HUMAN-HUMAN COLLABORATION

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Abstract: Collaborative work over remote sites is a challenge to developers of information- and communication technology as well as to the involved workforce. New developments on cost-effective connections are providing not only vision and auditory perception but also haptic perception. Research fields for improving remote collaboration are discussed. Social aspects as new requirements on the employees of networked and extended enterprises are considered. *Copyright © 2005 IFAC*

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1. INTRODUCTION

Collaboration is working together towards a common goal at different times, in different locations, at different companies in different functions. Principles are: support collaboration within the entire team including external suppliers and partners, support flexible team participation to minimize collocation as a team requirement, benefiting individuals by making their job easier and helping to achieve work-live balances, providing a collaborative environment, allowing the team to tap into their inherent creativity and power of sharing ideas, focusing on people, process, communication and relationships in addition to technology. This sounds like the intentions of sculpting a learning organization/enterprise as it was theoretically developed by Senge (1990) and Watkins & Marsick (1993). But now the challenge is to extend this theory to globally distributed companies. The benefits of collaboration are: reduced problems of resolution cycle time, increasing productivity and agility, reducing travel to remote sites, enabling more timely and effective interactions, faster design iterations, improving resource management and facilitate innovation.

At a recent workshop of the IFAC-Technical Board held in Rotterdam, The Netherlands, 2003, Human-Human Collaboration among others has been identified as an Emerging Area for Automatic Control.

Extended and networked enterprises distribute the design of products, planning of the production process, and manufacturing regionally if not globally. Employees are therefore confronted with collaborative work over remote distances. A cost effective collaboration depends highly on the organization maintaining a common understanding for this kind of work and a suitable support with information and communication technology. Developments providing not only vision and auditory perception but also haptic perception are very desirable.

Technological aspects: 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.

Individual, social, and cultural aspects: Enterprises investing in the new information-technology and communication infrastructures have also to consider the important issues to develop a culture and shared values that can facilitate the adoption of such technologies. Investment in advanced technologies may not necessarily result in improved communication by and between the employees. Often managers and the developers of IC - technology assume too much about the anticipated use of the technology by the employees. For most employees, interacting in a virtual mode via mediating

a challenge to engineers and the management of the involved enterprises. Most developments supporting remote service are sticking on transferring vision and sometimes sound as well. Demanded for are solutions to transfer also realistic haptic feedback.
The contribution deals with recent technological developments capable of supporting the work between remote sites and the individual and social aspects.

