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Modelling of Tractor Implement Combinations as a Network of Autonomous Agents

The requirements on modern production planning systems (PPS) and mobile work teams can easily be compared to the general features of decentralized, complex systems. In both cases the historically possible solutions have comparable shortcomings, which at least in the case of PPS could be solved in initial specified user scenarios through modelling a network of autonomous agents. Therefore, it makes sense to design each implement in mobile work teams by an agent and let them communicate per ISOBUS.

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Keywords

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Literature

Literature references can be called up under LT 07SH20 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

The challenges and the system concepts for their fulfilment can be well compared between tractor implement combinations and PPS. [4] is collecting the main problems of PPS as follows:

- „Current research in the field of FMS (Flexible Manufacturing System) control is mostly based on static models for specific system environment. Most of the models are not generic enough and are not adequate to address the dynamic natures of FMS, in which changing of products requires fast system reconfiguration. [...] One basic reason of lacking generality, scalability and flexibility in most control models lies in the conventional centralized, top-down modelling approach in which the overall system features are defined first, and the representation of system components is usual hypothetical and highly simplified.“ [3]
- „Common production planning systems concentrate on a global plan. Disturbances of the workflow require a time consuming development of a new or changed plan. The implementation of the production control as a distributed planning task can provide a more efficient process, if no global central plan is needed.” [7]

Comparability of Requirements between Tractor Implement Combinations and Production Planning Systems

Agricultural production processes don't lead to concrete products. They deliver a fully completed operation sequence on the field instead. The challenges for the management of machine setup are higher in agriculture, as each action could utilise a different configuration.

The central planning in agriculture is provided until now by the farmer or a driver, who can optimise the workflow only as good as he has the needed in-depth knowledge, overview and time, to derive an optimal working procedure. A farmer has for example to calculate the intensity of soil tillage, which is needed for optimal performance of succeeding tasks like seeding. First he has to measure the current soil state, so that he can determine the needed tractor and machines.

The manufacturer of a tillage machine has the expert knowledge to determine the input parameters, which are needed for the desired soil granularity. This intelligence should be provided as part of an ECU in the running system, so that it can adapt the work parameters to the current soil conditions. Thus the farmer can concentrate on the definition of central work tasks, without the need to define the details of preparatory work.

Thomas Wagner displays the characteristic processes of an automation system in *Figure 1* [14]. Similar to the agricultural engineering industry, the developers of automation systems realise, that these consist of items from different manufacturers with different technologies (e.g. BUS protocols), so that a better standardization is needed.

Challenges from Complex Automation Systems

The development of production systems started with simple control tasks with small ECUs (Electronic Control Unit) in a comparable way to agricultural engineering. The ongoing development of automation lead to more and more complex control levels with an “automation pyramid” named structure.

A production process is implemented inside this model by inter-connection of description blocks. This leads to an abstraction level, which is very near to implementation with strong focus on machine properties. All models have in common, that they describe a network of passive nodes, where the description is oriented at function and sequence.

Units with a growing “intelligence” and growing complexity have been introduced to get a higher automation level with a better vertical integration. The resulting system is comparable with the properties of a common complex and decentralised system which are described by [6]. A canonical modelling leads to too fixed definitions of the interactions between all parts. Additionally those mechanisms are not suited to represent the system inherent organisation structure.

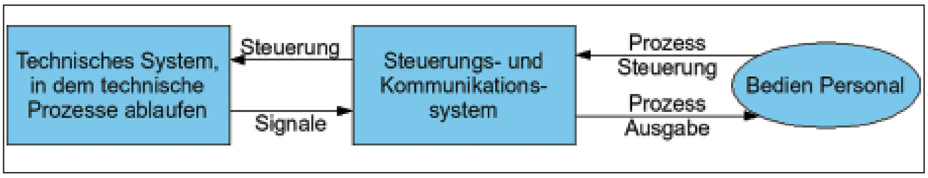

Fig. 1: Elements and Information Flow of an Automation System [14]"

Optimisation of Production Planning with Multi-Agent Systems

An agent based approach allows the transfer of sub-systems and their components to agents and their structures. Interactions are represented by co-operation, co-ordination and negotiation mechanisms. Finally, relationships are implemented by explicit mechanisms for dynamic adaptation [5, 6]. This results corresponding to [20] in:

- Agents are representing the de-centralised structure of the problem domain. This abstraction leads to a better controllability of the software complexity.
- The abstract interaction between agents provides mechanisms for flexible organisation structures. This influences dynamic bottom-up co-ordination and supports dynamic software customisation to the environmental conditions.

