Using multi-agent systems to increase system availability

In a project with the University of Kassel that was promoted by the German Research Association, a tool-assisted procedure is being developed to allow the design of an agent system. The goal of the research is to enable the universal design of distributed agent systems that are adapted to the unique requirements of automation technology. The methodology is intended to support the developer with the systematic querying of the requirements and system analysis all the way through to development and implementation. The project's basis is a uniform descriptive form that is based on SysML (System Modeling Language), which maps the various aspects in a universal system model. The agent system being developed will be directly executable on controllers conforming to IEC 61131-3 without any special agent platform. Prof. Dr.-Ing. Birgit Vogel-Heuser and Dipl.-Ing. Andreas Wannagat from the Department of Embedded Systems at the University of Kassel provide an overview of the project here.

In the future, it will become virtually impossible to cope with the increasing demands for flexibility of automation systems using traditional procedures. This could be due to the widely diversified manufacturing of products with small lot sizes or the increase of availability due to the detection and compensation of errors occurring at run-time and the increasingly parallel character of automation hardware. Or it could be due to the distribution of control tasks in the field or the use of controllers with several arithmetic units (multi-core CPUs).
Initial steps towards coping with the increasing complexity of modern control programs have been taken with the entry of object-orientated concepts into IEC 61131-3. Other approaches that facilitate the modularization and distribution of control tasks are based on IEC 61499 but have not achieved a breakthrough to date. Both objects and components have been used successfully for decades in application development. However, with the trend towards multi-core systems, a paradigm shift is taking place here that could be useful for automation solutions on account of their often distributed structure.

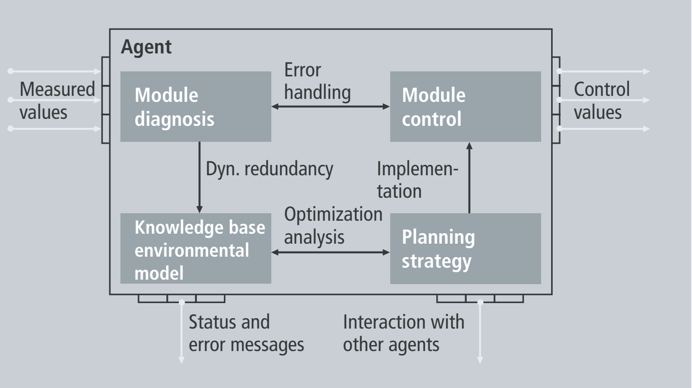

Fig. 1: Structure of an agent for automation technology

Flexibilization of the control solution using agents

The concept of agents offers several conceptual advantages, with regard to both the flexibilization of a control solution and the distribution to several arithmetic units. Agents allow intuitive access to an automation solution. Exactly like objects in the object orientation, they summarize structures and functionality, but over and above that they also exhibit an autonomous behavior.
Within the framework of an automation solution, an agent represents components of the technical system that perform a closed automation task (service) within the process. Unlike modules, agents exhibit an autonomous behavior, which means that, on the basis of a specialized model (knowledge base) of the sub-process to be controlled, they are able to evaluate the current situation and derive decisions from it. These decisions are made within the scope of the technical possibilities of the underlying components and with regard to the agent's optimization goals.
On the basis of this knowledge, a large number of additional aspects can be implemented in an agent when compared to an object, including both the analysis of the current situation and future alternative actions. The knowledge base, as a model of the underlying technical system or process, can be used both for the model-based diagnosis and compensation of errors and for the optimization of the control strategy.
Distinction is essentially made between two types of agents within an automation solution: on the one hand, agents that provide the services of their underlying automation components and, on the other, agents that request and select these services in the sense of the process to be executed. In doing so, both agents pursue local goals. In the case of system

