ALGORITHMS FOR DATA ANALYSIS AND FIRST RESULTS OF AUTOMATIC DATA ACQUISITION WITH GPS AND LBS ON TRACTOR-IMPLEMENT COMBINATIONS

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ABSTRACT

Improved farm management, optimised decision support systems and the trace-ability of farm products require automated acquisition of geo-referenced process data. Using a standardised electronic communication system on the tractor and the implements together with the satellite positioning system GPS affordable and reliable systems can be established. Based on the agricultural BUS System LBS DIN 9684 the implement indicator IMI® serves to identify equipment without own electronics and to run specific measurement programs. A specific task controller programmed with the open source library LBS_{lib} collects data and stores them on a PCMCIA card. To analyse and to aggregate the data collected in such a system, measurement programs on the IMI® and a database application named IMI_{lyzer} were also developed and tested.

INTRODUCTION

Precision farming not only means site specific crop production, but also improved farm management together with decision support systems, optimised fleet management and field robotics with autonomous vehicles. In the present discussion on animal diseases and the use of trans-genetic plants also the trace-ability of agricultural products seems to become important. Therefore detailed data and reports will be more and more necessary in future farm work.

In this context the integration of electronics and information technology into farm machinery opens a high number of possibilities in monitoring and control. That means on modern farm equipment a lot of different values are measured today. Unfortunately most of these data detected on tractors, self propelled and other machines are not collected and stored because they are only used for control processes like the draft force for the electronic hitch control.

Collecting these base data and additional process data together with site information like position and time, the aggregation and analysis of this data will create the base for improved farm management and the trace-ability of farm products.

PROBLEMS

Process data acquisition can serve as base for the above mentioned applications if it can be realised complete and universal for all on farm tractor machinery combinations. Therefore it is necessary to automate it and to use a standardised electronic communication system.

The realisation of the automated acquisition of geo-referenced process information will cause a huge amount of data. Therefore algorithms have to be developed to analyse and aggregate this "raw" data to the needed significant data.

AIMS

Aims of the investigation were to establish a system for automated acquisition of geo-referenced process data based on the satellite positioning system GPS and the standardised electronic communication LBS for tractors and implements and to define algorithms for online and post-processing analysis and aggregation of the collected data.

MATERIALS AND METHODS

The configuration of the electronic devices needed for automated data acquisition is based on the satellite positioning system, the already established electronic communication standard in the "Landwirtschaftliches BUS-System (agricultural bus system) LBS by DIN 9684" and a specially developed "Implement Indicator" IMI®. The system is defined and described in detail by Auernhammer et al. 2000. An example of the typical configuration for automated data acquisition on a tractor during tillage is shown in figure 1:

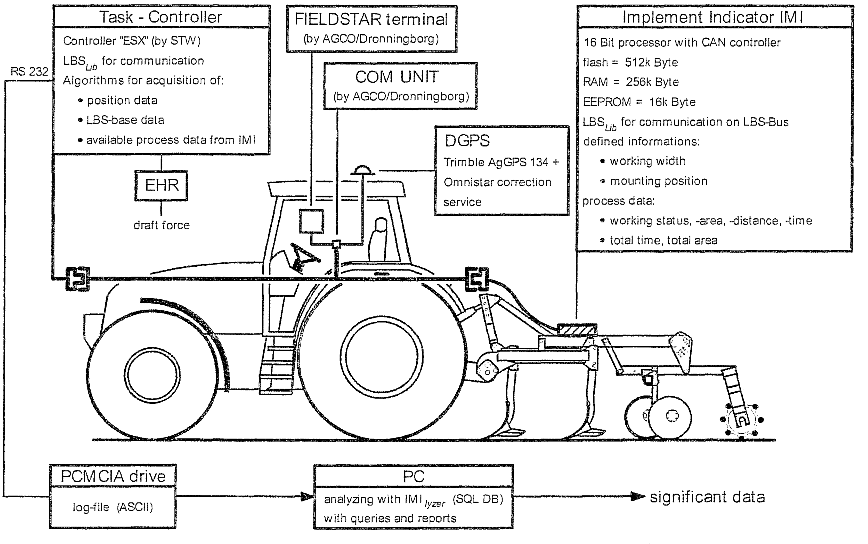

FIGURE 1. System configuration for automated process data acquisition with GPS, LBS and IMI® (Tractor Fendt Favorit 714 Vario with Lemken Smaragd 3 m working width)

