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An Experimental Multimedia Process Control Room

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Abstract

The centralised control rooms of large industrial plants have separated people from the processes they should control. Perception is restricted mainly to the visual sense. Only telephone or radio links provide narrow-band voice communication with maintenance personnel down in the plant. Multimedia equipment can *perceptionally* bring back the operator into the plant while *bodily* keeping him the comfortable and safe control room. This involves video and audio transmission from process components as well as sights and sounds artificially generated from measurements. Groupware systems support interaction between operators, engineers, and managers in different plants. With support from the German government, the state of Hessen, and industrial companies the Laboratory for Systems Engineering and Human-Machine Systems at the University of Kassel establishes an Experimental Multimedia Process Control Room. Core of this set-up are two high-performance graphics workstations linked to one of several process or vehicle simulators. Multimedia periphery includes video and teleconferencing equipment and a vibration and sound generation system.

Introduction

Today, operators in few or even only one central control room are separated from the process control large industrial plants. Increasingly sophisticated control systems shift the role of the human operator from manual to supervisory control, and research for autonomous operation of large plants is in progress. However, the presence of the operator in the control room of a plant is still necessary. Thus, the interface to the process and its control system remains an important component. Process operators, seeing only selected physical measurements of large systems on their small displays, and physically separated from the equipment loose contact to the process.

Before introduction of CRT technology, process control had walls showing mimic diagrams, electro-mechanical instruments, and mechanical switches. Still today, mimic diagrams and instrument walls influence the design of CRT displays. While the number of process variables increased, the task of deriving the necessary information about the process state out of all these variables is still mainly left to the operator. The operator has to perceive a vast amount of information. Except for acoustical alarms, the visual channel has to convey the majority of this information while conventional interfaces do not yet take advantage of other human senses and new, multimedia-based technologies.

Experience in nuclear power industry shows, that plant operators do not need support systems during 95% to 98% of operation. In the remaining cases, support systems do not always provide the support necessary and the operators depend on their own knowledge. Although highly trained and motivated, operators are unable to cope with situations when they cannot access the necessary information about system state and performance. In the 2% of operational cases, that are unusual, complex, and mostly new, the operator needs all available information to solve the problems. This information may comprise phenomena not transferred by usual measurements and unsuited to conventional displays. Additional media, integrated in the control room, may be able to convey the information.

Extensive task and knowledge analyses performed by our laboratory in a variety of industrial processes showed that an experienced operator uses more information from a plant than just the measurements displayed in the control room. The noise spectrum, sounds, vibration, temperatures, direct vision, even odour adds information to form the overall picture. It may be helpful to bring this information back, specially to the operator who is more and more separated (physically as well as conceptually) from the process. Opposed to hardware and software used in process control rooms today, equipment and procedures used in computer graphics show immense improvements. This offers the generation of virtual images based on physical measurements, abstract data, and process structure. Multimedia technology can bring the process closer to the operator in a distant control room by adding some of the lost sensory channels. Instead of showing the icon of a tank besides a level measurement, the computer-generated image can show the tank itself, along with the correct liquid level inside and a sound depicting liquid flow. Using computer graphics and virtual reality algorithms, other measurements can enhance the image, for example component colour for temperature, surface structure for efficiency. Using an image of a process component instead of physical measurements, showing live videos along with stereo sound from the process can again establish the close contact to the process. Simulating a reality sufficiently close to the operator's view of the process will enable the operator to identify problems quickly. A live video image can show process failures not captured by measurements. In parallel, video conferencing enhances contact between process control operators and maintenance personnel in the plant. Beyond this, groupware and co-operative interfaces for multi-user interaction in plant-wide control and communication can support problem solving on all levels, such as the operational, the maintenance, or the management level.

We know from own experience, how much the background sound in a control room next to the turbine room and boiler changes with slight variations in the plant state. Experienced operators will benefit from good reproduction of these phenomena. Besides giving back information to the operators they had in conventional systems it is also possible to use these additional media to transmit new information and to support collaborative work.