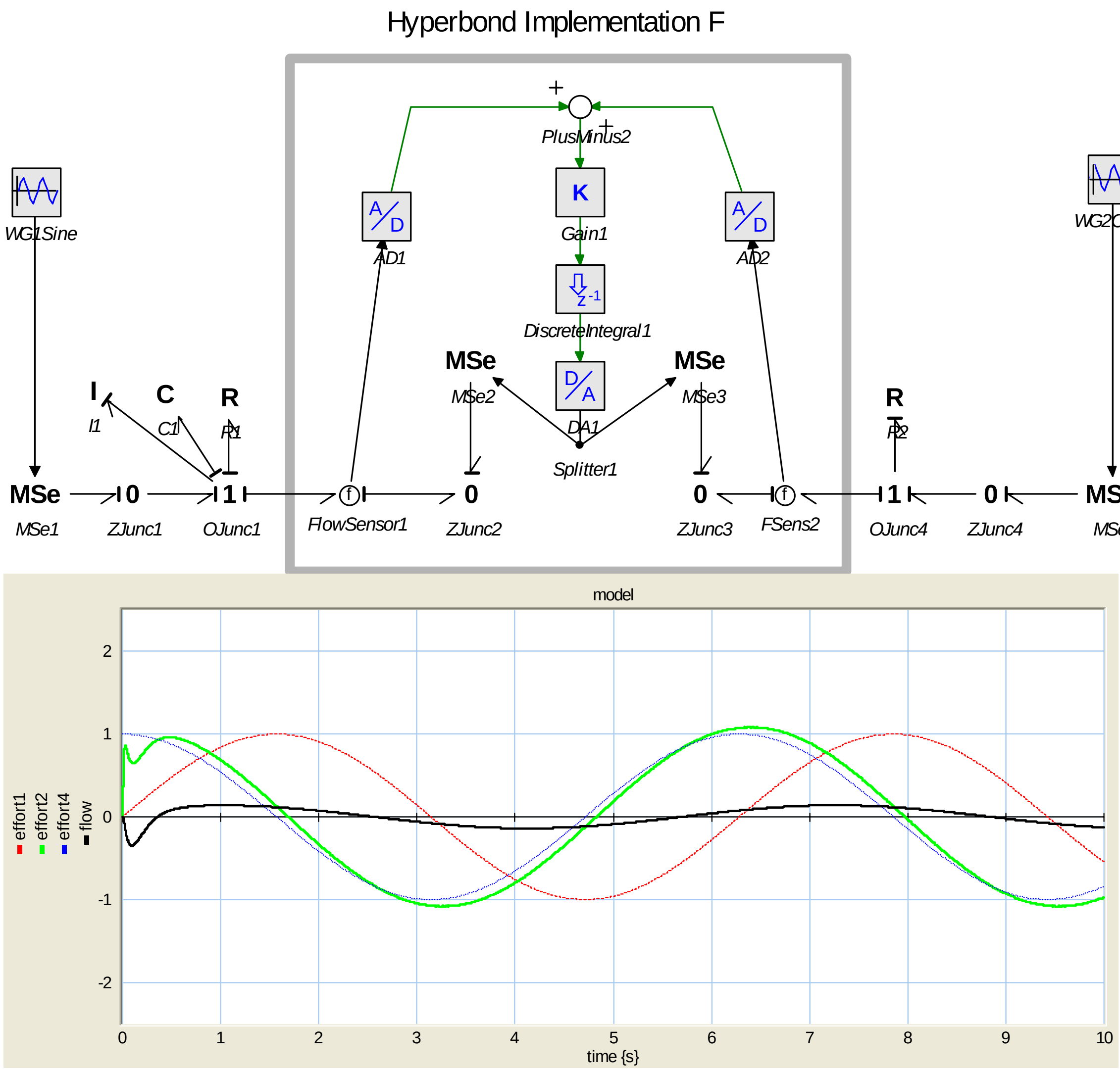


Fig. 1. Hyper-bond sensing flow, generating effort (modeled with 20-sim, v. Amerongen (2000)).

technologies may be totally new and may cause anxieties. The loss of human contact could be balanced by maintaining continuous communication as well as by holding occasional face-to-face meetings for information sharing and support.
The development and implementation of information- and communication-technology (ICT) suitably adapted to the needs of the workforce facilitating remotely distributed collaborative work is

2. TECHNOLOGY FACILITATING COLLABORATIVE HUMAN-HUMAN WORK

2.1 Hyperbonds and mixed reality

Bruns (2001) developed Hyper-bonds as universal interface type connecting reality with virtuality (Figure 1). It is a mechanism based on the translation between physical effort/flow phenomena and digital information like any other analog/digital and digital/analog conversion. But it aims at a unified

application oriented solution connecting the physical with its virtual representation and continuation. The name Hyper-bond has been chosen because of its relation to the description of dynamic systems with bond graphs, first introduced by Paynter (1961) and later further developed by Karnop et al (1990).
Hyper-bonds have been first used for discrete events creating learning environments through connecting remote labs (Bruns, 2001). Figure 1 shows a more sophisticated hyper-bond. The (modulated) sources of efforts are wave generators on both sides. The difference of the efforts on both sides of the hyper-bond generates efforts in a control loop to preserve the overall behavior of the wave generators with two resistors R, Inductivity I, and capacity C (Bruns, 2004).
Hyper-bond technology can be used for tele-collaboration in manufacturing and maintenance via the internet. Employees working at remote but real workplaces are connected via the internet. In a work application real objects at remote distributed sites can be handled with force feedback collaboratively through workers on both sites (Bruns & Yoo, 2004). While experiences with remote training of workers in

