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Self-adaptive and self-learning management for mobile machines

Control systems in mobile machines are designed on the basis of predefined configurations to control target values according to an operator's reference, whereas disturbance variables are considered indirectly. In this article this issue will be defined more distinctly and a notion of holistic optimization will be given. According to that, an alternative control-architecture in an interdisciplinary DFG-promoted project called OCOM (Organic Computing in Off-highway Machines) will be presented. Due to this, the possibility of a basis for a self-adaptive and self-learning operating strategy (realization of a target function) in mobile machines is given, to optimize the machine holistically.

Keywords

Machine-management, organic computing, self-learning, generic architecture, optimization, fuel consumption

Abstract

Landtechnik 65 (2010), no. 4, pp. 240-243, 2 figures, 6 references

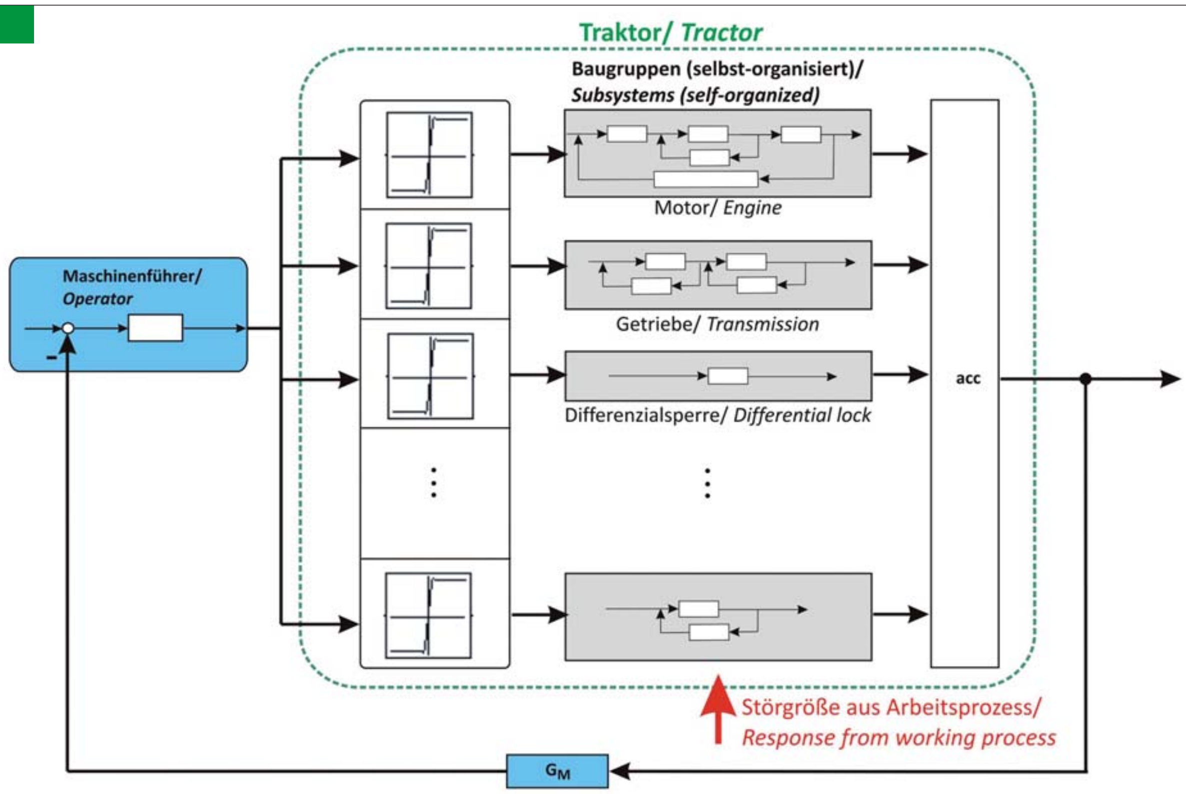
Developments in the area of mobile machines, like for instance increasing importance of electro-hydraulic actuations and continuous variable transmissions, have led to a growing number of degrees of freedom in such systems. These can no longer be set by the driver, that's why an automated machine management (GMM) must be introduced. A GMM is the sum of hardware and software implementation to realize an operating strategy. The design of todays' GMMs is illustrated in **figure 1**. The (human) operator provides the essential directives which, accordingly converted by using static characteristic curves or fields, serve as control variables for certain components of the machine. These characteristic curves or fields are designed to optimize the working point under specified and predefined circumstances. Control variables are set in many cases independent of other components like for instance differential lock or all-wheel clutch. In each single component these control variables are individually controlled, without taking interactions between them under consideration. The output of each component are accumulated to an overall working output, measured by the human operator (G_M) and controlled by him to fulfill his defined goals.