The Future Control Room: Co-Operative Work and Multimedia Support

Because of the growing complexity of systems, more operators, even in different locations in the plant need to co-operate. Telephone or radio communication provides only poor means to exchange process measurements and drawings from operation manuals along with views and ideas for co-operative problem solving. The co-operation between different human user classes (e.g., operators, engineers and managers) can be facilitated by the combination of several multimedia representations on different abstraction levels. The different information needs of these user classes are considered in the multi-human interface design by providing them with dedicated windows or screens and audio information. Engineers and managers may more often want to use goals-means hierarchies and multilevel flow model presentations whereas operators can use the less abstract presentations of ecological and topological displays. However, free navigational access to all display options must be allowed for all user classes, based on the different focuses of their individual preferences. The concepts of visual momentum and cognitive layouts should be implemented in such a way that they support the integrated view among team members of multi-user groups across all different forms of graphical representations. Related video and audio information further support this.

A large number of pictures in a complex display network is characteristic for many industrial applications. In such cases, only some of these pictures may be individualised for different user classes. Tani *et al.* (1994) suggested to use a large screen as a shared display for all group members, together with detailed personal displays on individual workstation screens for each of the group members. Multimedia presentations of live video can be combined with computer graphics presentations. The visual momentum is implemented by means of highlighting manipulated objects as well as by corresponding movements of individual cursors for each group member in the shared and detailed screens.

Relatively new communication technologies for human-machine interaction have been developed with the field of multimedia. The main idea of multimedia communication is to combine and integrate different visual and auditory media for the display and visualisation of information about tasks to be performed with a machine or a computer. In particular, the following media are combined with each other: computer-generated visual displays, video recordings, and auditory information such as recordings of noises and synthetic speech (Steinmetz and Herrtwich, 1991). In addition, three-dimensional stereoscopic video scenes and stereoscopic computer graphics can be superimposed upon one another (Milgram, *et al.,* 1990). Even music and haptic information as well as smell may be used for multimedia communication.

A connection of multimedia objects with an information network can be used interactively, for example, in travel agencies and libraries (Jerke, *et al.* 1990). In this pure human-computer interaction, the querying technique is combined with the method of browsing in a hypertext environment. A hypertext system is a network of information nodes that are connected by links, in a non-sequential way, to arbitrary non-linear information structures (Bogaschewsky, 1992). A hypertext network has been combined with an automatic fault-diagnosis module in order to support the problem-solving activities during trouble-shooting (particularly, motor diagnosis) tasks of human technicians in car-repair shops (Hollender, 1995).

In general, the human user can navigate through a hypertext network by analysing the connections between the nodes. Conceptual connections between alternative interaction procedures lead to a hypermedia information network. The separate nodes of this network are related to the separate types of information, such as text, graphics, video or audio, which are different forms of multimedia. Thus, ″hypermedia″ represent an information concept connecting several media (Begoray, 1990), whereas ″multimedia″ encompass a combination of different presentation media. The terms ″hypermedia″ and ″multimedia″ are, thus, distinguishable from each other in a similar way as the dialogue and the presentation layers are, in a user interface management system.

Multimedia communication systems will be introduced in the future in several application domains. We mentioned libraries and travel agencies already above. In addition, the entertainment industry is highly interested in this new technology. Particular applications will be possible in medicine, for co-operative conferencing between physicians (Kleinholz and Ohly, 1994) and for surgery. Industrial applications may be possible in glass production, the paper and pulp industries, the chemical industries (Heuer, *et al.*, 1994), the power industry (Zinser, 1993), and the maintenance of networks such as those for distribution of electricity (Akiyoshi et al., 1995). Tanaka et al. (1988) suggested a tutoring system for the latter case.

Alty and Bergan (1992) emphasise that many questions still exist with respect to the application of multimedia communication in dynamic industrial process-control tasks. The general problem of the interface design remains: ″Which information is needed by the human user, when, in which form and why?″ This problem becomes more severe with a larger number of technological options, which increase further with the multimedia domain. Therefore, the information needs of the later human users have to be investigated by means of task analyses. This requirement becomes even more important in the cases of co-operation among several human users in co-operative work situations.

Expert analyses (performed in a cement plant, as a kind of unstructured task analysis) indicated some aspects of the co-operative work situations in that particular application domain. The face-to-face communication is absolutely mandatory. In addition, the audio channel, e.g., telephone communication, is very important. Multimedia technologies can be used for integrating the video information from some of the equipment, which is now available in the control room on separate video screens. Otherwise, video observations are rejected as a ″spy system″ in this application domain. Consequently, the important aspects of multimedia communication for cement plants comprise: (1) computer graphics and related video presentations with interaction facilities for human-machine and human-human communication, as well as (2) teleconferencing with highly improved face-to-face video presentations and screen-based audio communication. Both aspects need to be related to one another and integrated in a task-oriented manner. Overlapping windows need to be avoided as much as possible, as usual in process control applications.

