

Some Interactive Multimedia Applications in Manufacturing

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Abstract¹

The authors of this paper give a short summary on the research and development actions carried out and on results achieved in the CIM Research Laboratory in the past years, partly during a Hungarian National Research and Development Program addressed as “Digital Factory”. This paper outlines some tasks solved in relation to interactive multimedia and tele-presence based industrial applications. These solutions may be helpful for test, diagnoses and quality control of the production, or sometimes they just help the operator’s work. The basic research phase of the work was followed by applied research and development, while the concluding phase enabled industrial applications and test scenarios.

1. Introduction

This paper gives some details of the R&D works devoted to interactive multimedia and tele-presence applications for Digital Enterprises and Production Networks (Digital Factory in short). Information technology developments have given faith to system designers to plan for a new generation of manufacturing environment. Some experts tend to call this new era as “digital revolution” in manufacturing, and foresee a time in the near future, when the “old idea” of the “paper-less office” will be replacing the present workplaces. In a similar process as the design and planning, also the execution and control of the manufacturing processes in a factory will (or could) run in a paper-less style, and this vision has led to the birth of a new topic: “running a digital factory” [1].

2. Main Goals of the Research Work

There are several fields within a factory environment, where it is essential to involve human experts to observe, to test, to control and to feel the details of the production

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processes, both in the design and the planning stages, and during the manufacturing, testing and verification processes. As soon as digital technology reaches a complexity within the environment, appropriate digital communication and information processing subsystems can meet the above listed user requirements. These new features raise the quality level, the efficiency, the observability and controllability of the production, but also allow the customer and end-user to actively take part in the processes of manufacturing. Implementing interactive multimedia services for tele-presence, advances the technology of the given manufacturing facility into a new, higher level. Dreams were envisaged to introduce such tele-presence oriented multimedia services within specific production scenarios at several industrial factory sites. The foreseen applications and dreams were giving us an inspiration, and helped us to achieve the basic goals.

3. Tele-Presence from Different Viewpoints

The In an early stage of this research we could realize that the terms we were using were not at all definite for us, and no wonder it was deeply confusing for others, who just started to deal with these phrases. Even after a course of basic technology presentations, newcomers could heavily hinder the progress of our work in defining the detailed work. As it will be shown in the next section, our work had started with a wide range of ‘fundamental underlying technology’ familiarisation, and only after that could we start to focus on a narrow gap for selecting our experimental domains.

As a beginning 3 viewpoints were identified for understanding tele-presence, each of them is in respect to multimedia.

3.1. The historical approach of tele-presence

One of the ancient ambitions of mankind is to overcome our time- and dimensional-limitations. We have gained several great achievements derived from this ambition like writing, telephony, radio, TV and movie. However a new media, the Internet made the real solution possible. The opening of the direct tele-presence research was the

cybernetic tele-operation in the sixties of the twentieth century.

That time the cybernetic model of human behaviour has been worked out. The first definition was formulated by Csikszentmihályi in 1975 [2]: tele-operation is concentrated on some tasks as to render one unconscious of stimuli outside of the task, including even awareness of self and the passage of time. In the beginning of the nineties the tele-presence research changed its focus, and instead of the remote control of an object the sensing of an object became the goal of the investigation [3]. Tele-presence is called "as a compelling impression of being at the location occupied by the slave device" and identified it with the phenomenon called distal attribution, in which a person "externalizes", creating an identification of self to include the external world.

One of the most general definitions of tele-presence was drawn as the ultimate goal of these efforts as to produce a transparent link from human to machine; a user interface through which information is passed so naturally between operator and environment that the user achieves a complete sense of presence within the remote site. Considering the up-to-date intermediate link, the *tele-presence* is the ability to operate remotely in a computer-mediated world. On the other hand a *virtual presence* can also be defined in the frame of tele-presence as experience by a person when sensory information is generated only by and within a computer compels a feeling of being present in an environment other than one is actually in [4]. The virtual presence involves some new definitions, too, such as *virtual reality and augmented reality*. Virtual reality is a modelled environment generally generated by high capacity computers. This environment illustrates a real environment however it has not got any connections with the real environment. Augmented reality works using graphical objects mounted onto the pictures of the real world, and shows an alternative reality of the environment.

3.2. The Multimedia approach

All the previously mentioned definitions contain the time and dimensional independence of the connection of a subjective part and an objective part. We can define the tele-presence as a general and natural set connection of a subjective activity with an object that is independent of the time and the distance. The earlier definitions however did not analyse this connection sufficiently.