Thus Multi-Agent-Systems (MAS) are regarded as integral and universal solution from field bus up to enterprise level. [8] lists some successful solutions in the automobile industry. [10] presents some more examples which include even machine control tasks [8, 9, 11].

The development of MAS in production planning has been blocked for a long time by a number of different, proprietary agent languages, -protocols and -platforms [10]. Since 2000 the EU research project "Plant Automation Based on Distribution Systems" (PABADIS) develops a new, international supported approach [2]. PABADIS uses compared to other MAS approaches a combination of stationary (attached to assembly cell) and mobile agents. Connecting an agent via RFID-Tag to a product enables a very high, single item based flexibility. The PABADIS concept has been especially designed for unreliable networks and systems and supports a high level of scalability.

Tractor Implement Combination as Multi-Agent-System

The production target of the above described example of seed and soil tillage work is a combination of seed-density and seed-depth, which gets broken down by co-ordination of agents in single work process steps.

Each agent that represents a machine or a device in a ISO 11783 (ISOBUS) network, has to synchronise received control requests and information with its internal modelling of system state, so that all data can be validated. CAN messages can get forged by propagated evaluation faults, electronic interferences or by malicious network members, which can result in a potential threat. Due to the high flexibility and variability in the open communication system of ISOBUS, a system design should regard misleading information more as the normal case rather than as an exception. Therefore, every single device should get accompanied by a adequate safety concept during its development phase.

Compared to common agent based systems, which can utilize a capable and flexible communication with TCP/IP and Java/Jini, a CAN based network has to utilise a strict schematising of all interactions without leading to a strict dependency of the controlled device. Thus, the controlling process data variables, that get selected from a standardised data dictionary, should be as abstract as possible with as wide as possible control value sets (i.e. prefer possible open interval before single value). Needless strict dependencies from too low-level process data variables or too definite target values reduce the degrees of freedom and advance the risk of resource and interest conflicts between and inside the single units and finally in the complete system.

In contrast to "Agricultural BUS System" (LBS, DIN 9684) [1], ISO 11783 (ISOBUS) doesn't provide any possibility for sending control values as global process data messages. Thus the bottom-up controlled breakdown of production targets has to be ported in a slightly adapted way, if it should be based on the existing definitions in ISO 11783-7 and ISO 11783-10. In ISOBUS each agent has to detect, to which other agent he could pass on the next working steps.

The farmer could define his work targets in the described example as application maps for seed-depth and -density, which can get transferred to a Task-Controller (TC, ISO 11783-10). The agent of the seeder could derive based on the current system state the appropriate intensity and depth of soil tillage, which it should finally send to suitable other agents. The agent of a power-harrow could derive based on those control values, the needed Rounds Per Minute (RPM) of the Power Take Off (PTO) per driven distance, so that the wanted preconditions for an optimal seeding procedure can be provided.

Summarised, a farmer could define application maps for seed-depth, -density and soil types, so that the concrete machine setup can provide an optimal work result under all conditions.

Conclusions

An ISOBUS network is basically usable for a multi agent system. However, some extensions of the process data communication are needed. Additionally some system global behaviour patterns are needed for implementation of abstract interactions based on sequences of single messages.

An efficient development of behavioural patterns based on ISOBUS, which can be used across different manufacturers, can be supported by an open accessible implementation of the communication protocol. This could be based on the Open Source program library ISOAgLib.

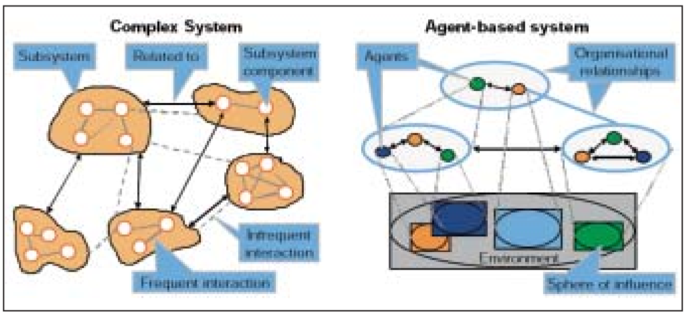

Fig. 2: Canonical View on a Complex System in Comparison to an Agent Based System [6]