The important aspects for travel agencies do not include the teleconferencing part. However, a much more substantial search for related multimedia objects in an information network is required (Jerke, *et al.,* 1990). The human user classes are travel agents and customers, who are possibly also co-operating with one another for more efficient customer support. Special computer skills cannot be expected from the average customer. This leads to the necessity of easy-to-use multimedia interfaces with related text, picture, graphics, video and audio information.

The same general tendency exists with the important aspects of multimedia communication in the entertainment sector. Everybody wants to participate and enjoy in an easy, direct and interactive way, comparable to strolling through a garden or singing a song, e.g., in a Karaoke environment (Tamura, 1995). This most intuitive computer use required in the entertainment domain will probably contribute strongly to new powerful and highly user-friendly multimedia systems. Although they will appear more as game instruments rather than as conventional computers, they may become the next generation of multimedia computers also in industrial and service applications.

The research into computer supported co-operative work (CSCW, 1994) and groupware deals with theories, design concepts, architectures, prototype systems, and empirical results for co-operative work situations in application domains such as offices, classrooms and factories. Electronic mail systems, computer and videoconference systems, office information systems, organisational knowledge bases, shared window systems and other communication and co-operation systems are being investigated. Some of these systems do not allow the human users to interact or co-operate with each other directly in space and time. New approaches for the integration of action space and time have been suggested, e.g., by Ishii, *et al.* (1992). Such support for co-operative work seems to be particularly required in industrial human-machine systems.

As the results from the expert analyses in the cement plant indicate, co-operative work should be organised as far as possible using face-to-face communication. Large projection screens are not welcome, because they are very soon too overloaded, and are not adaptable enough. However, they have already been implemented in some other application domains, but the concept of overlapping information for different human user classes has not been taken into account in the information content of these projection screens. Thus, their use for co-operative work needs to be rethought. Display screens for group meetings in different offices and the control room are welcomed as multi-human machine interfaces in the cement plant. They will also be accepted as dedicated human-machine interfaces in a network, and for discussions of smaller problems over the telephone.

The display screens for the group meetings may consist of one screen with four to five windows. They allow access to all pictures in the control room, rather than having just printouts, as presently available. Different, most favoured pictures may be selected by different user-group representatives. All the selected pictures need to be seriously considered by all members of the meeting, because co-operation rather than ego-centred views are required, where each user-group representative contributes. Modifications of control-room pictures are foreseeable for the display screens in group meetings. Quick-change and easy-to-use editing facilities may allow the selection of important lines or variables from a table, qualitative zooming-in and selection of subareas of component flow diagrams, and manoeuvring or selection by sliders or text menus through different levels of abstraction. The latter range from physical forms, such as scanned-in photos, e.g., taken from databases or just of broken components (inside a pump, etc.), to goal hierarchies via multilevel flow-modelling representations.

The consistency and coherence across selected and edited multimedia has to be guaranteed. This will support the visual momentum, which is now already available, when a trend curve is selected by the cursor for a particular variable in the component flow diagram. The consistency will be increased when the computer completes the other selected pictures shown in parallel, e.g., consistent with the information reduction in the just-edited picture. The information filtering, reduction and qualitative modifications may be supported by the computer, or can be done solely by the group members. Further, computer-supported drawing facilities, e.g., for straight lines or for rapid prototyping (sketching) of new pictures and ideas or for modifying existing ones, are possible. However, they may be more suitable for exploratory purposes rather than for normal group meetings, because the latter might become too long with too much computer interaction.

The overlapping information for the different user classes has already been considered in the logbook, now available on a PC in the cement plant. This information has still to be implemented further in the presentation, the dialogue and the explanation facilities of the human-machine interfaces, particularly of the display screen for group meetings. Thereby, the visual momentum between different windows, which relate primarily to different user-group representatives, has to be supported.

