# Mixed Reality Web Service
# "Air through the Internet"

Martin Faust, Wilhelm Bruns
Research Center for Work-Environment-Technology
University of Bremen, Germany
{faust, bruns}@artec.uni-bremen.de

## Abstract

*A distributed and collaborative Mixed Reality Web Service is presented. The service integrates real and virtual, local and remote media under one common interface. The service makes Mixed Reality experiments accessible via WWW.*

*A key feature of the system is the tight coupling between the virtual and real world by using HyperBonds. The system is available 24 hours a day for exploration and experimentation. Only some special plugins has to be installed on the client computer.*

## 1. Introduction

Increased attention to Mixed Reality has lead to different prototypes that allow connections between the real and virtual world (e.g. by image recognition [17] or augmenting reality [1, 14, 19]). Fitzmaurice et. al. [7] laid some foundations for graspable user interfaces, resulting in a research program "tangible media" at the MIT [12]. Bruns et. al. [5] demonstrated how automation systems can be specified, in reality and virtuality, by grasping and gesture oriented demonstration. The BuildIt System [8] uses real handles to control simulation and visualisation in a colocated cooperation setting. With Studierstube [18] it is possible to cooperate on the design of geometric objects projected as virtual image on user specific head mounted devices construction one common virtual space of interaction. But until now there are only few examples of Mixed Reality Web Services for experimental e-learning available (e.g. [22]).

The presented system introduces a new level of distributed and collaborative e-learning platform (see Figure 1). Local and remote users can work together on different levels of abstraction ranging from real objects, three dimensional virtual worlds up to symbolic representations. The environment supports bridges between the real and virtual world with integrated simulations.

A key feature of the system is the function of freely replacing virtual parts by real ones and vice versa. With a special kind of coupling between the computer and real hardware, it is be possible to build hybrid systems which are a mixture of real and virtual parts.
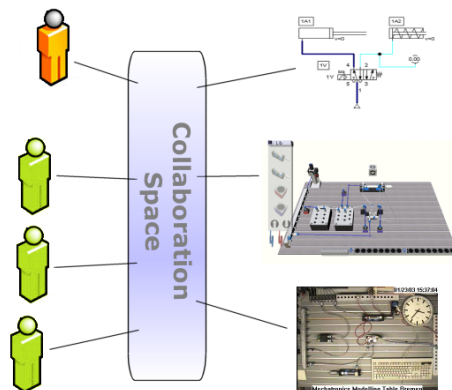


**Figure 1. Mixed Reality Collaboration Space**

Bruns [4] developed a tight coupling between reality and virtuality by introducing HyperBonds. HyperBonds follow the Bond graph [13] theory, a unified view on physical phenomena from a continuity of power-flow perspective. They can be used to describe dynamic behaviors of different physical domains with one formalism.

Changing a real setting normally requests a change in the interface but with HyperBonds it does not. This general purpose interface transmitts phenomena (air pressure, electrical potential, ...) from one side to the other. The direction is automatically determined by the flow in the system. If there is real voltage on a connector then virtual voltage is generated or vice versa. The flexibility of the coupling by HyperBonds makes the system adaptable to new requirements on the fly – even while a session is running.
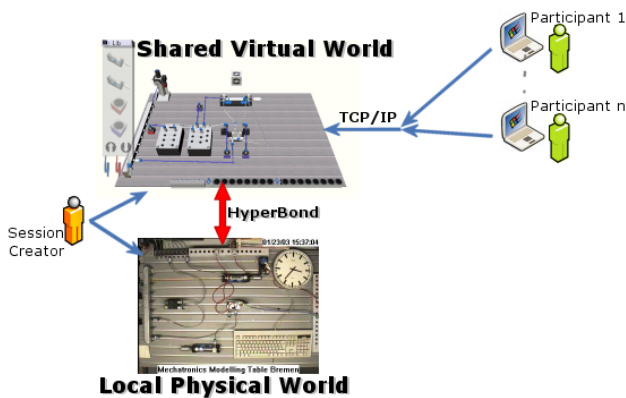


**Figure 2. Sample Setting of an Experiment**

Figure 2 shows a sample setting of an experiment. Local and remote users are working together via a shared virtual space – all are modifying the same virtual scene. In addition the system supports connections to local real hardware by the use of HyperBonds. The coupling mechanism is based on transmitting phenomena (e.g. air pressure) from one side to the other. Both sides do not know anything about the setting of the other world. Modifications in the real world do *not* lead to an update of the virtual world if they have no influence on the HyperBond interface. But if they have, the virtual simulation model reacts accordingly.

