Multisensor Data Fusion Algorithm for a Real-time Process Control for N-fertilization

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Outline

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2. Objectives
3. Materials and Methods
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Introduction
IKB Duernast Integrated Research Project

„Information System Site Specific Crop Management Duernast“

Real-time process control for a sensor based fertilizer application system

R. Ostermeier, H. Auernhammer
Crop Production Engineering

Sub-project 8:

problem solving paradigm: Rule based System (Expert System)
Objectives

1. Formulation of an alternative problem solving paradigm (multisensor data fusion algorithm)

2. Software-Implementation of this problem solving paradigm and integration into the ISOBUS (ISO 11783)
Materials and Methods

Control engineering view

- Expert-Knowledge
- Ecological-economical optimum

Information
"Precision Farming Maps"
On-line sensor technology

Input
Fertilization
Process (System)
Output

Plant, Surrounding

Activation, Control, Feedback
Documentation

State
State
Intervention

(decided according to Auernhammer)
**Multisensor Data Fusion Technology**

"Data Fusion is the process of combining data or information to estimate or predict entity states"

Steinberg and Bowman (2001)
Multisensor Data Fusion Technology

"Data Fusion is the process of combining data or information to estimate or predict entity states"

Steinberg and Bowman (2001)
Multisensor Data Fusion - Functional Model

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

DATA FUSION DOMAIN

Level 0 Processing
Sub-Object Assessment

Level 1 Processing
Object Assessment

Level 2 Processing
Situation Assessment

Level 3 Processing
Impact Assessment

Level 4 Processing
Process Refinement

Database Management System
Support Database
Fusion Database

Human / Computer Interface

SOURCES

EXTERNAL

DISTRIBUTED

LOCAL

Sensors
Documents
People
*
*
*

Data stores

Crop Production Engineering

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Situation Assessment (Level 2 Processing)

- **Diagnose** of current crop and soil condition based on plant and soil attributes, weather

- **Enlargement of solution space**, more detailed “image of the reality”. (yield potential)

- Take **constraints** into account. Environmental protection, operator inputs,

- Estimation and prediction of entity states on the basis of inferred organizational, causal, biological and spatio-temporal relations among the objects:

  - "Comparison" to a model-based perception of a economic and ecological optimum

- Human / Computer Interface

- Level 2 Processing
  - Situation Assessment
- Level 3 Processing
  - Impact Assessment

- Level 4
  - [Diagram with arrows and boxes indicating process flow]
Neural Network

Our brain consists of an enormous amount of neurons and connections between them.

If the neuron gets an electric pulse higher than a certain threshold value, it will fire a pulse.
Artificial Neural Networks

• Create units that will simulate neurons

• Connect them with weights that represent the strength of the connection

• Tune the weights to fit known examples
The Perceptron model

The sigmoid function is used to refine the neuron’s output

\[ V = \sum_{i=0}^{n} w_i \cdot x_i + x_0 \]

Output \[ = \frac{1}{1 + e^{-aV}} \]

X1-X5 = Input signals, X0 and W0=+1 (bias, synapse), W= weights, a= Inclination parameter
The Multi-layer Perceptron Model

Initial tests using a Borland Delphi 6.0 Environment

Using the software Clementine 8.0 for the neural network weights generation

Two Neural Networks (multi-layer perceptron) with two different topologies

(A) Topology 6:2:2:1 with 96% of accuracy and (B) topology 6:3:1 with 94% of accuracy.
Results

The EXCEL table using the weights in the perceptron equation to Calculate the N Predict

The C++ Code using the weights to Calculate the N Predict

The C++ program using the weights to Calculate the N Predict
Integration into Agricultural BUS-System ISOBUS

In-field Controller
central fusion node

Neural Net

distributed sensor network

ISOBUS (ISO 11783)
Initial steps using ISOBUS (ISO 11783) - CAN (Controller Area Network) communication

IsoAgLib - Open Source Project

origin: Achim Spangler, IKB-Duernast sub-project 2 (1998-2001)

http://www.tec.wzw.tum.de/IsoAgLib/

Accessing the CAN card
Conclusions

• An alternative problem solving paradigm (multisensor data fusion algorithm) has been formulated for a process control for nitrogen fertilisation

• The selected problem solving paradigm is a neural network

• Testing with Clementine 8.0 using different neural network topologies showed slightly differences between the outputs accuracy. Nevertheless, very complex neural network topologies with many neurons and layers result in more calculations needing more data processing capability.

• A neural network with a topology “6:2:2:1” has been implemented in Software (C++).
Open Questions and Outlook

The object oriented software development is quite different to procedural programming. IsoAgLib has been updated very often and it was not adapted to Microsoft Visual C++ IDE (Integrated Development Environment) which is necessary for our Vector CANXL-Card. So I have had to spend a lot of time in getting the environment running instead of working on the application.

Compare different Multisensor Data Fusion algorithms (Measures of Performance (MOP) and Measures of Effectiveness (MOE))
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