All the suggested designs of human-machine interfaces for co-operative work also have to consider face-to-face communication. Otherwise, the social contacts would not be improved if this face-to-face contact were to disappear. Tele-co-operation is often not feasible because the contact with the production will be lost, e.g., the feeling for clinker quality will disappear. In addition, the work climate will deteriorate and, thus, there will eventually be no co-operation.

Design work is often accomplished in teams where human users interact and co-operate with each other directly in space and time. New approaches for the integration of action space and time have been suggested, e.g., by Ishii et al. (1994), as mentioned above. Two people work on the same drawing for design and, at the same time, see the co-operative design partner through the transparent digitiser sheet. The two designers can physically work in remote places from each other. The basic metaphor of this concept is "Talking through and drawing on a big transparent glass board." Thus, it is believed to be very important to have face-to-face communication as well as audio communication with each other in a team.

Similar design principles were used for a co-operative work support system, which allows the supervisory control as well as the maintenance of a power plant (Muraoka, Ohi, 1995). Not only image data but also audio and drawing data are combined with each other. Several windows on the display screen allow to visualise in parallel topological component-oriented presentations and video scenes from the plant or, alternatively, from the face of the communication partner, e.g., of the maintenance person in the field work. Additionally, a communication board can be shown in a further window. The communication board can be used as a white board or a pin board on which selected information, cut out from any other window, can be pasted. This white board is shown to both communication partners in the remote sites. They can circle and mark or write anything they wish on top or besides the pasted information, again visible also for the remote site. Thus, a direct telecommunication can be used for co-operative problem solving.

The already mentioned multimedia means of video conferencing with audio and face-to-face communication are even more important on the management and the marketing levels. As the facial communication is regarded as very important in many cultures, it seems to be worthwhile trying to reduce the huge amounts of data to be transferred in telecommunication. It is feasible to simulate computer images of a person in the remote partner’s place. Then, only minimal parameter sets, which characterise the perceived impressions of a human face, e.g., fierceness or gentleness of a face, have to be transferred. An example of such investigations of facial features was presented by Kato et al. (1995).

Advances in virtual reality technology allow to explore freely the virtual environment, e.g., of a maintenance situation by manipulating 3D graphical objects. Liquid-crystal glasses and data gloves have to be used for viewing and manipulating the stereoscopic display. Currently, the possibilities for exploiting such virtual reality and multimedia technologies for learning and training environment and for marketing are investigated (Akiyoshi et al., 1995).

Integrating the above approaches across all levels in an appropriate human user- and task-oriented manner will be a major challenge of the next coming years. It will be important to think about desired work organisations, first, and to pursue corresponding cognitive task analyses in order, then, to build plant-wide control and communication systems which will be welcomed with high user acceptance. It is also very likely that remarkable cultural and socio-political differences with respect to optimal or, at least, satisfying solutions may exist even within individual countries between different companies.

Even in the next future, process control rooms will need the presence of human operators. Those cases, when pre-programmed automatic systems would fail to control the process specially demand for skill and knowledge of the operators. In these rare cases, all available information on the process and the combined skills and knowledge of operators, technicians, engineers, and managers is needed for co-operative problem solving. The integration of new media for information presentation and co-operative work to support humans in these situations is a main research topic of the new Multimedia Process Control Room established in the Laboratory for Human-Machine Systems of the University of Kassel. The next sections describe the desirable capabilities of such an experimental instrument and the current implementation.

Essential Capabilities of a Multimedia Process Control Room

For technical (and financial) reasons, the multimedia process control room in its current configuration addresses the auditory and the visual sense with some support for perception of vibrations. Visual and acoustic information is presented supporting perception of directions and depth. Artificial, fully computer-generated information, play-back of pre-recorded information, as well as life presentation is foreseen. In detail, a multimedia control room should provide

- Computer-generated and animated visual displays, showing process information and incorporating textual, pictorial, and graphical objects, combined with live or pre-recorded video;
- life video image display for plant supervision as well as visual inspection of equipment or products and video presentations for operator and maintenance support;
- life, reproduced, or computer-generated audio, vibration, and speech for supporting visual perception, alerting, and informing operators;
- 3D stereoscopic and holographic presentation of the generated visual scene and spatial presentation of audio information;
- face-to-face video communication and conferencing, incorporating document exchange, drawing and annotation facilities; screen-operated telephone and radio communication; and,
- maybe in the future haptic information, motion, music, odour, and more.

