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Manufacturer independent system for process and machine data analysis

Within the scope of the Agro-MICoS research project a system to record and visualize agricultural data – independent of the machine manufacturer – is being developed. The data analysis uses geographic position data and CAN data of the machine's network system. The developed system provides data for analysis of agricultural processes. The system itself and results of field tests are presented in this paper. These tests are focusing on machine related data analysis. The results show the potential of Agro-MICoS as an open and machine manufacturer independent data management system.

received 14 April 2014
accepted 11 June 2014

Keywords
CAN-Bus, data analysis, ISOBUS, machine condition monitoring, Precision Farming

Abstract
Landtechnik 69(4), 2014, pp.196–200, 2 figures, 1 table, 6 references

The demands of modern agriculture are rising constantly. In times of green house effect, it is essential to cut down the consumption of resources and for this reason the emission of green house gases. Farmers have to comply with emission limits regulated by law. Furthermore agricultural production processes have to be documented in order to meet product liability acts. Additionally, small and midsized farmers are experiencing an increase in competitive pressure due to the proceeding globalization; the American-European Free Trade Agreement [1] is just one example. Optimized uses of machinery, as well as, a load-dependent maintenance are increasing farmers' competitiveness. This paper introduces a system which is able to document process- and machine data continuously and thus provides the basis for optimization of an agricultural holding.

Agro-MICoS

The joint project Agro-MICoS aims to develop and test a computer aided solution to the problems mentioned above. This solution consists of an economically priced hardware as well as the creation of a proper data infrastructure and analysis algorithms. Thus, the optimizations of many facets of a farm are enabled, for instance the documentation of production processes, the condition monitoring of agricultural machines and the analysis of energy and resource consumption.

Agro-MICoS is above all addressed to small and midsized farmers with a divergent vehicle fleet. Furthermore, the system should be able to do common precision farming tasks for such farmers. The Agro-MICoS project should offer an open platform for creating farmers' own, machine manufacturer-independent evaluation and analysis methods.

The systems components are a data server, developed by our project partner Agri Con GmbH. The data server collects, saves and visualises the data. Another component of the system – the Agro-MICoS box – is an embedded system which is connected to the information network of an agricultural machine. It collects both machine and process data.

In order to improve the data basis for farmers, the system is equipped with several interfaces which make an easy implementation of sensors on a machine possible. The collected data is saved geocoded due to the GPS-interface every box is equipped with. The possibility is given to send all collected information via the mobile communication network to the global data server. Secondly, the data can be transferred via radio, which is completely independent of the mobile communication network or the current cell reception. The radio communication was developed and tested from our predecessor project LaSeKo [2]. The Agro-MICoS box uses Linux as operating system (kernel version 3.4.77) and hence can be easily customized. The hardware of the box was developed by the project partner Logic Way GmbH. It consists of two circuit boards. The first one is carrying the ARM Cortex A8 CPU with a clock of 600 MHz while the second one includes all interfaces.

Concept

The Agro-MICoS box logs, among others, the position and time in an interval of one second. Both acts as reference input for further logged data. It is collected via the CAN interface from the machines bus system. Signals are used primarily for the analysis, which are implemented in accordance with the SAE J1939 and ISO 11783 on the machines.

Machines can be extended with additional sensors. Thus, it is possible to work with the Agro-MICoS system on older machines which do not support CAN bus as well. The extensibility is a big advantage for farmers who still work with outdated machinery and who want to gain the benefits of modern information technology. Therefore the box is equipped with a second CAN interface. As a result, it is ensured that the existing information network is not interfered by additional sensors.

Figure 1 shows the process flow of the system, including all important components and process steps. The database is important for the configuration of the system. It stores all valid and standard-compliant signals detected on the machine bus. This database can be stored locally at the farm or globally on the Internet. In addition, it contains standardized information of all the machines in the farm. The database saves all the information that is necessary for the individual configuration of the Agro-MICoS boxes.

An initial CAN trace has to be recorded for every machine in order to reveal all available signals for a machine specific configuration. The CAN trace is searched for all signals complying with the standards of ISOBUS and SAE J1939. Furthermore it is checked whether the signals are valid or not. Subsequently, all valid signals are added to the database and linked with a specific machine. After the initialisation is complete, a configuration file has to be created. The configuration tool designated for this purpose gets all the necessary information from the database. The configuration file determines the set of logged signals and their pre-processing methods. The pre-processing aims primary to reduce the size of data. Also basic statistical operations are available, for instance, mean or variance. The system is open to implement further evaluation and observation functions that are performed during operation of the machine.