Distant users may view a live video stream from the real hardware. In Figure 2, a session creator is working on real hardware and a shared virtual world. Other participants are connecting over the Internet to the virtual world and work only on it. It is possible to have more than one link to real hardware (there is no limitation either in the number of participants or number of real hardware connected to the experiment). Having multiple real hardware integrated we refer to the experiment as "cross reality" because we are crossing the borders many times.

## 2. Mixed Reality Web Service

The system was implemented as a Web Service to take advantage of the possibilities of the WWW, like:

- Available 24hours a day

- Accessible from any computer connected to the Internet

- Hypermedia based help system

- Easier to maintain.

The Web Service provides a multi-linugal e-learning environment for Mixed Reality experiments. Following later variations of Activity Theory – namely the Theory of Expansive Learning [6] – the user learns through exploration and examination without being restricted by traditional task settings and open for an integration into local work context. In order to support free exploration and experimentation a lean management system was implemented.

The service supports the IEEE Learning Object Metadata (LOM) Standard, which can roughly be summarized as: *To enable learners or instructors to search, evaluate, accquire and use Learning Objects.* LOM helps - by its standard vocabulary - to integrate the different experiment notations and expressions into one framework. Also other applications (course tools, web portals, search engines) may use this information to link to experiments running on our platform. LOM definitions are readable for computers but it does not really make sense to present them directly to humans. Instead there is a processing step inbetween that prepares a readable form for the user (e.g. generates a special HTML page). Figure 3 shows the integration of LOM into the platform.

Figure 4 shows an overview of the design. Central module is the MR Server which realizes the Web Service (based on the HTTP/1.1 [9] standard). It processes HTTP requests and also manages the sessions. In addition to this, every file belonging to an experiment is stored on the server: VRML models, HTML pages, teaching material, background information, videos, ... .
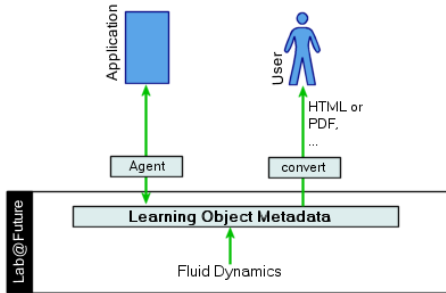
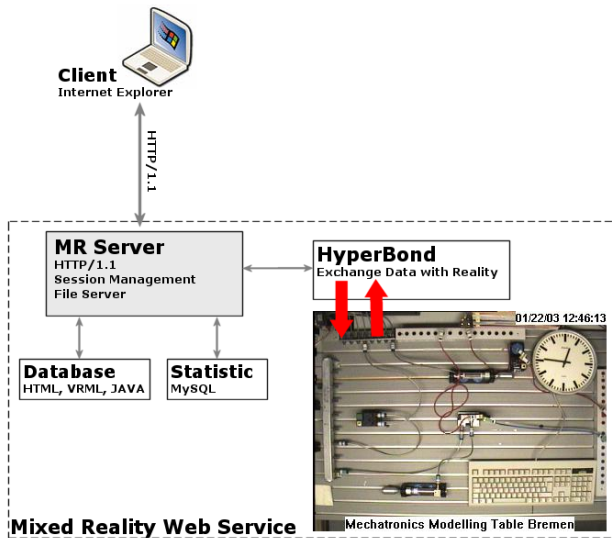**Figure 3. Integration of LOM**



**Figure 4. Web Service Overview**

The Web Service supports multi-lingual content by evaluating the language in the HTTP requests that are sent from the users Browser(Accept-Language entry in HTTP/1.1). Content, feedback and help are shown in the corresponding language. If no supported language is found a default one is used. Switching between languages is possible by reordering the language tags in the Browser.

The statistic module keeps track of access to the system but does not monitor any experiment. As a nice gimmick we are using Caida's NetGeo library which maps IP addresses onto geographic locations. [15].

### 2.1. Front End

The WWW front end is an HTML page including our Virtual Construction Kit (VCK), a video stream and a chat window.