For research and experimentation in this area, an experimental set-up needs in addition facilities for development of software, scenes and environments. Some additional preparations necessary are

- recording equipment to take audio and video samples in existing plants, import filters for CAD data from existing environments;
- modelling software to generate 3D objects and assembling those to scenes together with audio and video objects;

- various means for manual interaction like mouse, joystick, keyboard, together with related analogue and digital input channels;
- software to generate realistic behaviour of the interface, like plant, process, and communication simulators; and
- support for supervision and control of experiments, data collection, and evaluation.

The following section describes some functions of a multimedia process control room with examples assuming a live process environment.

Computer Graphics and Video Support

Today, computer graphics in process control rooms are still too much copying the traditional means of walls with control instruments to the computer screen, while separate monitors provide video information. Current research shows the value of displays developed into two directions. One is creating more abstract views that are appropriate to the operators' task, behaviour, and knowledge (Ali, 1997; Ali and Heuer, 1995; Johannsen et. al., 1997). The other direction supports the objective to bring back the operator into the plant by generating views close to reality (Wittenberg, 1997). In both cases, integrating video information can support the view.

The demand for further enhancement of a computer generated view leads to stereoscopic and holographic displays. *Stereoscopic* displays extend the view from the flat screen into the third dimension without taking account of the observer's position. The common technology generates separate images for each eye of the observer, displayed alternately on one screen or in parallel on two screens. Head-mounted devices providing one screen for each eye support the second solution while the observer needs to wear special glasses for the first version.

Stereoscopic views look abnormal to the observer when moving around the scene, as a 3D stereo view presents the image seen from one specific position only. The advantage is that the image is the same for every viewer from every position. The disadvantage is that the viewer cannot just walk closer or around the image. Even shifting the head from side to side or forward-backward does not change the view as expected from natural scenes and creates an annoying effect.

Holographic views take into account the observer's eye-point by tracking the position of the 3D-glasses. A holographic projection adapts to shifts in all directions (left-right, up-down, to-from) within the range of the tracking device. The observer can see the scene from different directions as long as he looks towards the screen surface. This feature easily adds to stereoscopic views with additional tracking hardware and software components. The display generation, however, supports only the view of one person; other persons need separate sets of display, glasses and tracker. Using head-mounted screens and sensing position and orientation provides means for full virtual reality that also shows views from the reverse side. The drawback is the weight of the helmet to carry and the isolation from the real world. The latter also acoustically, as common headsets moreover provide headphones. With this set is possible to walk around the display in the virtual world but difficult to avoid at the same time falling over the objects in the real world.

Besides video integration to enhance personal communication and conferencing, we see the necessity of two different video applications in process control: Live video for equipment or product observation, and video sequences for operator support. Live images from the plant, integrated into computer generated diagrams enable operators to inspect critical equipment visually. Cameras either placed in strategic position down the plant or hand-held (or even helmet-mounted) by maintenance personnel may provide these signals. In case of failures, video clips can instruct operators as well as maintenance personnel on correct procedures.

Audio Support

In a conventional control room, the audio channel provides the operator mainly with alarms. A multimedia environment adds acoustic information from the process as sounds and noises that provide the operator with relevant information on process state. These need to cover the full range of audible frequencies and include vibrations. Acoustic information from the process can be collected live in the plant or generated from process measurements. Process sounds can give a static acoustical picture of the process or focus on specific sections of the plant according to operator needs or current operator focus and actions. Individual microphones, placed at strategic points in the plant area can collect a live acoustic picture. The individual signals need appropriate mixing taking care of different sound intensities, thresholds and masking effects. In contrast, it is also possible to generate a synthetic acoustic picture artificially from plant data using stored sound samples or from noise and sound generators. In all cases, the spatial arrangement of sound sources must meet the layout of the control room.

As an example, the control room of a fossil-fired power plant shows a spatial separation between furnace and steam generation and turbine and power generation. Instruments and controls for steam generation cover the left, those for power generation the right side of the control room. Important parameters are the continuity of the combustion process, the balance of heat and water on the left side and the turbine revolution rate and vibration on the other. In the past, operators were able to feel harmful vibrations of the turbine in the control room as long as it was sufficiently close to the turbine. The current load as well as the revolution rate provides a continuos background sound in the turbine building. Microphones can pick up the sound down in the plant and speakers on the right side of the control room play it to the operators. Special transducers or low frequency speakers provide vibration information. As operators have to keep turbine speed very close to the nominal rate, an artificial generated signal, providing more contrast in deviations from set points, may be of more use. In this example, acoustic information provided on the left side of the control room relates to the steam generation system. As an example, sounds of flowing water with different intensity can provide state information. Besides spatial arrangement, such sounds show good contrast to the noise from the turbine in frequency and complexity.