The configuration file specifies the type of data processing during the running operation. The C-program “amcanlogger” does this processing which was developed in this project [3]. It decodes incoming CAN data, logs the current position as well as sensor values. One task of the embedded system is a short term analysis of the received data. The user is able to create his own analysis functions in order to control and analyse the current condition of the machine.

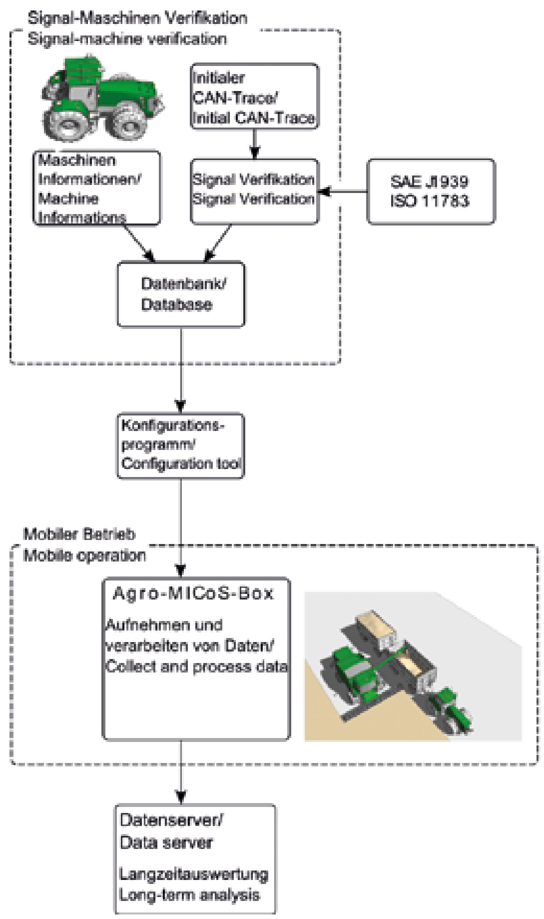
In order to look upon a longer time span the data has to be transferred to the data server. This is done either directly via GSM/HSDPA or via short-range radio data hopping [2] from box to box to a local computer located at the farm. The transmission from the local computer to the Internet and global data server is done afterwards. The data server is responsible for storing and analysing the data over a longer period. Furthermore the server visualises the data in order to provide a user-friendly graphical user interface. In contrast to the Agro-MICoS box, the data server is able to provide analysis over a longer time span from several hours up to a complete season.

Implementation

Since machines from different manufacturers with different and partially unknown CAN signals are added to the system, a short initial CAN trace of the machine is required. Hence, a short Linux-shell script was written. It records a CAN trace in the desired format. The script can be executed by the box or any other Linux computer with a CAN interface. This recording of the CAN data is used as input parameters for the C-program for signal verification. The decision whether a signal is valid is made according to two principles:

1. The J1939 standard defines a general range of validity [4]. If the most significant byte of a signal is less or equal than FA_{16}, the signal is considered as valid. Discrete signals are considered as invalid if their value is 11_2.
2. Additionally, the signals maximal and minimal values are taken into account which is given by the standard too. First,

Fig. 1



Process flow of the Agro-MICoS system

the signal has to be calculated out of the resolution and the offset. If the signal exceeds the given borders, it is invalid. If the value of the signal is considered as valid, the signal is added to the database. It provides a list of valid signals for specific machines. Finally all valid signals of an initial CAN trace can be found in this list.

The database is based on SQLite. It contains information about all the available machines on the farm as well as information about both standards SAE J1939 and ISO 11783. The relationship between machine and valid signals is the most important table of the database. It is estimated by the signal verification tool. Furthermore, the databases stores information about any additional sensors mounted on a machine. As a result, the lack of important CAN messages can be compensated.

The configuration tool for the amcanlogger was written in C++ and the Qt-framework was used. By the use of the platform independent Qt-library the program can be executed under Windows as well as Linux. The configuration tool generates a list of all available signals on a machine. This information is provided by the database. The user is able to select all signals out of the list he wants to log for an analysis. Afterwards, he is able to activate basic statistical or mathematical operations. Beside the calculation of mean or variance, the user is able to define logical operations in order to combine or compare signals. Thus, new information is generated. In the simplest case, the configuration consists just out of several CAN signals. Additionally, it could contain the type of signal processing. As mentioned above, the processing possibilities are reaching from basic statistical operation to logical operations.

In order to cover as many machines as possible, all defined operations should use common signals. The fuel rate [l/h] or the engine speed [1/min] was detected on almost every examined machine during the initial measurements. Furthermore, the GPS-position is provided by the box. Moreover the acceleration and the velocity can be estimated out of the position data. For instance, the fuel rate represents the energy consumption for a specific task and is therefore and is therefore important for the economic evaluation of different machines.

