23

COMPLEX OBJECTS AND ANTHROPOCENTRIC SYSTEMS DESIGN

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A new kind of collaborative systems design based on merged 3D-virtual and real media with interchangeable real and virtual components is introduced. This environment is supported by a special knowledge space, that allows the accumulation of concrete haptic as well as abstract physical and logical knowledge. A special kind of complex objects, having a real part and various virtual parts of different levels of abstraction, is introduced. These complex objects allow a synchronous generation and manipulation of coupled real systems and their virtual counterparts. These objects can stimulate itself to simulate their own potential environment. With this mechanism we are able to freely exchange real and virtual parts of a system in a distributed design space. This kind of design environment is expected to support new forms of interaction, suitable for individual traditions, cultures, norms and conventions of design and working styles in networked enterprises.

1. INTRODUCTION

In this paper I will introduce a vision of an environment for the design of balanced automation systems and show first steps of its implementation. It will be shown that even these first steps open already some interesting perspectives for future learning and technology-shaping environments with respect to mechatronic systems. Balanced systems are considered as being optimised not only from a technological or economical perspective but also from a strong reflection about human and ecological aspects. The Dual Design Principle of the VDI[1] (VDI, 1989) is one attempt to support this approach methodological, the Human-Centered Methods (Laessoe, 1989) another one. Our aim is to provide a tool environment for these approaches.

After several projects of simulation support for factory planning, harbour design, transport optimisation we come to the conclusion, that balanced automation solution heavily rely on the interdisciplinary perspectives of broad design teams (Bruns & Heimbucher, 1992). The available design tools of construction and simulation however are not suitable for a transparent support of different cultural, knowledge and interest backgrounds. Systems designer with a special ability in formal language handling are privileged and may play a dominant role in the design process. This would be a contradiction to the presumptions of the above approaches. Faulty implementations, implicit determinations and unbalanced assumptions may be the

[1] VDI-German Society of Engineers

consequence, yielding to real systems different from those planed. Our aim is to support designers by a process of flexible and transparent merging and substituting of real and virtual system components, allowing a fast and easy change of concrete and abstract perspective. Concreteness has always been a fruitful source of new ideas and the improvement of communication (Ferguson, 1993) and therefore should not be omitted in favour of the virtual view.

Coupling tangible objects of real work spaces with information spaces of digital representation has been subject of increasing interest during the last decade. Weiser (1993) set up the vision of a room with ubiquitous computer generated information and action. Wellner et al (1993) emphasized the paradigmatic shift of computer-augmented environments: back to the real world. Fitzmaurice et al (1995) lay the foundations for graspable user interfaces. Resnick (1993) introduced behavior construction kits based on real objects. Since then, many prototypical applications have been published. To name only a few: Kang & Ickeuchi (1994) proposed a concept of programming robots by concrete teaching, the MIT Media Lab is hosting a strong research group working on tangible objects (Ishii & Ullmer, 1997). Suzuki & Kato (1995) use real AlgoBlocks for programming, Rekimoto (1998) developed intelligent rooms, Rauterberg et. al modeling desks with projection and real handles (1997) and a series of workshops now has a focus on the integration of information into real Buildings (Streitz et al., 1998).

Our own vision goes far behind these approaches. Imagine a design environment, a modelling desk, where you can easily switch between a real physical parts and their virtual representation, having a full functioning mixture of virtula and real objects. The computer based model allows different levels of representation of form, function and behaviour of the system. The merging takes place, in that the computer-internal parts of the system are light-projected into the scene by means of a beamer and can replace or overlay real parts on the modelling desk. The modelling desk may even be distributed, so that you are working on one system design in a dislocated way. At one place you have certain parts of the system materialised and the surrounding as virtual projection, at the other place you have the reverse situation. The completely new technology in this merging of realities is the possibility to emulate the physical phenomena of the connections between real and virtual parts by a computer driven mechanism of stimulation. This stimulation is generated by a mechatronical hidden layer.