Acoustic information from the process control system includes alarms and attention getters. These can be generated or pre-recorded tones, sounds, or voice messages. The system should provide means to spatially separate attention-getting audio on and arrange it according the general control room layout.

System Components

Following a market evaluation in 1996, we selected the equipment and implementation begins in late summer 1997. The Hardware selected includes high performance graphics workstations as well as high-end consumer electronics. The main software component is a set of programs for generating, animating, and displaying virtual worlds.

Hardware

Central components of the hardware are two graphics workstations, a SGI Octane/MXI with two 195 MHz R10000 processors, 256 MB memory, 4 MB texture memory, and a SGI O2 with 180 MHz R5000PC processor, 96 MB memory, Video I/O and camera. Both workstations are equipped with identical 20“ monitors capable of displaying stereo and holographic images.

Hardware for holographic presentation of images consists of active stereo glasses with liquid crystal shutters, an infrared emitter synchronising the shutters with the monitors frame rate, and a tracking system to determine the actual eye point. The system from CrystalEYES will be used in combination with the 3rdEYE software.

As an input device, the Space Mouse will be used. This device, developed by the German aerospace research establishment DLR, is basically a force stick. However, along with the x- and y-axis, it senses translation force in the third dimension (z) and rotational forces in three dimensions (pitch, roll, and yaw). A 3D audio system will be added in the future. A possible candidate is the *Acoustreon.* This system, hosted on a separate workstation, applies signal processing to given audio data. Given the distance and direction from the observer to the sound source the system filters the audio data such that the observer has the impression of a distant sound source in this position.

The conventional audio periphery centres on a 6-channel amplifier and equaliser.