The developed system enables the creation of CAN-based individual analysis and evaluation functions for agricultural machines. Depending on the user's subject and level of knowledge, he can focus on the analysis of harvest data, energy consumption or machine data. The configuration tool allows saving and restoring configurations which have proved to be successful. These configurations can be used for other machines too, in case the same CAN-messages are available.

Results

In collaboration with TU Dresden some machines of the chair Agrarsystemtechnik as well as machines from a field-test partner have been included to the database. Furthermore, CAN bus signals have been recorded and analysed in order to extract all valid signals of those machines.

Table 1

Mapping of the engine load

Motorlast [%] ***Engine load [%]***	**Bedeutung** ***Meaning***
0–25	kleine Last/*low load*
25–60	mittlere Last/*middle load*
60–90	hohe Last/*high load*
90–125	Volllast/*full load*

Fig. 2

Logged engine load data of a John Deere 8360R

The field tests have been executed in April 2014 on a mid-sized farm in Saxony. One focus during these tests was the implementation and validation of an automatic condition monitoring. As an example a function that classifies the load in different states has been developed according to von Toll [5]. The source signal for the function is the engine load in percent from the standard of SAE J1939 [4]. The engine load signal is available on almost every examined machine. The following load states have been created within the configuration tool (**Table 1**). Subsequently, the created configuration file was transferred to the Agro-MICoS box. The box was mounted at a John Deere 8360R. The log files were transmitted via GSM to a server and afterwards copied into the data server of our project partner Agri Con in order to visualise the results (**Figure 2**).

Several conclusions can be drawn out of the collected data. According to von Toll [5] the data can be evaluated if a machine is suitable for a specific task. The recognition, if a machine is either under- or over-powered for a task, can be automated. As a result, several negative aspects are made visible like high wear or high fuel consumption. Additionally, the load of the machine is georeferenced. **Figure 2** shows a John Deere 8360R with a harrow as add-on device. The machines load is low while entering the field. In contrast to that the machine works more often with full load on the left hand side of the field.

The advantage of mapping CAN-signals in ranges is not only the data compression but also to visualise complex processes in an intuitive way. Furthermore, it is a preparation for the creation of histograms as well as load-dependent operation hour's accumulation.

Another advantage of the Agro-MICoS system is time in saving sophisticated post-processing. Since the the signal is logged in a decoded format, it does not have to be decoded from the raw CAN frame. Additionally, statistical operations can be executed during the process of logging.

Prospect

One example about getting additional information out of very common CAN signals is the identification of the working state of a harvester. This is possible by combining the actual fuel rate and the actual vehicle speed, without assembling further sensors.

If there is a typical harvesting speed and a minimum fuel rate for operation condition, it is possible to count operating hours of the chopper or threshing mechanism. While the machine is consuming more fuel compared to the minimum fuel rate and the speed is typical for the operation, the operating hours of the chopper or threshing mechanism can be counted. Furthermore, the operation hours can be weighted by the power output of the engine. A benefit of this evaluation is that the system operates after the setup without the upkeep of field edges or the like.

If there is further information of the machines network available – like the actual pressure of the pneumatic system – it is possible to apply additional condition monitoring functions. The pneumatic pressure is governed by the machine in the operating range. The maintainer of the machine is also interested whether the machine is operating effectively, for example if the pneumatic system of the machine is dense in the tolerance range. This information can on one hand be used to increase the lifespan of the pneumatic pump, and on the other hand, save energy for air compression.

Conclusion

The developed system is able to analyse and illustrate agricultural process- and machine data. The user is able to create his own analysis and monitoring functions. Due to the configuration process and the usage of amcanlogger, there is no CAN data post processing necessary. Additionally, the user has an overview of a range of standardised signals, such as the SAE J1939 and the ISOBUS for the development of further analysis.

The primary usage is the analysis of machine data, as shown in the results. Further usage, according to von Toll [6], include the analysis of energetic data like the fuel consumption and the analysis of the agricultural process chain and its consumption of resources.

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Acknowledgments

Our thanks go to the funding sources of the Agro-MICOS project (grant number: 10040641), the Federal Agency for Agriculture and Food and the Ministry of Food and Agriculture. Furthermore, we want to thank our colleagues and partners of the Chair Agricultural Technology at the Technical University of Dresden, led by Jens Teichmann, who organized our field tests. We also would like to thank our project partners Logic Way and Agri Con for productive cooperation.