The connections in tele-presence can be demonstrated using a 3-dimensional diagram. The 3 dimensions represent the time, the distance or dimensional and the functional connections respectively (Fig. 1). The time variable of this diagram shows how the tele-presence is realized: as real time connection or as a delayed one.

A more interesting meaning of the time domain analysis considers if the previously sensed information can be gained in parallel ("storytelling function"), and – as a new approach – how the information is used in forecasting. In this aspect the scale of the time axis demonstrates the perspective of the forecasting and storytelling ability.

The dimensional variable of the diagram is not a simple distance measure, it means mainly how the object in the sensing environment of the subject or the sensor data of the remote environment are concentrated (positive direction) either in a control room, or in the intranet of an institution or under internet-connected realization. Another conceptual realization of tele-presence is, when not the senses but the virtual realization of the object can be reached in a control room, or in the intranet or in a less concentrated way (negative direction).

The third dimension in the function diagram demonstrates the less analysed connection set. In this axis only the positive half is valid and the scale of the dimension measures how rich is the transmitted information between the sensing subject and the object. The different information forms start from the simple binary codes through the numerical or audio files till the video information or the combination of these. The highest level of the tele-presence function is the physical remote presence using mechanical activities as tele-robotics for example.

3.3. The manufacturing approach

The integration of the appropriate software solutions (CAD, CAM, CAPP, etc.) with the up-to-date manufacturing systems and the computer networks resulted in the paradigm of the computer integrated manufacturing (CIM). The simplified definition of CIM contains the parallel realization of the material and information flow that is necessary for the manufacturing of the product and provides a more efficient production infrastructure. In the information flow we need to follow the manufacturing of the parts (this dimension represents the life cycle of the product) including the assembly activities.

The information must be provided for all the participants of the production such as the designer, quality team, manufacturing staff, accounting and resource management or the general management (this dimension represents the production tasks), and the information must be present in the full hierarchy of the production from the process level to the factory level (hierarchy dimension). A possible information model of the production is demonstrated in Fig. 2.