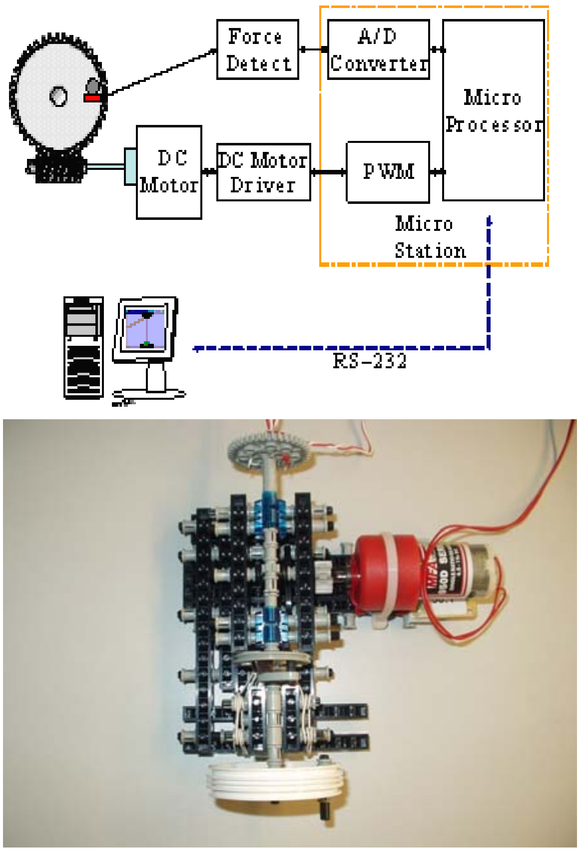


Fig. 2. Low cost momentum handle

control technique of electro-pneumatics are available, applications of this promising technology for bidirectional tele-work are still under development.

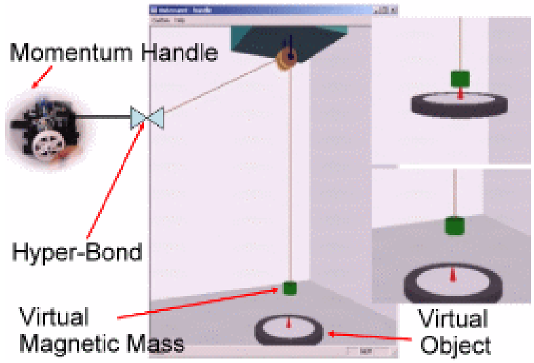
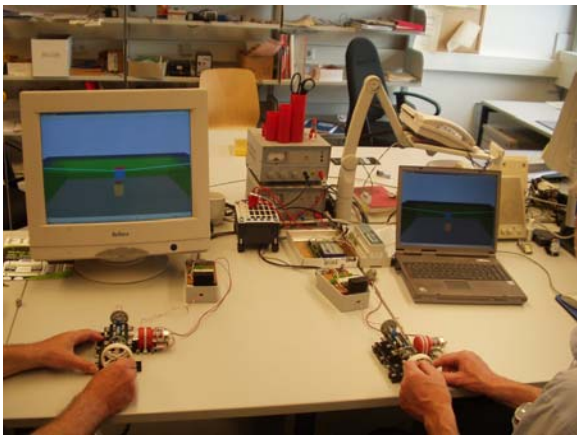


