UBIQUITOUS AUTOMATION – A GOAL FOR FUTURE WORKSPACES?

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Abstract: Future workspaces will be decentralized and connected via the internet. Collaborative work will be computer mediated. Physical phenomena will be ubiquitously sensed and transformed in information. Analog-digital continuation of events is under development to assisting distributed workspaces to immersing in a common work of engineers or workers. Impacts on working condition are considered.

Keywords: collaborative work, ubiquitous sensing and generating, cobots, software agents.

1. INTRODUCTION

Ambient, pervasive, and ubiquitous computing is seen as the key to a future where people in an almost effortless way can do things or can work by means of technology they do not perceive. While ubiquitous computing (Ubicomp), coined by M. Weiser (1991), are more or less restricted to sensing, ubiquitous automation may be understood as sensing and acting (Bruns, 2005a). Data of distributed sensors are elaborated by tiny computers to provide information. Actions based on this information can be triggered by humans or automatically. Who is responsible for the effects of the action?

It will be possible in near future to sense dangerous situations in car-driving. Who acts accordingly to avoid accidents? That could be the driver based on the sensed information. Or actions could be done automatically to handle the situation. The driver will not perceive that he/she for this moment is not in control. To navigate ships or planes some years ago specialists were necessary aboard to interpreting sensed data for to put the master or pilot in a position to safe steering the passage. Today navigation is highly automated by sensing data of GPS, to locate easily where you are, and to steer automatic together with inertial navigation. Computers control the actions, sometimes not perceived by the masters or pilots.

Yoo & Bruns (2004) and their group developed simple computer animated virtual environments (CAVE) that generates a feeling of immersion in a virtual world without headsets or other special devices. Canvases are fastened on hexagonal scaffolding, and computer controlled video-projectors beam a landscape onto the canvases. Inside the cave one can walk through the landscape. The movements are sensed and generate actions of the projectors. The people inside the cave do not get aware of computers.

A project "Future Workspaces", funded by the European Commission, developed the vision: Supported by CAVEs engineers will be able to work seamlessly in their workspace environment with documents, scientific models and virtual prototypes, both alone and collaboratively with distant colleagues as if they were in the same room. Virtual and hybrid prototypes will be available as means for engineers to design new products. They will access specialized services via intelligent and secure network infrastructures that can detect, predict and satisfy user demand at any time and any place through location- and device- independent applications, which are able to seamlessly migrate across network technologies. The computing power necessary for executing compute-intensive simulation tasks in real-time will be available through GRID technologies. A step-by-step work timeline could be stored by the system, allowing another user to understand the previous course of the work and thus be able to effectively carry on with the tasks in the process.

The reducing cost of technological equipment will enable companies to implement technologically integrated spaces, housing large embedded displays, networked furniture, wireless devices for tracking people and remote access to supercomputers etc. (Figure 1). The integration of technology with physical space will make the present computer systems and interfaces less visible or transparent in the future environment. The future may also see the use of satellite workspaces, secure out-of-town places for multi-business employees to work. Here they will be able to access their company's network and dock down to work for part, or all, of the day.

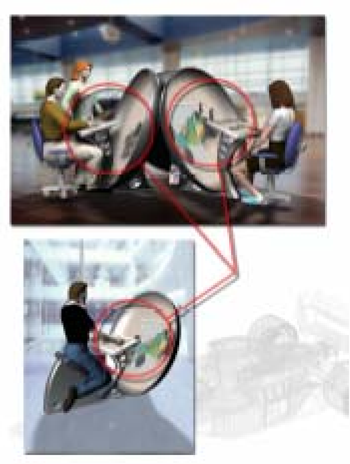

Fig.1. Sketch of connected workplaces (Future Workspaces, 2002-2003).

Despite the number of potential economic advantages, there are also substantial risks involved when relying on ubiquitous-computing technologies for large parts of an economy. The increasing automation of economically relevant aspects and the exclusion of humans as decision makers could certainly become a cause for concern. Under "normal" circumstances, automated control processes increase system stability – machines are certainly much better than humans if they have to devote their whole attention to a particularly boring task. But situations that have not been anticipated in the software can easily have disastrous consequences if they are not directly controlled by humans. Other problems might arise from the intricate interplay of several automated processes, which might quickly escalate into an unanticipated feedback loop that gets out of control (Bohn et al, 2004).