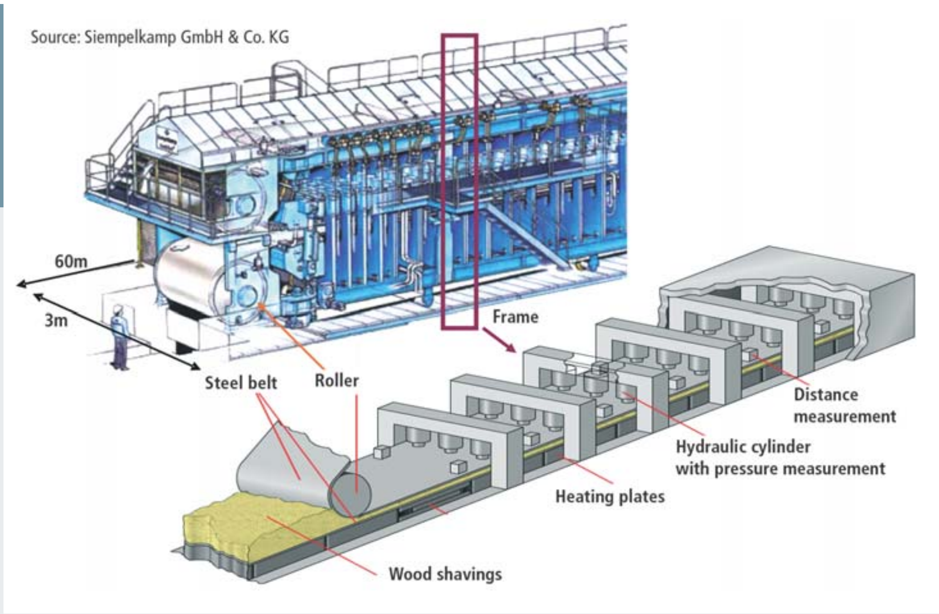

Fig. 2: Construction and flow of material of the press

agents, these goals are high performance and availability; in the case of process agents it is product quality. By means of the interaction of these two types of agents, the entire system is optimized at run-time and in the context of the current situation.

Since it is only specified at run-time which components of a technical system (system agents) are to be used by a workpiece (process agent), each workpiece can be based on an individual manufacturing plan. This defines the order and the way in which the components of the technical system are used. Conversely, in a continuous system a process agent contains a recipe with the sequence and specification of the sub-processes to be executed. The processing stations will be parameterized and used according to their arrangement and suitability. A change in the recipe merely leads to new specifications for the services to be performed. The changes in the structure of the technical system are expressed in that a new component, or in the case of a defect, a component participates less in this allocation mechanism.

Increasing reliability

Assuming correspondingly redundant processing stations, the failure of system components can be compensated by a service allocation mechanism, thus increasing reliability. However, the following example of a hydraulic, continuous hot press for chipboards shows that the negotiation mechanism can only be used meaningfully if an error can be circumvented, i.e. if alternative services of other system agents can be used. In contrast, the failure of a sensor or actuator within an agent evades this mechanism, but can also be detected and compensated by the agent's knowledge base.

The hydraulic press that underlies the agent system has 25 press frames, each with five or six hydraulic cylinders that press the incoming wood/glue mixture under high pressure to form chipboards. Temperatures

Dr. Josef Papenfort, TwinCAT Product Manager at Beckhoff, explains the background of this research project: "In this transfer project, which is promoted by the German Research Association (VO 937/8-1), Beckhoff and the University of Kassel have successfully proven that the methods gained and the tools developed from fundamental research at a university can be directly utilized in industry. A great deal of scientific research has often been made into agent systems in particular, but until now there has hardly been any implementation in industrial products. With this work, we have succeeded in convincing several users of the potential and benefits of agents."

Beckhoff is involved in a large number of different research projects, from application studies and technological developments to fundamental research. Emphasis is always placed on the most industry-applicable research projects. The rapid implementation of the ideas and experience gained from research projects in products is the primary goal. In the opinion of Beckhoff, cooperation with universities is absolutely necessary in order to promote innovative forces and technological leadership.