Figure 5 shows a screenshot of the front end. The main component is the VCK, a VRML based tool for assembling virtual worlds. By dragging and dropping objects from a library onto the working area new elements are added to the scene. Each object has a number of connectors which can be linked to other ones. Links can either be tubes (air pressure) or wires (electrcity) in the current implementation.
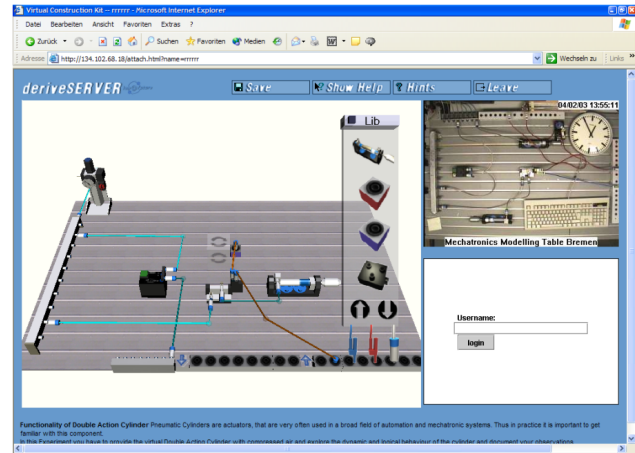


**Figure 5. Virtual Construction Kit**

Part of this scene is the HyperBond object (here at the bottom of the scene) which has two parts: a real and virtual one. Any flow into this object is automatically forwarded to reality or vice versa (simulation is running over real and virtual parts).

Changes in reality are distributed by an updated simulation but also by a camera observing the real hardware. Instead of using a simple WebCam a H.261 coded video stream is used. The continuous video stream allows better image quality and advanced update rates.

The virtual part of a running session can be stored on the server and reloaded later to continue the experiment.

### 2.2. Implementation

The Mixed Reality Web Service is implemented in C++ using a free HTTP/1.1 library. Requests are processed by this application and sent back to the user. Each server has a specific XML configuration file with the following information:

- General settings

- Definition of supported languages

- Errors/Strings in supported languages

- Experiment descriptions

  – Name and short description

  – Link to background information

  – Applications to launch.

If an experiment is started, the experiment is added to the list of running ones and can be entered by other users. If a session is terminated by the user or by death of a started application all used ressources are automatically freed.

The front end is build using HTML, Java, JavaScript and VRML because of previous work. The video stream is displayed by the Java Media Framework.

## 3. Experiments

The Mixed Reality Web Service is located at http://lab.artec.uni-bremen.de. After the index page has loaded, the user is guided through a set of pages where he can create new or join experiments, get help or additional materials.

In order to create a new experiment a template must be selected (see Figure 6). The templates are settings with different tasks to solve. After filling some additional parameters (name, scope) in, the experiment is created and ready for use and participants can join now.

The creator of an experiment has the right to terminate the experiment. Joined clients have the same rights but cannot terminate a session. There is no further distinction between the clients. Normally an experiment is open to everyone (public scope) but sometimes this is not sufficient because everybody can join the session at any time without any restriction. Therefore a private scope was added where a session is password protected. Only persons with the right password can join.

Figure 7 shows the system in action. Part a) shows a circuit for an oscillating cylinder. If the virtual air pressure is turned on, the cylinder drives oscillating in and out. Part b) shows the Mechatronics Modelling Table that is connected to the HyperBond. Now, parts of
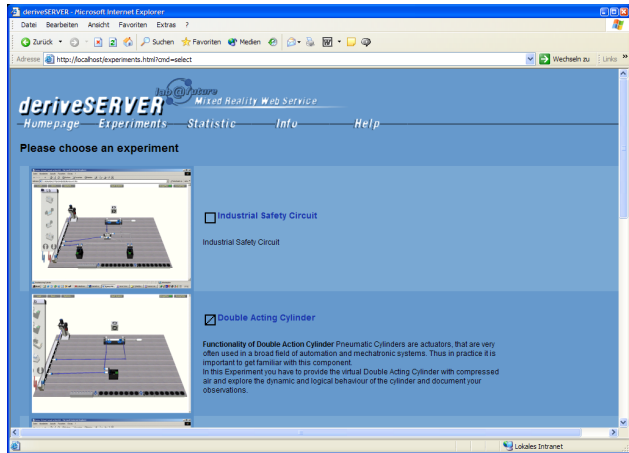


**Figure 6. Select an experiment template**

the virtual circuit can be placed in the real world preserving the overall functioning of the circuit. This is a special setup used for teaching mechatronics but the system itself does not require this Mechatronics Modelling Table hardware.

## 4. Evaluation

We evaluated this environment in various classroom settings in Europe and presented a prelimary version at the 2001 SuperComputing Conference (see Figure 8) in Denver, sending "Air through the Internet" from Denver to Bremen and vice versa.