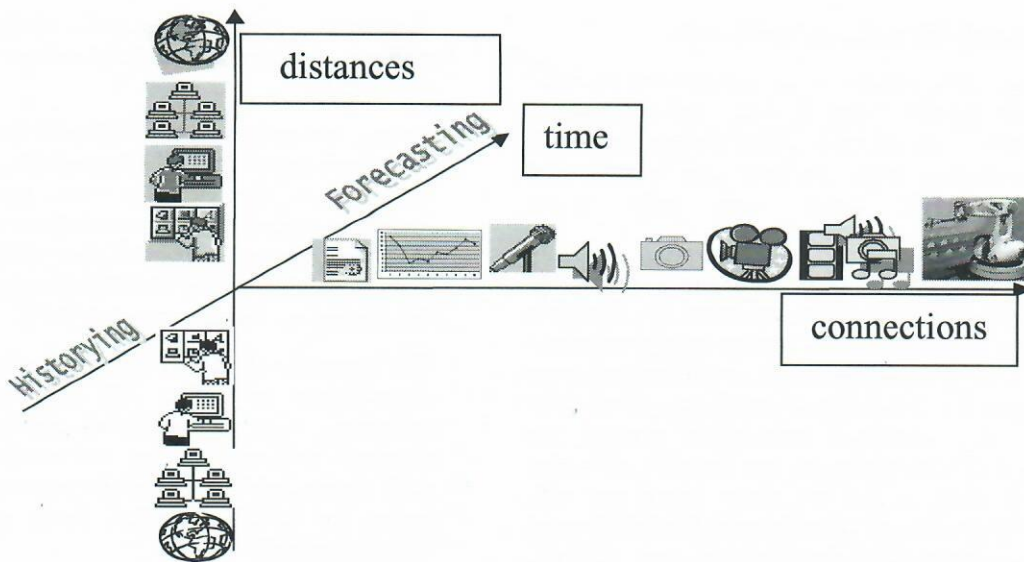


Fig. 1. 3 dimensional demonstration of tele-presence

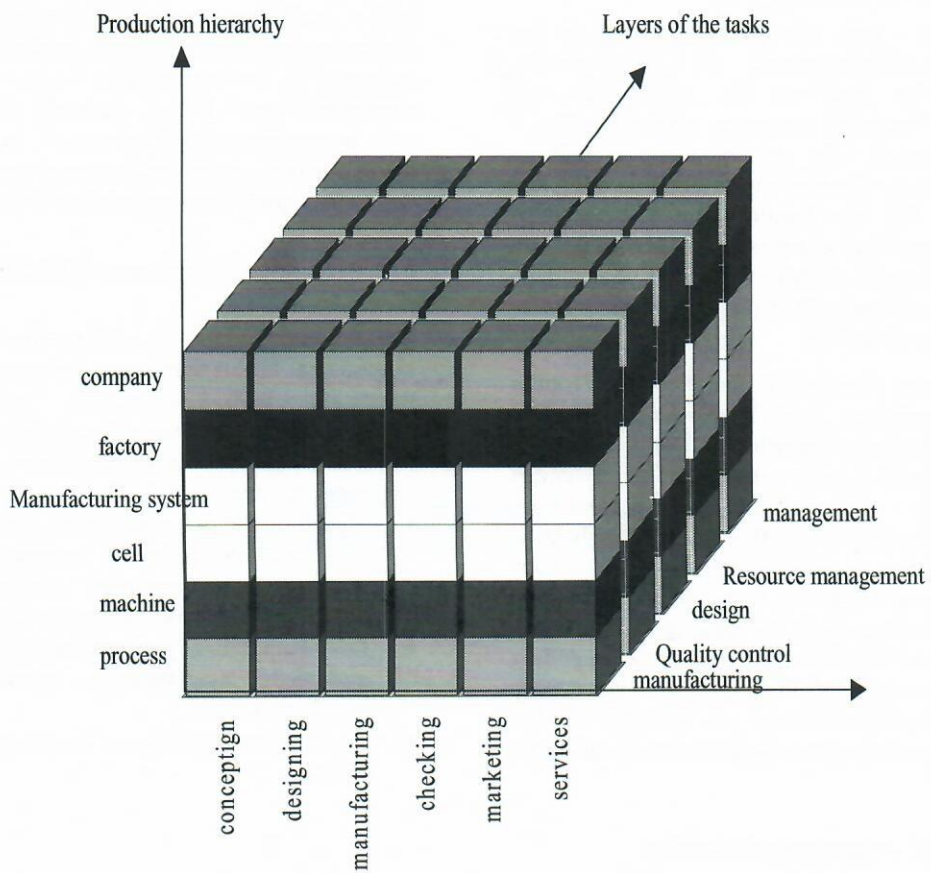


Fig. 2. Information model of a production system

4. Research Directions and Goals

During the first phases of the project we prepared assessment reports, trend analysis and requirement specifications. Based on the RUP design technology [5], new concept was introduced and learned. The following specific topics were under heavy investigation.

Reliability and safety – a trend analysis was produced to give an up-to-date status report on the available techniques and methods. A survey was prepared to detail the most well known industrial and consumer applications for tele-presence operations. Since tele-presence and interactive multimedia involve the integration of human persons, the research work also dealt with man-machine interaction means and with defining VMD (Virtual Manufacturing Device) devoted for human entities within the production area. A survey on wearable computers analyses the presently available technology for applying computer platforms around the human body.

4.1. Wearable Computers, interactive multimedia and tele-presence

A market trend report was prepared based on the available eye-glass-integrated or head-mounted monitors (HMD) and on the technology and architecture of wearable computer platforms. Fig. 3 shows the summary view of the analysed HMD-s. The focus of the research work was preparing the concept of a SW development for a generalized software that enables tele-presence operations with interactive multimedia features. The work that is now called as IMUTA stands for Interactive Multimedia for Tele-presence Applications.

Major effort was devoted to the planning of pilot demonstrator implementations. It was required to find such demonstration sites, which could well inspire the hosts and potential further customers to implement similar functions - and service-intensive applications. Models were developed for the specific application scenarios to derive a generalized framework. Such business models are becoming more and more common and important in the search for gaining market share. One of the steps in business modelling is the modelling of dynamic behaviour of the business. The activity diagram provides high-level (macro activity) view in the process of modelling the dynamic behaviour of the business.

5. Virtual and Augmented Reality

By integrating real-life vision and computer-animated entities, virtual and augmented reality services can be offered for specific user applications.