From a critical perspective the vision of ubiquitous automation is problematic because it could leave the users without control. Only in few cases is the focus of ambient computing on systems supporting humans in understanding what is going on at the level they choose, and supporting them in suggesting courses of action rather than action automatically. There seems to be a need for a balanced view emphasizing how ambient systems need to be visible, how they can be deconstructed, how coherence can be achieved, how they can provide stability and understandability, and in particular how users can stay in control when dealing with a large number of autonomous components (http://www.aarhus2005.org/).

2. HUMANS VS. MACHINES IN CONTROL

While the use of automation systems and the work with them penetrate all areas of life today, there are however many problems, which are not yet solved. They concern the acceptance on the one hand and on the other hand the reliability of the co-operation of humans and automation systems. The acceptance refers not only to the use of automated devices in household and leisure time, but likewise to the work with automation systems like machines and within plants. Effective, efficient and reliable work activities within and with automated systems are only possible, if the operators both know the consequences of their inputs into the system (operating) and can interpret the system feedback (understanding).

Semi-automated tasks could avoid problems mentioned above. Physical teaming of workers and robots in a shared workspace can help to solve assembly problems. There exist different concepts to do this. The Cobot-concept supposes that shared control, rather than amplification of human power, is the key enabler (Peshkin et al, 2001). The main task of the cobot is to generate a virtual environment, defined in software, into physical effect on the motion of a real payload, and thus also on the motion of the worker. An overhead rail system in gantry-style as used in many shops can be considered a cobot but without a virtual surface.

Virtual surfaces separate the region where the worker can freely move the payload from the region that cannot be penetrated. These surfaces or walls have the effect to the payload like a ruler guiding the pencil. To draw a straight line free hand is not easy just as the unguided movement of a payload is for a crane driver. Virtual surfaces are generated by software, and therefore the payload is moved by a shared control of computer and worker. The worker does not perceive what the computer is doing in the background (Surdilovic et al, 2003).

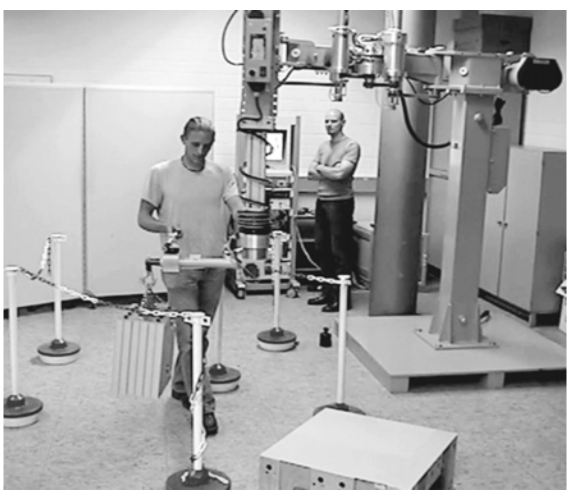

Fig. 2. Cobot operating mode, easy guidance along a programmed track between obstacles.

Laengle, and Woern (2001) consider a robot as an intelligent assistant for the worker. Instead of researching for solutions to achieve a complete autonomous execution of complex tasks in an uncertain environment the authors enter into a compromise wherein the operator helps the robot to finish the tasks correctly when uncertainties occur. The robot can switch from automatically to semi-automatically executed tasks with help of the human operator. For observing the tasks force- and vision- sensors are used.