Fig. 3. Lifting a virtual mass and Hyper-Bond

A multi-modal tele-presence technology, i.e. the extension of human sensory and manipulative capabilities to remote environments, attracted research and development efforts in recent years (Buss & Kheddar, 2004). The application is focused to tele-operation in hazardous environments (space/nuclear), long-distance tele-maintenance and tele-service. Realistic tele-presence requires feedback of information in multiple modalities of human perception: visual, auditory and haptic. The intentions of tele-presence are different from remote collaboration. No person are necessary at the remote site. But this could turn out as unrealistic, at least with respect to tele-maintenance. Then a bi-directional tele-presence is desirable. The application of Hyper-bond technology can transfer back the concrete force generated at the remote site.
Yoo, and Bruns (2004) propose a low-cost momentum handle for force feedback (Fig. 2). The handle, actively driven by a motor, is always in a momentum-equilibrium through the wheel with a virtual force/momentum. A pressure-sensor attached to the handle senses a force if the user applies a momentum. This analog signal is fed via an A/D-converter to a microprocessor. The microprocessor controls via a D/A-converter the motor driving the wheel. This micro controller is connected to a serial port of a PC, where it gets the virtual force/momentum from. As an example, Yoo & Bruns (2004) demonstrate the lift of a virtual mass represented by a programmed algorithm running at a PC (Fig. 3). The respecting signals are transferred to the micro controller generating a force at the handle via the motor moment.
Another interesting experiment regarding force feed back between remote sites has been shown by Yoo & Bruns (2004). A virtual mass at two computer screens of remote sites, connected through the internet, is moved through two momentum handles (Fig. 4). It is a consequent application of the concept of mixed reality. Research results until now could be enlarged for a remote human-human collaboration.



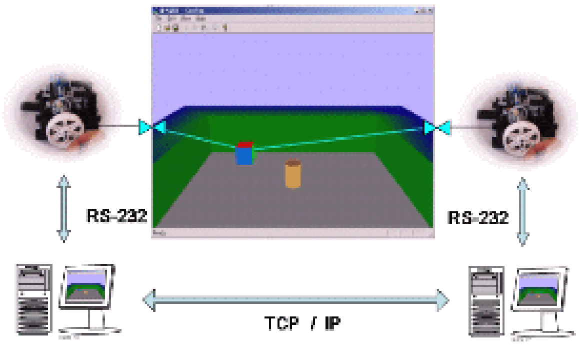


Fig. 4. Tele collaboration demonstration and model

2.2 Video conferences, tele-design and caves

Distributed design of products over remote sites is a strong demand of the industry for saving time and therefore costs. Centers for e-design got established at different universities, just to name Pittsburgh University and University of Massachusetts, Amherst (Nnaji, 2004), among others. The communication is mostly done with data-transfer using distributed CAE-systems like CATIA, i.e. a visual access to the products under the design process. The designers have to negotiate a shared understanding. This is done partly through video conferences. But in the camera-monitor mediated world of videoconferencing, the limitations of communications bandwidth and equipment capability tend to place a severe handicap on the senses of sight and sound and eliminate the sense of touch. As a result, even in state of the art videoconference rooms using the highest quality equipment, the sense of co-presence enjoyed by individuals in the same room is never fully achieved. "Gaze awareness, recognition of facial gestures, social cues through peripheral or background awareness, and sound spatialization through binaural audio, all important characteristics of multi-party interaction, are often lost in a videoconference", as Cooperstock (2003) put it. Cooperstock and his team developed a "shared reality environment" to improve videoconference environments with television monitors and stereo speakers to immersive spaces in which video fills the participant's visual field and is reinforced by spatialized audio cues. Moreover computers play a