Because of this performance todays' management systems are not capable of executing holistic optimization. Holistic optimization will be understood as follows:

- Holistic optimization is supposed to consider further influences like attributes set by the operator as well as the consideration of the current working cycle. Furthermore off-highway machines, like for instance tractors, perform a tremendous number of different working cycles. An a-priori parameterization does not lead to an optimized working output in each single circumstance. Compromises have to be accepted especially when considering the differences between heavy duty transportation and light maintenance operation. Holistic optimization is supposed to take these considerations, in the following denoted as external influences, into account and is furthermore supposed to adapt to changing circumstances.
- Holistic optimization is supposed to regard the system as a whole. Since a mobile machine is a complex system and consists of many cross-linked components, an optimization must not constrain to certain sub-systems but consider the system as a whole. Changes in one component may lead to an entire new system state which is only observable by a superior the entire system observing point of view. Nowadays the collection and analyze of this superior perspective is not possible.

In the following a new generic architecture will be introduced, which is able to fulfill holistic optimization according to the definition above. The architecture will be adjusted to the special requirements of a mobile machine and will be applied to a fully functional machine. Due to the fact that there is a tremendous

Fig. 1



Conventional machine management

number of different influences to an off-highway machine, an a-priori adaptation of parameters is not possible. Hence, the architecture needs to be equipped with certain learning capabilities to find best settings in current situations.
Although the testing vehicle is a Fendt Vario 412 from AGCO GmbH, the architecture is supposed to be implemented on general off-highway machines. The currently considered goal is to optimize fuel consumption; however, additional goals are easily conceivable. Preceding publication in this area is [1].

Initial situation and new solution

Systems like those described above which consist of individually controlled and regulated subsystems but cooperate with each other to achieve a desired goal, are called „self-organized". An architecture to control such systems efficiently is the Observer/Controller (O/C)-architecture developed in the DFG (German Research Foundation) framework 1183 OC „Organic Computing" [2; 3].

The system that is to be optimized, in this case a tractor, is shown in **figure 2** and called „System under Observation and Control" (SuOC). This SuOC is capable of performing its intended function on its own, but not necessarily in an optimal way. The O/C-architecture is intended to supervise the system as a whole and optimize it if needed. To adjust the current optimization objective, the architecture provides an interface for an external user (goals), who is able to set specified targets.

In detail those system data of the SuOC will be measured, that define the whole system state according to the target function. The Observer is designed to receive and analyze these information. Analyzing for instance means the recognition of currently driven working cycle based on different statistical values or principal component analysis as well as forecast of following system states in a predictor-module. All information is gathered and transmitted to the Controller. The Controller assigns actions on the basis of observations from the Observer in a so called action map.

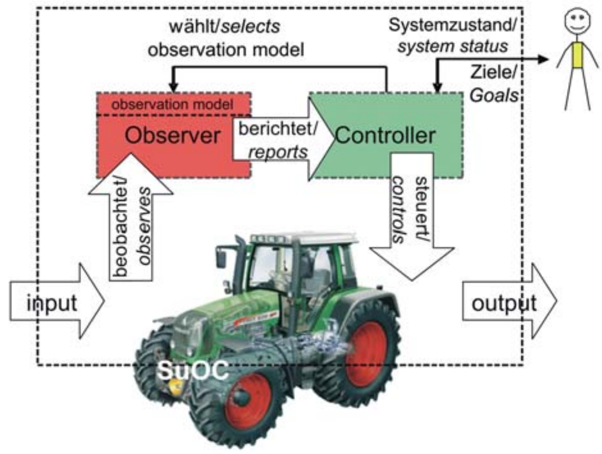
As mentioned before the architecture is meant to minimize fuel consumption. Therefore the Controller should be able to manipulate all changeable parameters that have influence on power flow through the machine. That means in particular:

- speed of the crank shaft
- gear ratio of the transmission
- velocity of the machine
- differential lock
- all-wheel clutch
- flow rate working hydraulics

Manipulations of engine control unit as well as auxiliary equipments are not considered in the first instance. Security critical manipulations should be displayed in passenger cabin as suggestions to the driver.