The Morpha-project funded by the German Ministry for Research and Education between 1999 and 2002 had the intention to "equip intelligent robot assistants with powerful and versatile mechanisms, which enable these robots to communicate, interact, and collaborate with human users in a natural and intuitive way". Besides robot assistants for housekeeping and home care the project developed manufacturing assistants as partners of human operators to achieve high flexibility at production lines and thereby saving costs otherwise arising for always necessary reconfigurations of highly automated equipment. Estable et al (2002) study an intuitive teaching of a production assistant for object recognition and programming by demonstration, and surveillance of the shared workspace. Stopp et al (2002) developed an assistant for an order-picking task. The task is taught using a laser pointer and a hand-held computer. The interaction is supported by speech output of the user. Kristensen et al (2001) developed a tactile interaction between operator and robot assistant for teaching and a direct collaboration. Also Wösch, and Feiten (2002) present results of their experiments with tactile robot-operator interaction. Ehrenmann et al (2001) use gesture recognition for the interaction. Hägele et al (2002) present the cost savings when robots share tasks with humans at production lines.

The examples mentioned above show a mix of human in control and automatic control. Itoh et al (2004) considers the problem that workers/operators sometimes overtrust automation. Reducing overtrust is becoming an important issues in human-machine systems. Many automated systems are becoming intelligent and powerful; still, their capability is limited. It is necessary to understand how operators become reliant on automation too much in order to clarify how to reduce overtrust in automation.

Several aviation accidents suggest that human operators rely on an automated system inappropriately when they misunderstand the limit of the capability of the automation. Such kind of over-reliance may occur even when an operator is highly motivated.

In the study Itoh et al (2004) investigated how a human operator comes to expect that an automated system can perform a task successfully even beyond the limit of automation. He developed a model of trust in automation by which one is able to discuss how operator's trust in automation becomes overtrust. On the basis of the model of trust, he conducted a cognitive experiment using a microworld of an automated mixed juice processing system to examine whether the range of user's expectation exceeds the limit of the capability of automation. The results showed that operators tended to rely on too much, when the operators were not informed the reason for the limit of the capability of automation. However, it was not sufficient for preventing overtrust to inform the automation limit and its reason. There were a few operators who became completely reliant on automation even though they knew the reason for the automation limit.

These problems could be even worse with ubiquitous automation, when the engineers or workers have no influence on decisions done automatically. Who is to blame if failures or accidents occur?

3. HUMANS AND SOFTWARE AGENTS

Multi Agent Systems (MAS) is a software technology capable of modeling individual and "social" behavior of units in distributed workspaces. Individual behavior of agents is characterized by qualities like autonomy, reactivity and purposeful concluding. Aspects like co-operation, communication, negotiation and co-ordination are characterizing the social behavior of MAS.

The agents have autonomous qualities, like developing plans and they are capable of communicating which each other to achieve given goals.

Agents can represent the behavior of the components of these processes and the humans provide the obtained experiences to the knowledge base for both, agents and themselves.

The agents can improve their information providing by learning about its environment given through the evaluation of done tasks compared to the goals. This evaluation can be done by humans or semi-automatically based on collected data of the processes. The agents can also improve their behavior when collaborating with other agents representing other components of the production process. From the point of view of agent systems it seems vital to develop methods that will ensure such behavior leading to acceptable sharing of resources, maximizing individual profits or minimizing the risk of average failures. They have to learn to solve complex production tasks collaborating with humans based on experiences.