In our last workshop "Experiments in a Mixed Reality Learning Environment" we invited teachers from interested schools. In the workshop teachers met the first time and nobody knew anything about the learning environment. In contrast to previous testings now the teacher was the target group and not students. The main purpose of the workshop was to give them the opportunity to get practical experience with the new tool and to receive comments from them about the prototype.

The teacher welcomed the idea of the Mixed Reality learning environment, especially the HyperBond concept was considered to be very fruitful in vocational training. After a short presentation of the project and the principal concept of the intended learning platform they began to experiment with the learning environment. For this purpose artec had prepared the outline of three experiments. The teachers were not at all
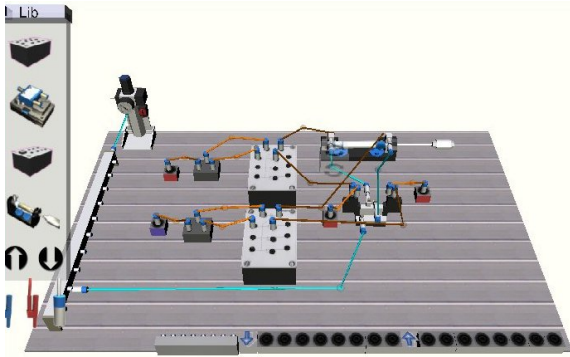
Figure 7. Assembling a scene in virtuality and reality



Figure 8. Presentation at the SC2001 Conference

afraid of playing with the hyperbonds platform. They had no problems to understand the tool. The experimenting phase took more time as foreseen because the participants were immersed in the platform and a lot of comments were immediately given while experimenting. Participants agreed in experimenting with our platform via the Internet interface and to continue the beginning discussion in further meetings.

## 5. Conclusions

The presented Mixed Reality Web Service integrates real and virtual, local and remote media under one common HTTP based interface. The main features are:

- Running 24hours a day,
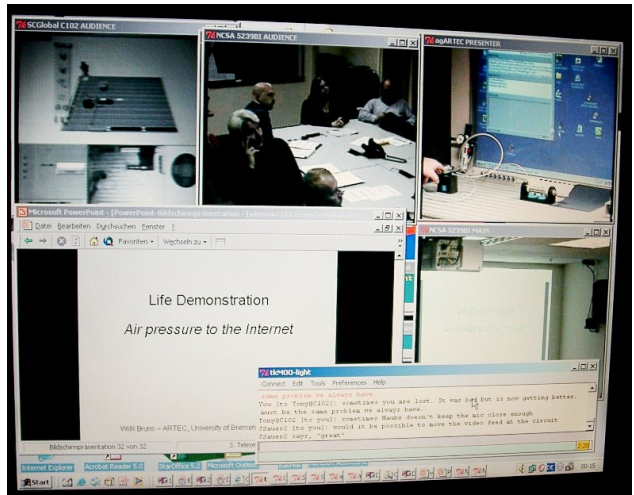
- Accessible from any Windows based computer,

- Only standard plugins must be installed and

- Tight connection to reality.

There are some restrictions to the 24h per day uptime when real hardware is used in an experiment. Some components don't have an unlimited number of resources and therefore need a reset after an experiment has finished. Also there are some security reasons arising. In order to work correctly some components had to be monitored by humans.

The supported bridges between the real and virtual world with integrated simulations are a unique feature of this service. It allows considerable freedom in the experiments. By connecting different Mixed Reality Web Servers together different real hardware can be integrated into one experiment.

Mixed Reality Web Services are a first step to ubiquitous access to reality from virtuality and vice versa.
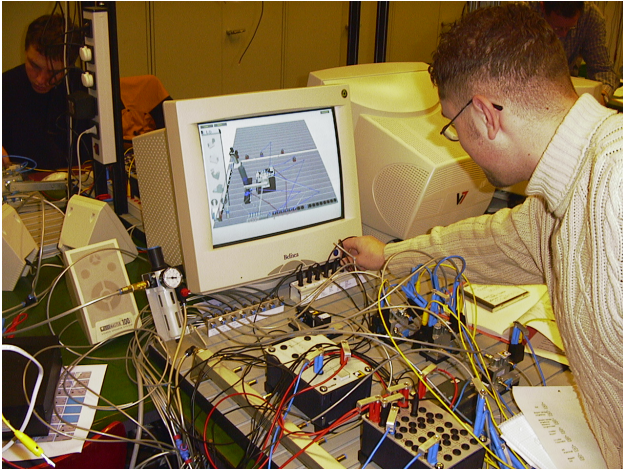
## 6. Acknowledgement

**Figure 9. Complex mixed reality experiment**

(Lab@Future [10]) and integrated into further development in MARVEL [11].

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