In a series of papers we introduced the concept of coupling real physical worlds with their virtual counterparts by a graspable user interface and its practical application in domains of robotics, flexible assembly system design and pneumatics (Bruns, 1993, Bruns & Brauer, 1996, Brauer, 1996, Bruns et al, 1997, Bruns, 1998). The basic idea of this concept is the introduction of complex objects (Figure 1). These complex objects have one single real physical part and various virtual, computer-internal representations that may be projected on the screen, wall or table. Real and virtual parts are coupled by a mechanism of pattern recognition, that may be either grasp-recognition of a sensorised hand (data-glove) or by object-recognition with a video-system, sensing the building area. Using a construction kit of complex objects it is possible to synchronously build a real system and generate its virtual representations (Figure 3). The prototypes we developed so far are able to combine real construction kits for pneumatics, robotics and conveyor-systems with

3D-VR models based on VRML, special and general application simulators, help-functions and control systems for programmable logic controller (PLC)[2]. As construction kits we used those from Fischertechnik and Festo Didactic, as simulators we connected DigSim, FluidSim, PneuSim, Cosimir, Simple++. A real object manager (ROMAN) which is responsible for the representation of the real world, serves as a central agent for possible internet clients that ask for a view-service on various layers of abstraction.

The advantages of this approach are manifold. For design purposes, it allows the support of individual, cultural and experience oriented styles, the building of mental models either by starting from the concrete and advancing to the abstract or vice versa. For vocational training it is most desirable to have three kinds of access to a new subject, by hand, head and heart. Müller (1998) recently elucidated these perspectives of learning by model building and simulation. But this approach is expected to be fruitful not only for learning but also for design processes.

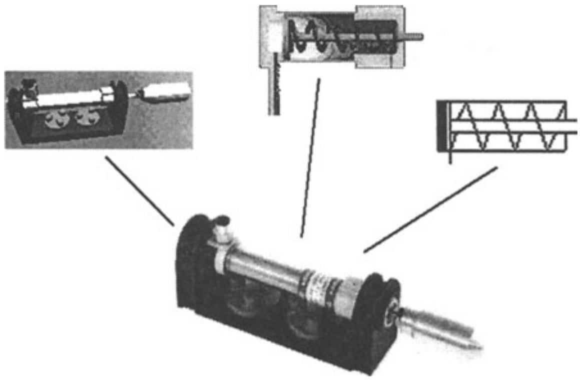

Figure 1 - Complex Object with real and virtual parts

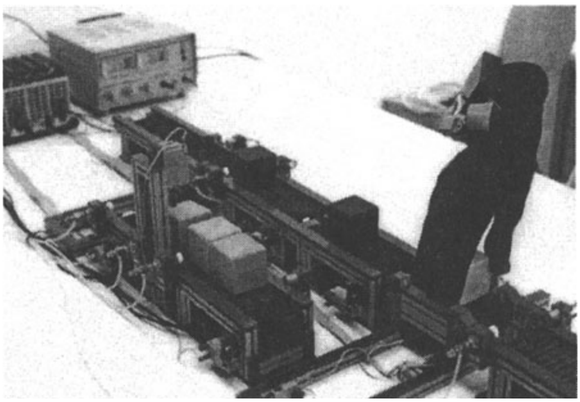

Figure 2 - Systems Specification by concrete Demonstration

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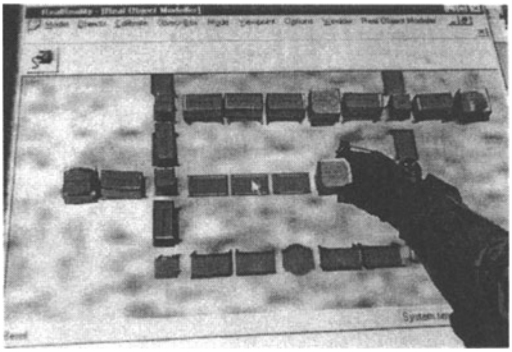