For this purpose we developed a distributed simulation and visualization environment for flexible manufacturing systems [6]. It enables its users to

visualize the results of a simulation of an FMS with 3D graphics, or visualize the actual data of a real system (see Fig. 4.).

On the client side we use VRML and Java, so we need only a web browser with the appropriate plug-ins to use it. The users can view the scene provided by the simulation system through an internet access, they can see it from the desired point of view and interact with it in the simulation phase. The IMUTA concept supports the integration of augmented reality [7].

The international MPEG standardization body takes responsibility to define and harmonize the new definitions, rules and methodologies for multimedia elements, tools and services. Our involvement was to get a deeper understanding of the present processes and design the IMUTA to allow future evolvement of MPEG standards.

The authors investigated and evaluated several computer platforms for applicability on humans. Special interfaces for mouse operations, mobile functions etc. have been studied to suggest versions for separate and independent IMUTA functions. An experimental wearable computer set up (Fig. 6.) was built in our laboratory with the simplest parts available. The main aims were to give the feeling of the wearable computer to the user and to have it with low cost commercial parts. During the early experiments there were no equipment to determine the local position and the orientation, so the experimental wearable computer was not yet good for augmented reality applications.

6. Enterprise Resources and Multimedia

IMUTA is a Framework of Resource Integration and Multimedia. In this framework we extended Enterprise Resources with multimedia information and functionality. The Extended Resource model provides a richer and more human oriented view of resources and processes, for example:

- Machining might visually be observed real-time and remotely; relevant process data, product drawings, technology plans, quality reports can be chosen and shown according to the needs.
- Documentation of products might be extended with multimedia attachments to ensure the customer satisfaction.
- Customers might observe the production flow of a product.

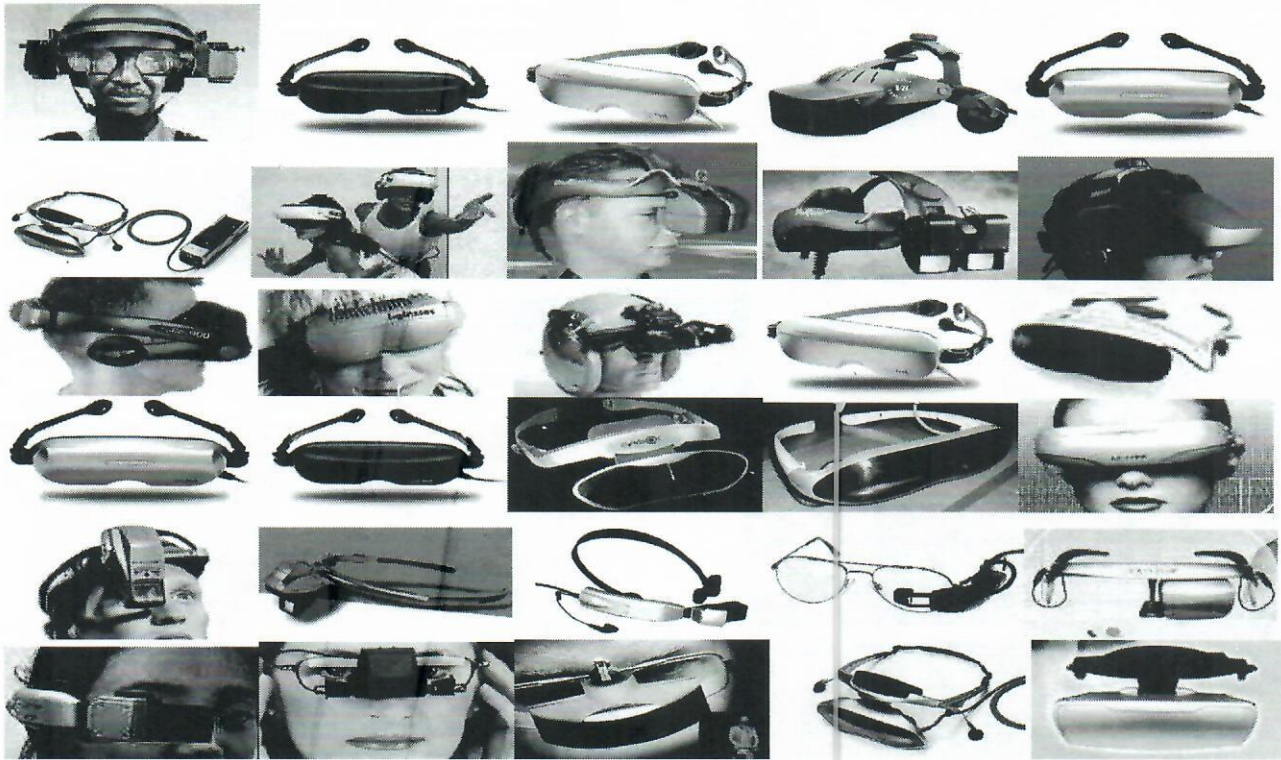


Fig. 3. Analysed versions for Head-mounted Displays (HMDs)