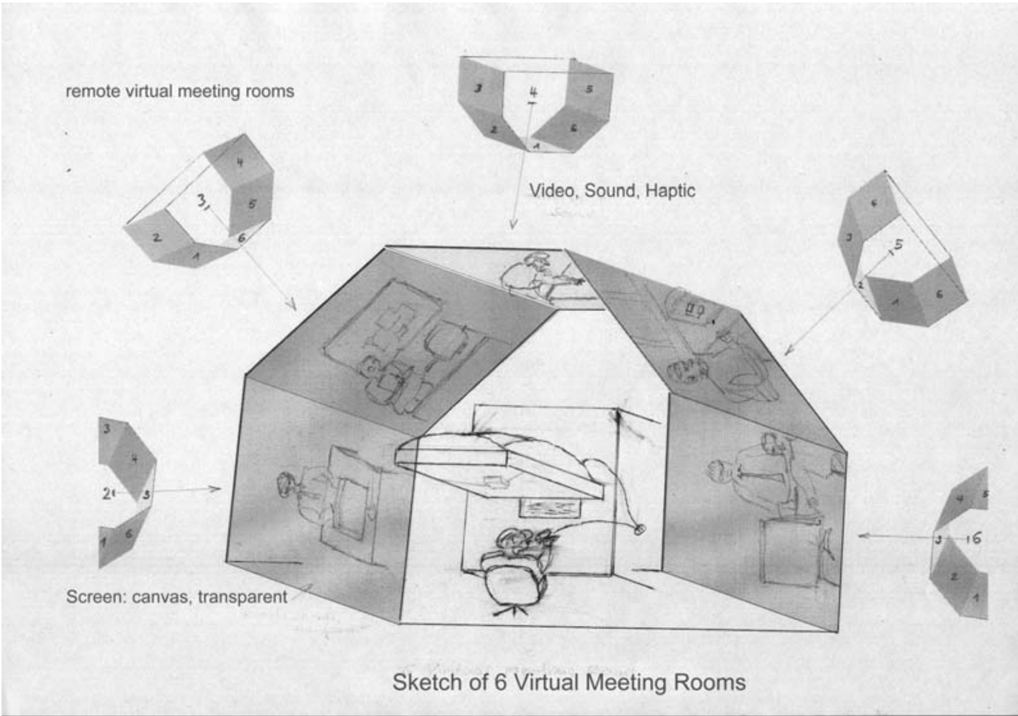


Fig. 5. Model of remotely connected caves

more active role.
While this research and development is not focused to distributed design and manufacturing but to tele-medicine and training, a haptic feedback would help bridging the physical separation of remote persons.
This feedback should range from reproducing the floor vibrations in response to a user walking about to the tactile response of a surgeon's instrument as it moves through different tissue.
Cooperstone and his team use a certain kind of self-made cave-technology as also Bruns and his group in Bremen. Available caves at the market are very expensive. But cheaper versions with nearly the same performance are possible. Integrating the hyper-bond technology into this cave-technology (Fig. 5) to support tele-design and tele-maintenance could solve the problem of the presently missing feeling when touching a part, as believed to be a necessity for collaborative work over remote distances. The work-action of persons controls via the hyper-bond signals, the cameras and video-beamers of the cave. This synchronizes the force-feedback mediated via the hyper-bond. Some research and development have still to be done to make this approach applicable for tele-cooperation. Fig. 6 shows a development of Bruns and his group at the University of Bremen.

Fig. 6. “Flying Carpet” in a cave

A ”carpet”, a platform, controlled by a person soars over a landscape video-beamed on the transparent canvas of the cave. The person controls the landscape with her movements on the platform.

3. CONTROLLING DISTRIBUTED COLLABORATIVE WORK

To make collaborative work between humans, humans and software agents, humans and automation systems (machines, robots) locally and globally effective it has to be controlled. Developments described in section 2 are of course not sufficient.