Figure 3 - Synchronous Modeling in real and light-projected virtual spaces

For systems design, it allows the specification of complex systems by concrete demonstration. This is not only the case for geometrical and topological features but also for the dynamic behavior. Thus it is possible to specify the synchronization of several tasks by a role play of different actors generating an abstract representation of this behavior (Petri-Nets). For systems design, this does not only improve the reliability of systems but will also decrease development time.
Furthermore, our concept of VRML-based socket oriented real object management allows the modeling in a distributed environment, having one real system in one place and various virtual representations distributed on Internet.

The synchronization between reality and virtuality is of course only possible, if the user manipulates real components. As soon as one turns to the edition of the virtual system, synchronization is getting lost. This can be fixed, by placing a robot system into the real scene to handle corresponding updates or by supporting the user with a light projection into the scene, to make corresponding changes.

Our prototype for pneumatic-circuit-design with video recognition, developed in the EC-project BREVIE has been evaluated in learning situations (Figure 4, 5) at colleges in Portugal, Netherlands, UK and Germany.

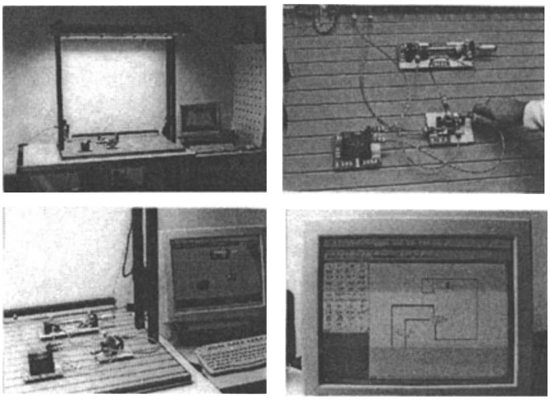

Figure 4 - Coupled real and virtual Learning Environment for pneumatics

It has been argued among pedagogical and design experts, that it would be desirable, if not only a whole real system could be coupled with a whole virtual system, but if we could freely mix virtual and real parts on one level of work. This would allow the construction and simulation of a system on a table, having some especially interesting parts as real parts connected by virtual, light projected links to the virtual environment. Although the virtual parts being only projected into the scene, they should determine the real functioning of the real part. This would allow completely new forms of co-operative distributed design in networked enterprises. In the following chapter we will introduce a concept to fulfill these user needs.

Figure 5 - Evaluation of the learning environment

2. BASIC CONCEPT

Our actual prototype allows the construction of a real system with real parts, mechanisms and real connections and the synchronous generation of a virtual system with virtual parts and virtual connections (Figure 6). If we want to replace real object 2 by a light projection of a virtual object and still have a physical behavior of its neighboring components 1 and 3, we have to serve the open connections by some means of simulated computer controlled stimulation of the concerned objects. This can be done by a hidden surrounding model attached to the real component. For each connection, we only have to provide a hidden junction, a source and a sink for this type of physical phenomena and an electrical controllable mechanism to stimulate and sense all input and output behavior of this junction.

Removing a real part and replacing it by a virtual one, would require the disconnection of all real wires or tubes from the real object and connecting them to the own hidden connectors, forming a closed loop on the remaining real object. This procedure corresponds to the well known technique of stubs and drivers for software-testing. The behavior of the real object remains physical real, but its connections to the virtual parts are stimulated by its hidden surrounding mechanism (Figure 7).