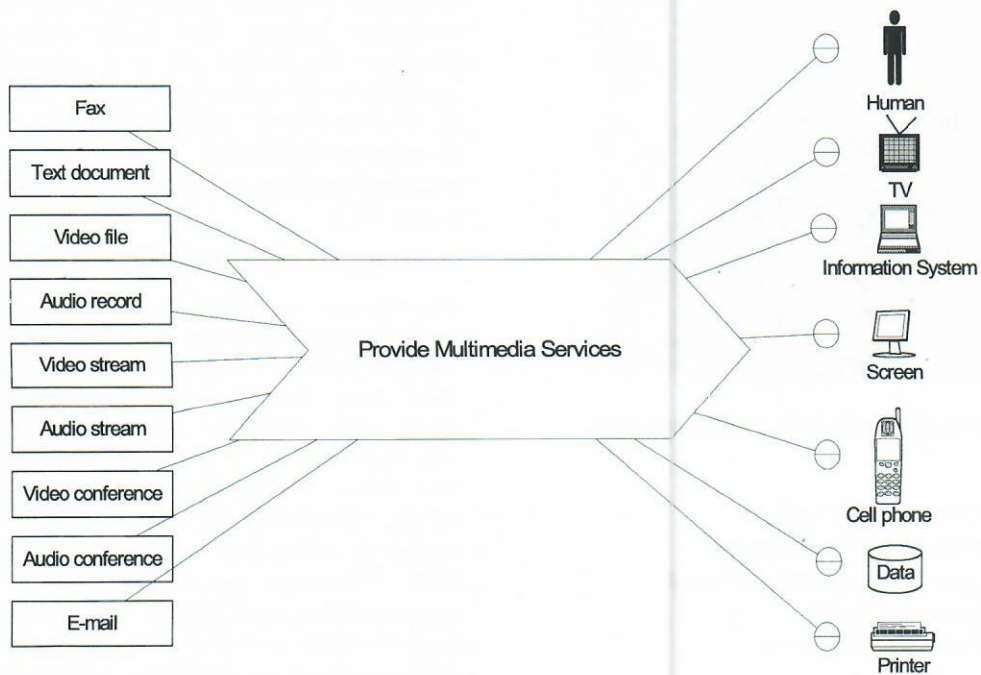


Fig. 5. Process model for providing MM services

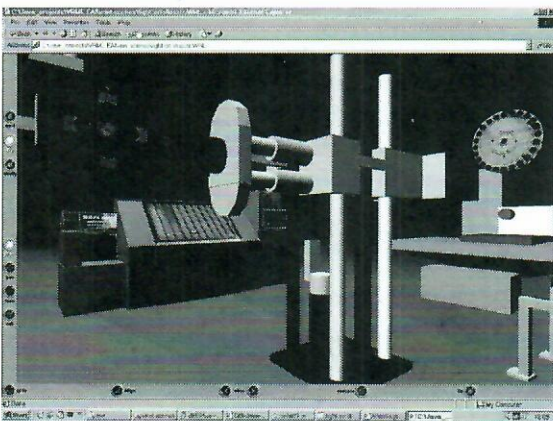
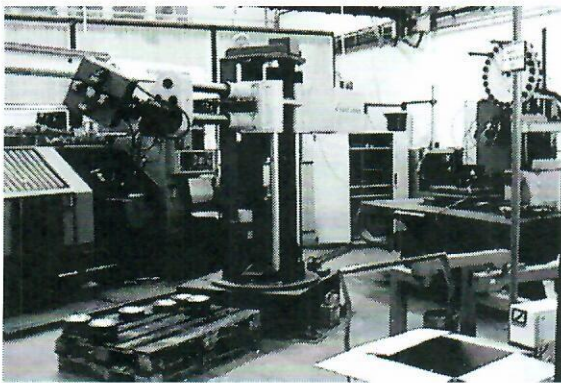


Fig. 4. A real and the simulated manufacturing cell



Fig. 6. Our experimental wearable computer

The framework features as follows:

- Multimedia Document Management
- Media Stream and Process Management
- Semantic Resource Model
- Resource Adapter Architecture

We considered semantic information management as a key issue of the resource integration. In our approach, semantic features make possible to identify the nature and behaviour of the entity. The applied semantic model is flexible and extendible, so we may feed more and more “knowledge” into the system. Since

enterprise resources do not form a well-defined and closed set of entities, the framework provides adapter architecture easy to implement for different types of resources.