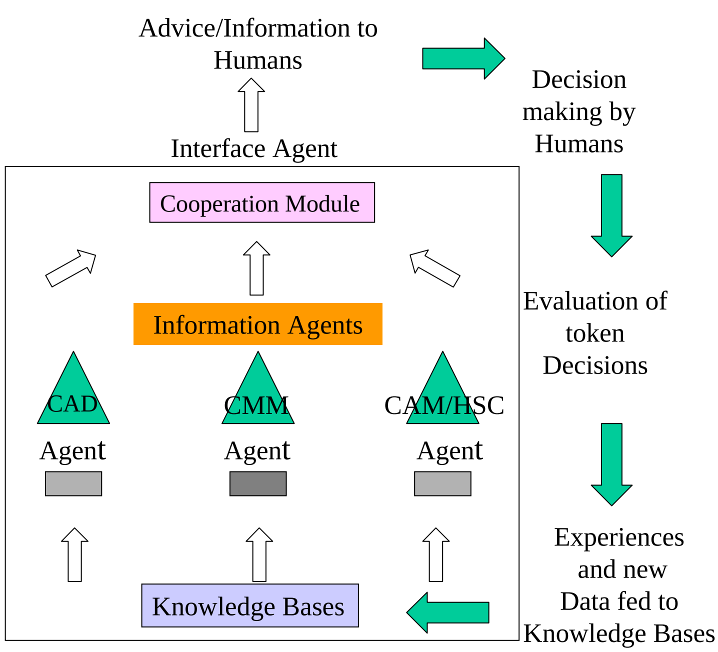

Fig.3. Schema of software agent assistance in manufacturing.

But it has to be stressed that the multi agent system should assist operators instead of make

decisions by them. The agents should only provide proposals for solving a problem.
Figure 3 shows a possible structure for multi agent assistance. Every agent has its knowledge base and are connected via a cooperation module. The knowledge bases will be provided with information of case studies, bench marking and experiences from the actual communicating humans, involved as designers and operators of the automated production process (order management, shop floor control, machining centers, and quality control). The concepts of information and interface agents could be useful for elaborating on data of component agents for presenting proposals to the human operators. Information agents are based on search methods.
Depending on the problem to be solved they examine data stored in the knowledge bases and combine them to proposals for solving the problem. They can also involve recent experiences with solved problems. The interface agent elaborates on this information to put them in a form capable of quick use of the human designers and operators.
With respect to ubiquitous computing or automation sensors could collect data and elaborating on it to provide information. The involved software agents consider the information to providing advices to the operators, or they could act by themselves.
An example of software agents assisting operators to identify and repair failures are given in a paper by Marzi & John (2002).

5. UBIQUITOUS AUTOMATION ASSISTING COLLABORATIVE ENGINEERING

With the trend to extend the designing and processing of products over different and remotely located factories the problem arises how to secure an effective collaboration of the involved workforce. The usual face to face work is going to be replaced at least partly if not totally by computer mediated collaboration. Collaboration demands a deep involvement and commitment in a common design, production-process or service; i.e. to work jointly with others on a project, on parts or systems of parts. Information mediated only via vision and sound is insufficient for collaboration. In designing and manufacturing it is often desirable and in maintenance it is necessary to have the parts in your hands. To grasp a part at a remote site requires force (haptic)-feedback in addition to vision and sound. Available Information and Communication Technology does not offer sufficient solutions. Tele-service developments restrict the information transfer to vision and sound. An immersion into the remote site to collaborate on solving maintenance or manufacturing problems needs also the transfer of haptic. This would help to make collaborative engineering more cost-effective by avoiding misinterpretation and therefore reducing the time-to-market, one of the drivers of a global manufacturing.
The connection of physical objects and digital information, or an analog-digital continuation, is a challenge of researches on Mixed Reality, Ubiquitous Computing, and Embedded Systems.
Collaborative work over distances connected by the internet faces some problems respecting time-delays, lost information, accuracy, and the missing immersion in a common work. If ubiquitous physical modalities, like haptic, kinesthetic, etc., would be sensed and transformed in digital information, that would improve the quality of distributed work. The demand for interactive real time modeling and for hybrid systems with analog/discrete and real/virtual interfaces is growing. Bruns (2005b) and his group at the University of Bremen provides interesting solutions in the sense of ubiquitous automation. The developed analog-digital continuation, called Hyper-Bond, is capable of to assist collaborative work via the internet.

4. CONCLUSIONS

The contribution discussed the impact of ubiquitous automation on working conditions and the requirements on supporting human-human collaboration. Until now, available Information- and Communication Technology do not properly support human-human collaboration. Tele-service developments restrict the information transfer to vision and sound. An immersion into the remote site to collaborate on solving maintenance or manufacturing problems is not supported. Recent results of research projects on hyper bonds and tele-cooperation promise a suitable support for the involved workforce if further developed. This would help to make tele-cooperation cost-effective by avoiding misinterpretation and therefore reducing the time-to-market, one of the drives for a global manufacturing.

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