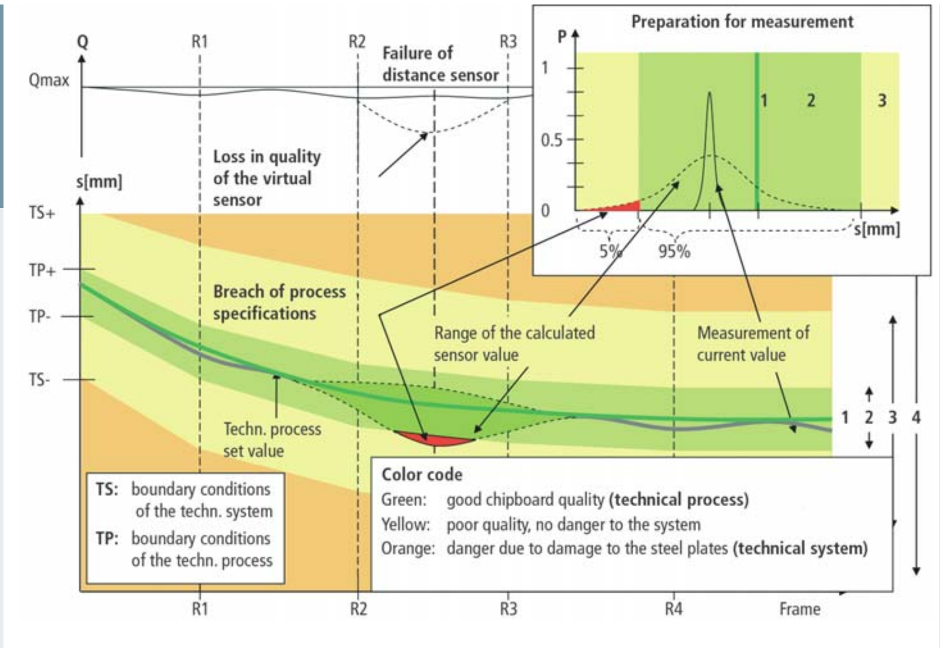

Fig 3: Tolerance ranges of the requirements and failure of distance sensor

of up to 240 °C (464 °F) are reached. Each frame is represented by a system agent which, in accordance with the local boundary conditions, implements the process agent's specifications while checking and controlling the parameters. The system agent has to recognize two error mechanisms: on the one hand, it monitors the local parameters to ensure that they remain within the specified tolerance ranges and, on the other, it uses contradictory redundant information in order to recognize errors. The agent's local knowledge base supplies this redundant information. This might include simple rules that check the plausibility of parameter combinations, or a system model that uses analytical dependencies and makes calculated values available for comparison in the sense of an observer. If an error has been detected, the same calculated values can be used for a compensation. An additional consideration of the quality of the real measured values and the calculated replacement values allows the agent to estimate the consequences for further operation. If the tolerance of the specifications for the agents is sufficiently large, the system can continue operation with an adapted control strategy; if not, the system must be shut down safely.

The agent is always able to judge the current situation with regard to the quality of the underlying information and to adapt its behavior accordingly. In addition, the determination of the measurement quality of real sensors allows the operation of a plant to be continuously adapted to a worsening situation and to throttle back production output in favor of constant reliability and adequate product quality.

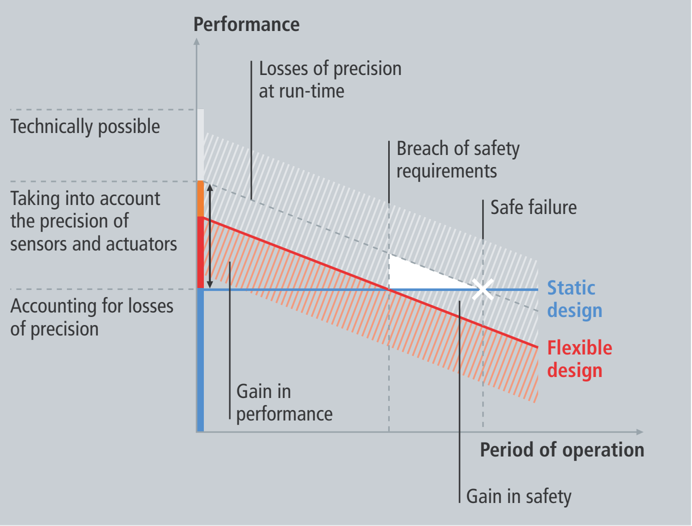

Fig. 4: Reduction of performance in favor of reliability

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