The hardware components are completed by data aggregation, data acquisition and data analysis programs working online in the LBS environment or in post processing mode at the farm personal computer.

Data analysing in the LBS environment

The developed and investigate system operates in two different configurations:

In a basic configuration the IMI® only delivers the identification of the used implement together with the information on the mounting location at the tractor (front or rear) and the working width to the LBS. This "low level" IMI® will require post processing data analysis and data aggregation.

In an advanced configuration the IMI® provides specific measurement programs to gain and deliver operation depending process data like real working area, working distance and working time as well as total work time consumption of operation to the LBS system. To identify the different types of area and times and to start, finish or restart the measurement programs when changing fields, the IMI® needs to get information on being in a specific field or being out of it from the task controller.

All data collection is done by an extended LBS "task controller". This controller may also serve to transfer electronic application maps into application set points for the job controllers of spreaders and sprayers. For data acquisition the task controller combines selected base data and process data from the LBS system with position and time from the GPS and writes them in a defined frequency into a file which is typically stored on a PCMCIA card. If the IMI® runs its own measurement programs it will request additional information from the task controller and will send accumulated data for storage back to the task controller. To deliver the information "in field x" or "not in a field" the task controller has to compare the actual position with the stored boundaries of the fields. These procedures are based on similar algorithms like the above mentioned transfer of electronic application maps into set points for the job controller.

In the tractor – implement configurations installed and used on the experimental farm of Duernast all functions of the IMI® and of the task controller relating process data acquisition are programmed using the LBS_{lib} (Spangler et al., 2001). Both data acquisition strategies are realised by using online measurement programmes as well as unfiltered data collecting with post processing types of process data aggregation and analysis using data base functions.

Data analysing in a data base environment

For the post processing analysis of the not pre processed geo-referenced data on a personal computer a SQL data base (Microsoft Access®) was chosen and specific data analysing applications were programmed on that platform.

The data base application is called IMI_{lyzer} and integrates a specific data structure and different calculation models and algorithms.

First all acquired and on PCMCIA cards stored process data are imported into a central table via a specific application based on the Access® text import assistant. Beside this central table there are at least three minor tables which content necessary machinery, farm and field data.

Data analysis and data aggregation itself is done using different combinations of queries and functions. Depending on the sizes and aggregation levels which are needed, data from several fields and columns have to be selected and calculated (figure 2).