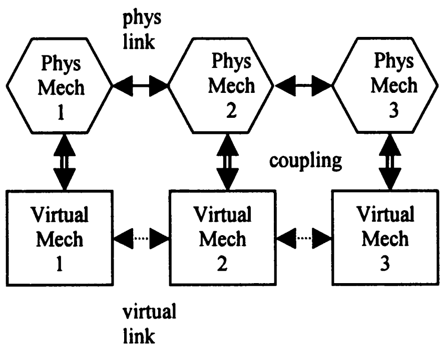

Figure 6 - Links within system boundaries

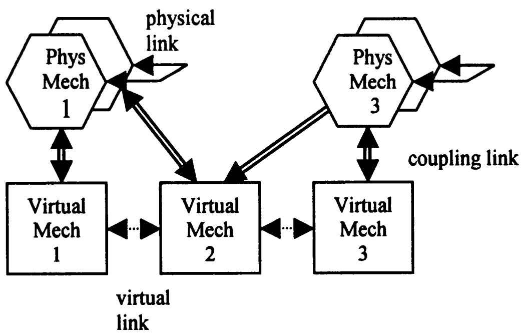

Figure 7 - Links across system boundaries

This concept may sound utopian. However, in electro-pneumatics we have exactly these mechanisms that could provide the hidden behavior. For other areas they have to be developed. Figure 8 shows the "virtualization" of a pneumatic cylinder.

Figure 9 shows a different implementation. The electro-pneumatic hidden layer is attached to the foreground pneumatic mechanism, in this case an AND. The open pressure tubes of the real parts are connected via a connection ledge to some hidden mechanism, driven by electro-pneumatic components controlled by a PC. The recognition mechanism identifies the correspondences.

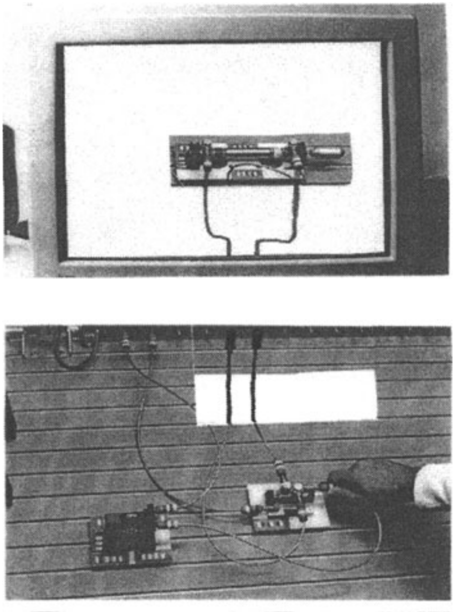

Figure 8 – Reality with a hole

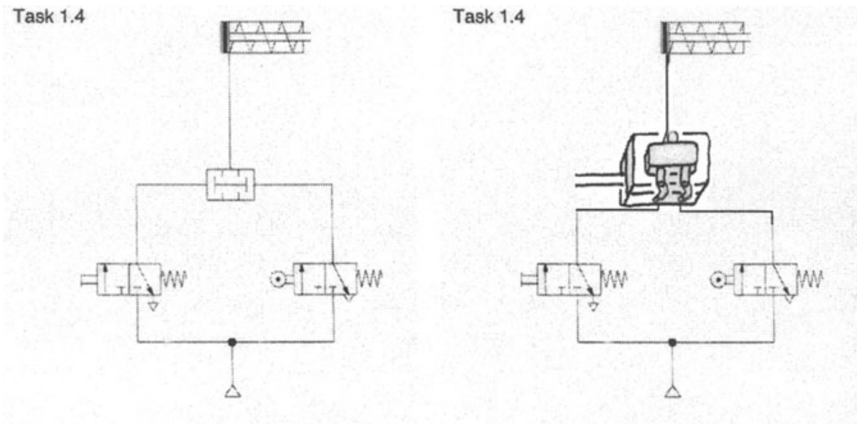

Figure 9 - Virtual pneumatic AND and a merged version

In generalizing this concept for mechatronic systems, we could be able to build very powerful learning- and design environments that allow the study and experimentation of concrete physical objects embedded in a larger complex system that might even be distributed over different places, being materialized here or there and virtualized at other places. Unified concepts of system description in terms of causal-functional representations and ONTOLOGIES would help to build such a system. In a new European Project (DERIVE – Distributed Real and Virtual Learning Environment for Mechatronics) we are developing a first prototype of this concept for the application field of electro-pneumatic systems design Figures 10-11.