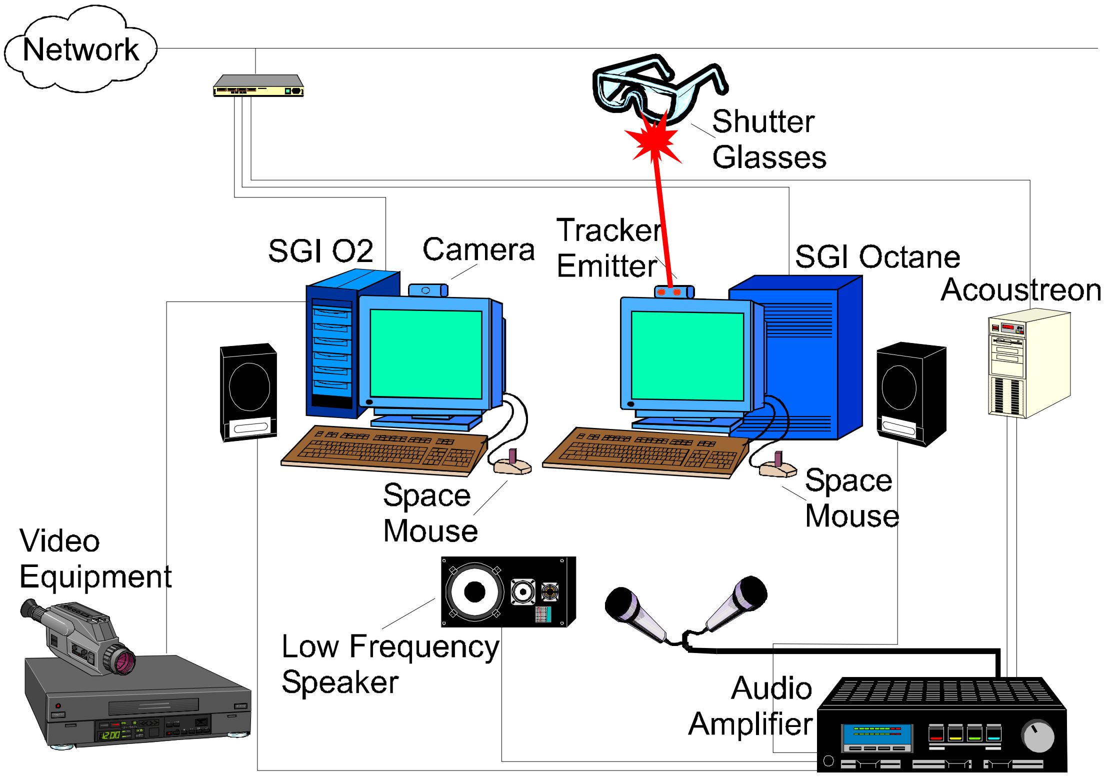

Figure 1: System Components

The two graphics workstations, a DAT recorder, and microphones provide audio inputs signals in stereo. For output, four speakers are placed around the workstations as well as headphones for privacy. The DAT recorder will be used to take high-quality samples of process noise and sounds during field studies. Integration of a special low-frequency amplifier and speaker (subwoofer) or a vibration device is under consideration. Such a vibration device, the *T.A.N. Vibrofloor System* is a disk with 20-cm diameter, coupled to the floor or the operator's chair. It can provide vibrations with a power of 100-Watt RMS with frequencies down to five Hz.

The video option of the O2 workstation provides Essential equipment for videoconferencing. This includes two input-, one output-channel and the monitor-mounted digital camera. A camcorder will be used for recordings in plants. We also imagine the use of portable, helmet-mounted cameras (for, e.g., maintenance personnel) coupled to the control room by radio links. Systems with a range suitable for in-house use are available at a price below 1.000 DEM. Besides this local video equipment, support exists by the universities Media Centre providing professional video cutting and editing facilities.

Both workstations will have access to the laboratories local area network, the universities future ATM network, and the local ISDN telephone exchange. The laboratory's network provides access to several simulators, among those are a high fidelity simulator of a distillation column, cement plant and power plant simulators, a small business jet and a simplified helicopter.

Software Tools

The major software are five components from the virtual reality package of the German company REALAX. The modeller enables to create 3D volumes or to import shapes from conventional CAD data. Objects are than grouped and combined to scenes in the editor, which also provides material properties (colour, reflection, transmission) and surface textures. The scene generated this way is displayed using the real-time component. Additional software in combination with the stereo glasses described above generates the holographic view. Features of this software important in our applications are *level of detail switching, morphing*, and *callback functions*.

Level of Detail switching saves limited computer capacity. Instances of an object are created with different complexity. The close-up view shows the object with all its details. When the distance between object and observer increases, displaying the less complex version keeps the number of polygons in the scene smaller.

With morphing, it is possible to use several (slightly) different shapes of an object and display a weighted average of these shapes. This feature is impressively demonstrated in animated sequence of car crashes. However, we can imagine giving an operator hints on pressure and stress by displaying deformations in boilers, pipes, and joints.

Inevitable in research, when own software extends existing tools or when simulation data will be integrated is a means to access and manipulate of the visual scene. Callback functions hand control to user programmes periodically or on defined events. They also pass pointers to scene data. When control is transferred and data is accessible, the scene can manipulated or information extracted for other applications. Thus, measurements provided from an external simulator can change dials in the scene and information on eye point position can be used for correctly generating 3D audio.

Intended Research Topics

Some of the features wanted for a multimedia control room are already build into or delivered with the computer equipment, such as the *InPerson* teleconferencing tool. This provides a shared whiteboard, on which the local and different remote users simultaneously view and manipulate images and video windows displaying the conference participants. However, the multimedia process control room is a research vehicle. Existing software provide only tools and existing solutions from other areas provide only pointers to own developments. Microphones, speakers, and the camera are standard equipment of modern workstations as they become to be for home computers. Now it will be our task to evaluate existing capabilities of hardware and software as well as known solutions from, for example, the entertainment industry for their use in process control.

Examples for possible use of multimedia in control rooms have been given already above. In all research performed in our laboratory we include the final user in the early phases. Considering the growing awareness of multimedia in present-day life we expect useful proposals from future users. Intended research topics include multimedia-supported co-operation between plant operation, maintenance, and management, management of information, user-support for large multimedia data bases.

Conclusion

The experimental Multimedia Process Control Room is a new vehicle to support future research projects of the Laboratory for Human-Machine Systems in cooperation with industrial partners. It will also enhance lectures and support diploma- and PhD theses.

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