Protocols at the work application level, such as Task Administration Protocols, are defined as the logical rules for workflow control. Protocols enable effective collaboration by communication and resource allocation among production tasks.
Nof (2004) recommends active protocols, “active” implies that the protocol can, under coordination logic, trigger and initiate necessary, timely interaction tasks and decision-support functions to further improve performance. In smart distributed systems, e.g., multi-agent systems, coordination protocols are used to guide and support the automated interaction of each agent or an autonomous entity in order to achieve the common goal of a system. The efficient coordination process will lead to effective collaboration.
Auction-based protocols (Nof, 2004) have been developed and analyzed by parallel simulators for distributed task and resource allocation in multi-agent systems.
In the future, multi-participant negotiation processes, group decision mediation, and conflict management processes will be developed. In addition, the dynamic characteristics of the protocol which acts or reacts to the stochastic nature of distributed environments will be of interest.
To save manufacturing cost the integration of tasks are challenges for design and planning of new structures of decision making, conflict resolution and task controlling. From islands of automation to global systems, from local optimization to global optimization are the demands fostering research and development. Integrated product and process development supported by concepts like the digital factory and through e- manufacturing and e-design is one of the outputs of this research.
S. Nof (2004) states: “despite the advantages entailed with e-Work and e-Mfg., there are common challenges that emerge with collaboration: (1) Greater work complexity; (2) More limitations caused by increasing inter-dependence; (3) Issues of integrity and trust; (4) Greater need for coordination, cooperation, and synchronization; (5) Communication challenges and failures, complicating systems’ requirements; (6) Problems of mismatch, e.g., inconsistent versions, cultural differences, etc.; (7) New users training requirements and associated costs. Failing to overcome these common challenges may explain why often, e-activities do not fulfill the expectation promised by technology”.
“These concerns reflect the challenges of new work abilities to interface more complex systems, involving more information transfers, many more transactions, and the dawn of computer and robot servitude: beginning the delegation of control and cognitive tasks from humans to computers, machines, and robots. One of the main new concerns has been information overload**.** It means that humans, each with a single brain, have to interact and contend with computer-based systems and machines that may have certain superior skills not only in physical tasks, but

also in information handling and computing. The objective is to reduce the information overload (only for the humans) by better design of interfaces and of computer systems, and by more training for the human users/participants" (Nof, 2004). Nof asks: will workers and managers be willing to trust the results obtained and delivered by autonomous systems like (multi) agent systems?

The application of software agents not only for information retrieving, but also for assisting interaction processes, such as business workflow, automated negotiation and error recovery have been developed.

The ability of a software agent to operate the same interface operated by the human user, and the ability of a software agent to act independently of, and concurrently with, the human user will become increasingly important characteristics of human-computer interaction. Agents will observe what human users do when they interact with interfaces, and provide assistance by manipulating the interface themselves, while the user is thinking or performing other operations. Increasingly, applications will be designed to be operated both by users and their agents, simultaneously. Agents learning together with humans could be a challenge for the future

Shop floor control in an individual company is well developed (Scherer, 1998). The support system can be fully automated or can be a shop floor oriented planning and control software semi-automated based on electronic planning boards operated by the workforce. The goal is to achieve an optimum with respect to material and time resources regarding the tasks to be carried out. This leads to the normal work practice. Additional express orders (or just not available resources) cause a fluctuation around this normal work practice or performance of the manufacturing system. Inappropriate planning and control caused by time and costs pressure, tight resources on personal, or deficiencies by illness, all unexpected issues are moving the system to the limit of the space of acceptable performance. This can occur unnoticed and sometimes are perceived only when the quality decreases, times of delivery are exceeded or through put time increases. The decision support has to intercept such movements of the normal work performance against the limit of acceptable performance.

What is more or less feasible in an individual enterprise without information overload for the workforce does not work in a network. To achieve an optimum of the manufacturing process of networked enterprises regarding material and time resources to fulfill customer orders seems to be only possible with software support controlling the whole process. That means: cooperative requirement planning e-work parallelism, error and conflict handling and e-work effectiveness measures (Nof, 2004).

4. CONCLUSIONS

The contribution discussed requirements on supporting human-human collaboration in manufacturing. 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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