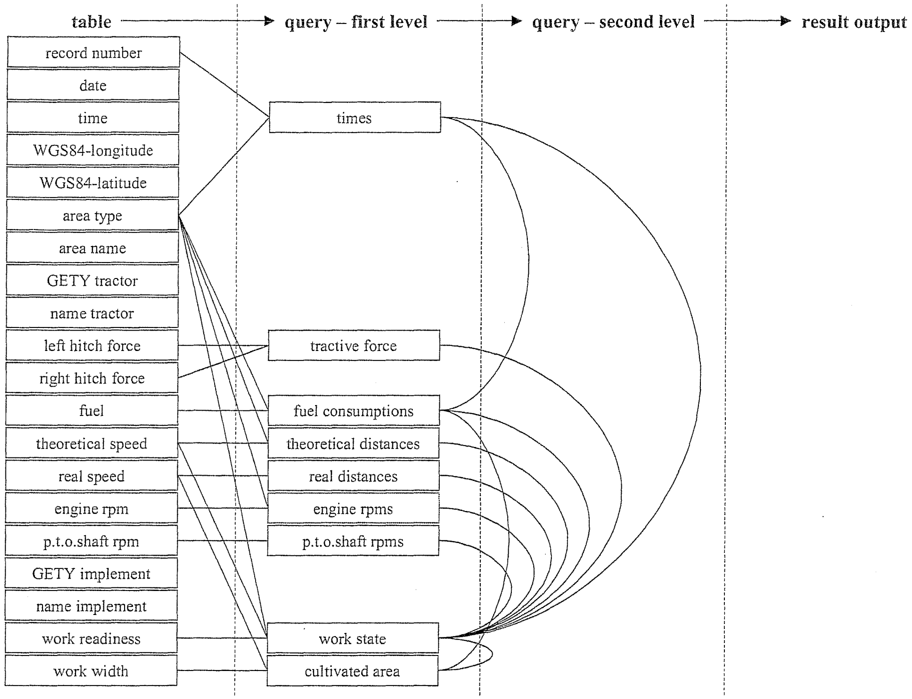

FIGURE 2. Definition of groups and data computation ways based on the acquired data.

The huge number of possible analyses require a clear structure of the resulting values. This was realised by grouping the target values into

- time/path related values,
- machinery related values,
- material related values (seed, fertiliser, fuel,…).

For all values of these categories sums (total, total per field, total per day,..), means (with standard deviations) and classifications can be computed.

The analyses of the three above mentioned groups can be computed related to

- specific tasks or operations,
- specific production procedures,
- specific machines or
- specific fields.

Like mentioned in the description of the online data analysis in the LBS environment the relation to specific fields is realised by using the position data of each data set and comparing them with the boundaries of the fields.

The output reports are generated based on the requirements of the data users and formatted in tables. Field reports, machinery reports and reports for specific operations are the commonly required types.

RESULTS

First results of the analysis of information gathered with an early test version of the online measurement program in the LBS environment using an IMI® and post processing data base programs on the personal computer for the same field work showed identical figures. But it became clear that the post processing analyses gives more freedom to realise different analyses (Table 1).

TABLE 1. Operation statistics of tillage (stubble mulching) of the field Schafhof in August 2000 (production procedure on the field level) based on automated acquired data.

Size	**Absolute figures**	**Relative figures**
Start time	12.33 p.m.	
End time	06.48 p.m.	
Total driven distance (in field)	45 386 m	100 %
Working distance (in field)	39 994 m	88 %
Turning distance (in field)	5 392 m	12 %
Field size (by field boundaries)	10.61 ha	100 %
Cultivated area (by working distance)	11.99 ha	113 %
Total used time (in field)	6.02 h	100 %
Working time (in field)	4.50 h	75 %
Turning time	1.08 h	18 %
Standing/waiting time	0.44 h	7 %
Working speed	Avg. 2.46 ms^{-1}	Sdv. 0.49 ms^{-1}
Draft force (lower linkage)	Avg. 25956 N	Sdv. 8155 N

In this example the relation of working to total driven distances and the relation of working time to total used time in the field will support a process to identify problems with this type of fieldwork and to comment the economic effectiveness of it.

Beside taking the average draft force into account and compare it with other fields or/and tractor equipment combinations, the geo-referenced draft force data which were measured by the electronic hitch control have also been computed with working speed and working depth and delivered input data for an approximated soil resistance map.

CONCLUSIONS

The first tests of the LBS based systems for automated process data acquisition based on GPS and LBS in autumn 2000 and spring 2001 showed that the system configuration is working well and fulfils the defined requirements (Auernhammer et al., 2000).

By parallel running the IMI® based online and the IMI_{lyzer} based post processing types of process data aggregation and analysis the amount of data collected is very high. But to develop and evaluate the algorithms for the online data analysis and aggregation within a LBS environment, the possibilities of the post processing computation of the acquired raw data with the presented data base program IMI_{lyzer} are necessary. Based on the results which data really are required, the number of data collected, stored and transferred can be reduced in future according to the needs of the different users.

ACKNOWLEDGEMENTS

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