The current version supports some key domains (see Fig. 7.):

- Actor: active participants outside of the system, users, software agents, etc.
- Media: media processing entities like streams, cameras, processes, etc.
- Content: entities of the content management system, like storages, files, documents, etc.

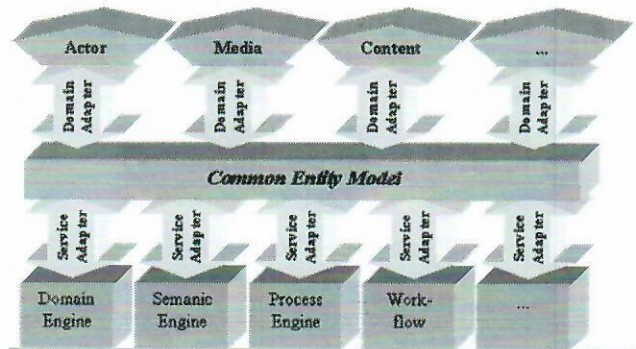


Fig. 7. IMUTA architecture

7. Intelligent document Management

Intelligent documents are aimed to replace traditional document formats, with highly sophisticated new functions for almost all user categories. Besides applying all the multimedia offered data element types, it offers intelligence embedded into the user-interface, it supports tele-teaching, tele-maintenance with guided measurement tasks, self-learning, verification of learnt materials, etc.

8. Multi-User Multi-Task Information

A multi-user, multi-task distributed audio and video capturing, processing and recording system (MUMUS) was developed (see [9]). The system is implemented in Java using Sun Microsystems, Inc.’s Java Media Framework (JMF) to assure portability and easy extension. It runs in Microsoft Windows, Linux and Sun Solaris environment. It uses the OS’ standard media management interface, so a wide range of capturing devices can be used. The software includes fault tolerance routines to limit effects of communication, configuration and resource faults and keep smooth operation of intact tasks and parts. Control is decentralized with different embeddable interfaces and provides flexible management of different tasks.

Developing MUMUS had two aims:

- versatile media playback/transmit/recording system, which could be used in the following

examples:

general-purpose surveillance system with archiving; videoconference system; production process monitoring and event inspecting with circular buffer, etc.

- real-time distributed media processing system. This would require an efficient and loss-less video codec for RTP transmission. Motion-JPEG could be used with care (high-quality settings). The processing algorithms depend on the task, so they are missing, but easy to add.

MUMUS consist of:

- one or more skeletons, to run the processing part on each participating computer,
- tasks spreading to a subset of skeletons of MUMUS meaning a definite task to perform (can be one of the above examples),
- modules, atomic parts of tasks providing functions like capture, file playback or recorder, transmitter, receiver, circular buffer for delay, etc.,
- internal media streams flowing from one module to another,
- sources and sinks which send or receive external media streams (to or from other application)
- one or more controllers, which are embeddable in other application and send commands to skeletons and receive answers, and
- messages to enable communication of skeletons and controllers.

The following example (Fig. 8.) consists of three computers. The first one captures audio and video and transmits them to the second one, which displays both. The video stream is split in the first one and in turn transmitted to the last one in low resolution and is archived. The following figure shows the participating computers according to their roles in this task (one skeleton and the interested controller runs on the same computer).

9. Use-Cases – Business Modelling

By analysing Use cases and applying business modelling with RUP methodology, *business process models* were developed in a sequence of joint work with the end-users [8]. The derived *object models* could be gained from the systematic approach and industry managers could also consult that intermediat level.

The final part of the technology enabled the preparations of the System Use case models. Fig. 9. shows a derived model that upgraded the process within a manufacturing plant.

