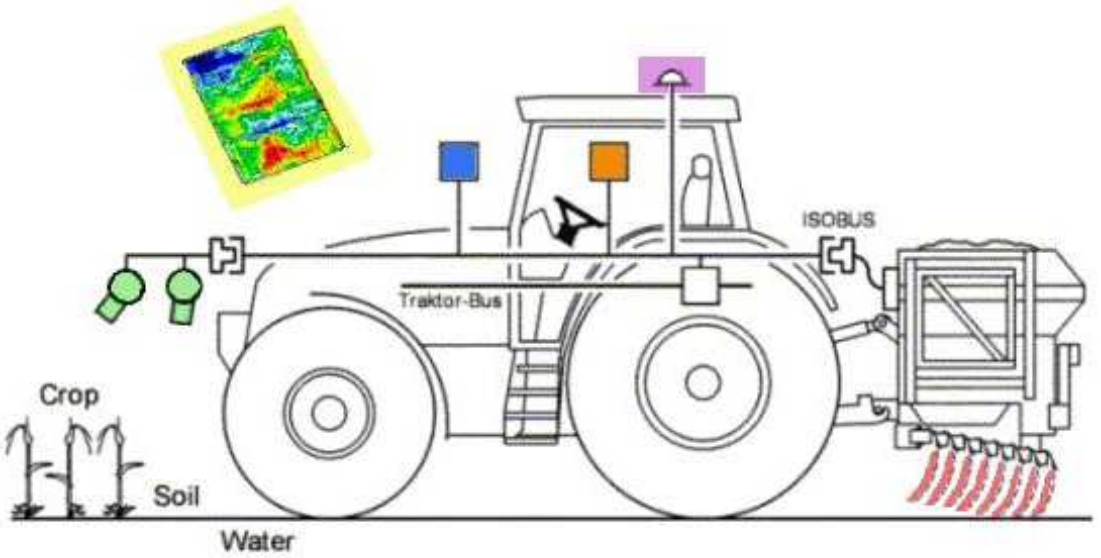
Explanation (SUM_UP & DETAILS)

SUM UP - RUN # 17 :
Nitrogen application setpoint:
> 60 kg/ha since rule < N60-2 >
> environmental limit restricts nitrogen application to 11.0 kg/ha
> selected control mode is < automatically >
> Adjustment factor due to user input: 1.0 [priority: neutral]
> 0.0 kg/ha were already applied for N2
==> results in: 11.0 kg N/ha
Quality Statement:

INFERENCE - Run # 17 :
< start: 1126989180845 stop: 1126989180875 > 30 ms

REIP
0.001 x nm
722.376
725000 724000 723000 722000 721000 720000 719000 718000

HOME



N-setpoint
1 x kg/ha
11
120 100 80 60 40 20 0

User Controls
yes REIP / no REIP
Manuell / Auto
User relative: +/- % 0
User absolute: kg/ha 0

In-field Controller Controls
infer | DB-query | random | start | stop | ON / OFF
read inputs from GUI and activation of inference mechanism

Conclusions

An **integrated analysis and design method** for a real time process control for mobile application systems using **MSDF** has been introduced. The conversion into an **ISOBUS compliant system architecture** which allows the scalable implementation of all three system approaches “Mapping approach”, “Real-time approach” and “Real-time approach with map overlay” was pointed out.

The **approach** is not limited to fertilizer application but **can be applied to other site-specific application systems** for e.g. seeding, spraying and irrigation too.

Extensions of the standard as the **"In-field Controller"**, an additional data element **"Overlay-Map (OMP)"**, the **data exchange** possibility between FMIS and MICS for **long-term explicit procedural knowledge** and new **data dictionary elements for plant, soil and weather attributes** are suggested. Furthermore, the definition of two complementary classes of MSDF node processors for on-line sensors would allow the **integration of wireless sensor networks**.

Open Questions and Outlook

There is no substitute for a good sensor. No amount of data fusion can substitute for a single, accurate sensor that measures the phenomena that you want to observe (Hall and Steinberg, 2001)

From a basic research perspective a need for further investigations can be identified. From a pure control point of view the extension of the investigated **mono-variable to a multi-variable process control** would be of a special basic research interest.

While from a MSDF perspective the exact proof and quantification of **superior performance** and **effectiveness** of a system solution due to applied **MSDF-technique** is one of the most interesting **challenges** of the discipline. Thus, **methods** are highly demanded **how to measure and to assess** the **effectiveness** and **performance** on different data fusion levels.

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