The Controller is equipped with self-learning algorithms, that's why the control behavior is better with time. The learning process performs online as well as offline. In case of online-learning, gathered experience from past parameter settings and resulting SuOC states is used to evaluate the Controller's decisions and adequate conclusions will be drawn. If the decis-

Fig. 2



Observer/controller-architecture

ion has positive consequences, it will be judged as good one. In case of negative effects the assignments will be modified. Offline-learning is realized in a similar way, the difference is that assignments won't be tested by the real machine but by a simulation model which is integrated into the Controller. This way of learning is used to check new assignments before they are gathered to the action map to prevent probable safety problems or severe declination of efficiency. The Controller is able to generate these new assignments based on observed situations and evaluates them on the basis of results of the integrated model. If the new rules lead to better results than the recent ones, they will be adapted to the action map.

Present work and first results

The Chair of Mobile Machines (MOBIMA) at Karlsruhe Institute of Technology (KIT) concentrates on creating quasi-static and efficiency afflicted tractor models in simulation environments MATLAB/Simulink and AMESim. Since MATLAB/Simulink was chosen to be the platform for the O/C Architecture, the MATLAB/Simulink model is as previously described used for offline learning. AMESim is a power flow oriented and topology based simulation program by LMS Imagine.Lab. With the AMESIM-model, the tractor will be simulated as SuOC in the first row to easily provide sensor signals as well as access to actuators. As model input the DLG-PowerMix cycles [4] are used, which are classified in eight different cycles covering all main duties a standard tractor performs. Communication between AMESim and MATLAB/Simulink is realized via so called S-function. Results of this „Model in the Loop" (MIL)-Simulation are the validation of the Architecture and defining requirements concerning communication with the tractor in the second part of the project.

The Institute of Applied Informatics and Formal Description Methods (AIFB) at KIT, which concentrates on information processing parts of the project, focuses on the realization of the Observer and in particular on working cycle detection. First results show, that isolated driven cycles can be distinguished from each other and assigned correctly. In the next step online data from SuOC will be divided into windows and assigned to stored cycles. Future work will focus on improving cycle detection, to achieve at least same probability of correct decision using smaller windows.

Conclusions

The described architecture is able to consider the system „mobile machine" as a whole and provides adaptive operating strategy. Finally a successive approach to the optimized operating point both under unforeseen conditions and changing external influences is achievable. World's largest agricultural engineering exhibition Agritechnica 2009 in Hannover [5] showed a major trend in improvement of handling and comfort. Described system shows potentials to relieve the driver by easier machine handling.

In the project OCOM fuel consumption is to be optimized exemplarily. Potentials of a holistic approach concerning fuel consumption optimization are shown in [6].

Average fuel saving potential from 5 up to 25 % in comparison to already existing machine management systems is achievable. In some cases the saving potential rises up to 30 %.

Literature Books are signed with ●

[1] [Kautzmann, T.; Wünsche, M.; Geimer, M. and Schmeck, H.: Self-optimizing Machine Management. 2nd International Conference on Machine Control & Guidance. Schriftenreihe Institut für Geodäsie und Geoinformation 16 (2010), H. 2, S. 107–115

[2] Schmeck, H.: Organic Computing - A New Vision for Distributed Embedded Systems. Proceedings to Eighth IEEE International Symposium on Object-Oriented Real-Time Distributed Computing, 2005, pp. 201–203 http://ieeexplore.ieee.org/xpl/tocresult.jsp?isnumber=30704; Zugriff am 18.03.2010

[3] Richter, U.; Mnif, M.; Branke, J.; Müller-Schloer, C. and Schmeck, H.: Towards a generic observer/controller architecture for Organic Computing. In: C. Hochberger und R. Liskowsky: Informatik 2006 – Informatik für Menschen. Köllen Verlag, Bonn, 2006, S. 112–119

[4] Degrell, O. und T. Feuerstein: DLG-PowerMix™. http://www.dlg-test.de/powermix/PowerMix_Teil_I.pdf; Zugriff am 18.03.2010

[5] Kautzmann, T.; R. Weidemann und M. Geimer: Agritechnica 2009 – Neuerungen begeistern trotz schwieriger Zeiten. http://bk.wai.de/magazines/!unlisted/VFMZ/Mobile_Maschinen; Zugriff am 01.04.2010

[6] ● Schreiber, M.: Kraftstoffverbrauch beim Einsatz von Ackerschleppern im besonderen Hinblick auf CO_2-Emissionen. Dissertation. Universität Hohenheim, 2006. Shaker Verlag, Aachen, 2006

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Acknowledgement

The authors gratefully acknowledge the financial support by the German Research Foundation (DFG). Furthermore they want to thank AGCO Fendt for their support and helpful hints.