10. Open System – Further Possibilities

IMUTA contains hooks and existing APIs that allow new and proprietary applications (e.g. home) to be built around remote access protocol. For example, third-

party monitoring and repair services for home appliances with proactive notifications of device failures, "health and wealth" monitoring for vacation homes, medical applications for senior citizens, and many others – all from the same back end installation. IMUTA serves as a tool to allow the partners to be creative as they look to design products and services that add a new stream of revenue, increase efficiency, and differentiate themselves from their competition.

Some of the applications that we offer today are following:

Energy management

Internet enabled wireless thermostats; Load controls (sprinklers, pool heaters, water heaters); Device control; Temperature scheduling (Local and Remote); Load shedding, curtailment, Diagnostics; Usage history

Security

Remote arm/disarm security system; Video verification; Streaming video (Local & Remote); Sensor notification (via e-mail, page, or cell phone). Power on/off controls; Full home automation functionality.

Healthcare

Fall detectors, Video verification for falls, Motioned detectors, Breathing Monitors

Appliance control and diagnostic

Remote Diagnostics, Remote Control, Remote Software Upgrades

Home automation

Streaming video (Local & Remote); Sensor notification (via e-mail, page, or cell phone); Power on/off controls; Door locks; Lights

11. Application Scenarios

Based on the modules prepared, and based on the business case evaluations, test scenarios or "IMUTA IMPLEMENTATIONS" were set up at our industrial partners sites'. Complex structures of media-elements, streams of video and sound - with text and graphics, documentations and PowerPoint presentation slides are managed harmoniously under the IMUTA, to enhance important management functions within production control, supervision or quality control.

Test scenario No. 1: "Customer Witness". When large-scale expensive products are manufactured, the customer has an obligation to pay for its order in instalments, according to the status of the product being prepared, and tested, verified. The visits to the production sites are very time-consuming and rather expensive, but due to legal obligations, most often they cannot be neglected. A long list of actions and tasks are devoted to these verification phases.