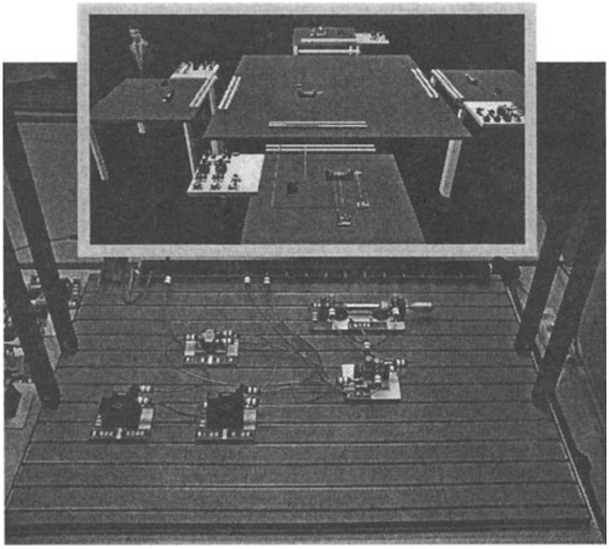

Figure 10 - Real Subsystem of a distributed whole System

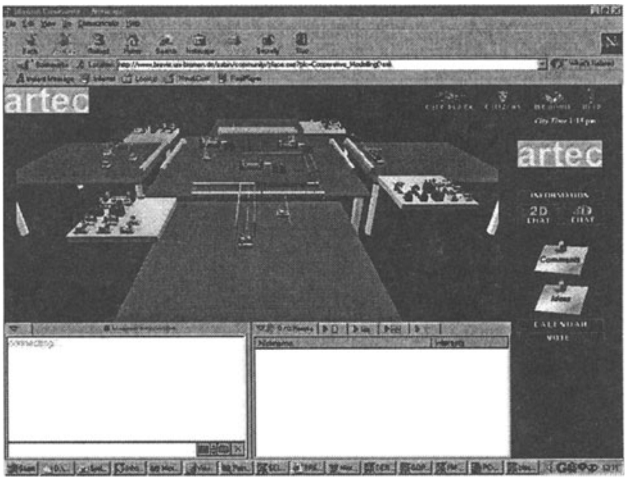

Figure 11 - Distributed Design Environment

Imagine an application scenario. Some system designers, production experts, skilled workers and managers are standing around a modeling desk, discussing some features of the planed system by talking and demonstrating dynamic behavior by gesture and use of concrete bricks. Thus, they come to a first version of a static and dynamic model of the automation system, let say a conveyor belt system with working cells and buffers. At the beginning, the modeling bricks are just dummy parts without behavior. During the building of the real model, the computer generates by some recognition mechanism a representation that can be projected into the modeling scene. Now you specify the dynamic behavior and detailed structure and function of all parts and their connections. This may be done by selecting certain existing behavior patterns from a library or by specifying it through some mechanism of concrete demonstration or abstract programming. Now you can have a projection of the simulated behavior into the scene and validate it. The control mechanism driving the simulation should automatically be generated and remain the same for the control of the later real system by PLC. The system can be evaluated immediately. This would open not only new perspectives for system design but also for remote service support.

3. CONCLUSION

By introducing a new kind of agents with hidden surrounding models, we enable a collection of connected elements to be a mixture between real and projected virtual parts. Thus, complex circuits of many parts may be designed computer-based, being viewable on a screen or a video-projection on a table, while some parts of the system are present in real physical form, allowing a stepwise look on real phenomena and their behavior under certain constraints. This procedure would not only help to reduce complexity for learning purposes. The implemented surrounding model would also help to modularize and facilitate systems design and test.

4. ACKNOWLEDGMENT

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