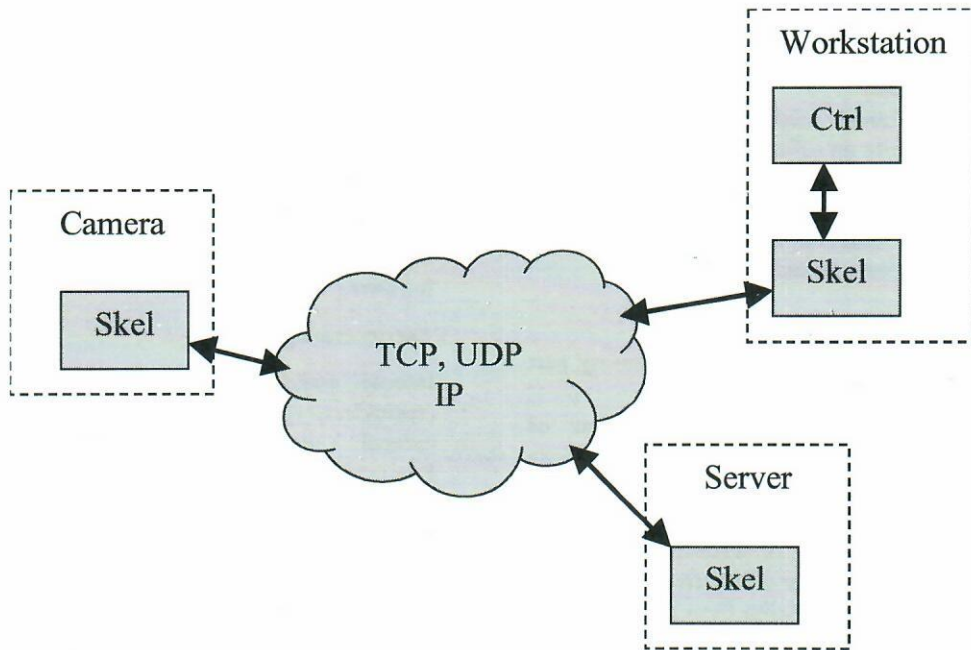


Fig. 8. Editing the project file

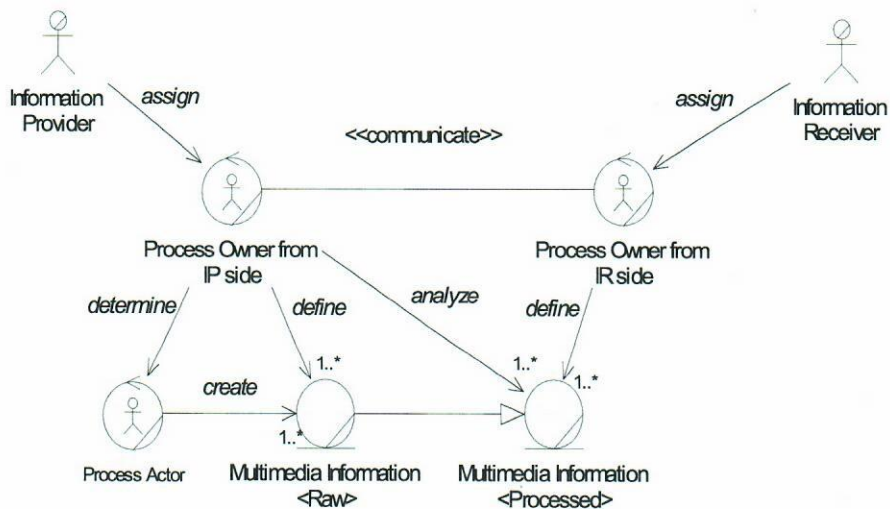


Fig. 9. Example of Business Class Diagram

By applying IMUTA services, interactive multimedia solutions can help in avoiding many of the problems identified and modelled in the definition stage. Not necessarily all and every, but predictably most of the factory visits can be substituted by tele-presence-oriented interactive multimedia.

The IMUTA-based multimedia solution can provide the customer with all necessary information almost online. With a flexibility to run and schedule the test

operations, the customer-representative can see, hear and witness the testing procedure at the very same acceptance-level as through real physical presence. All documents, reports, calibration and measurement devices' output data can be recorded by the measuring devices, while being connected to both the commanding computer node, and also to the video and sound-documenting subsystem.

Test scenario No. 2: "Enhanced trading with internally produced expensive parts". Where large-scale expensive products are manufactured, the parts not reaching the tiniest tolerance or the highest quality grade can still be valuable for another level of customer. A quality inspection point inserted into the production line or sequence will monitor the products, usually one by one. The inspector, who might use high-precision measuring machine, will be able to check for the basic metrical parameters, but not all the problems can be directly seen by the human body's limitations. When second quality grade products appear, the shop-floor engineer must take the decision on that part, to be reworked, or to be disposed, or to accept it as top-quality product. The tested scenario has evaluated in details the actions, activities, information flow and decision making processes, and with business modelling steps, redesigned the complete process. The IMUTA software system helps in the generation of mixed media document items, like text, drawings, video, still pictures with high resolution, and also for voice, all that involves information on the given product piece. The reselling of such "second-grade" products is a good financial activity, compared to the "lost" value, when the piece is just discarded or thrown to the scrap.

Test scenario No. 3: When products are manufactured in a "fast running technological site", – e.g. at a conveyor belt – some activities' effects and real results can only be measured, or tested after certain time has elapsed. When the measurement points out the scrap products or injured modules, already several dozens (hundreds) of products had already been produced on the line. The feed-back time might not be shortened, when the technology can not support it, but the IMUTA software can still help, by storing all production oriented and monitored values, or sights. At our test environment, each minute 30 products are awaited at the end of the transfer line. When problems occur, the dispatcher or service person receives an automatic notice, and the video and other relevant production-related information elements are recalled from the multimedia real-time storage subsystem. The time-stamps, the digital measurements are stored and documented. In a control room environment, the dispatcher or the service personal will have full access to the details of all previous operations, and will be eager to "run back in time". By archiving the key production processes through video and sound and text files, tele-maintenance operations can also be implemented. In this case, the service people – without being trained for a specific action list – will be directed on-line by replaying the canned courses and training sessions.

All test cases proved valuable for the end-user company, and also for the developers to get some feedback on applicability.

Conclusions

We prepared a development work on interactive multimedia for tele-presence by research on several underlying domains. The focus of the work was to develop a generalized software (IMUTA) to allow the easy integration and management of multimedia information flows. The main results are the following:

- a coherent definition on term and terminology of tele-presence, & interactive multimedia (IMM),
- basic research in the field of security and safety in MM application environment,
- specific and general models of business cases,
- a better understanding of the emerging MPEG standards,
- integrating virtual environment interfaces for augmented reality,
- systematic approach for the preparation of industrial implementations.

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