

# Virtual and Remote Laboratories in Cooperative Knowledge Spaces

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*Abstract - Cooperative knowledge spaces create new potentials for the experimental fields in natural sciences and engineering because they enhance the accessibility of experimental setups through virtual laboratories and remote technology, opening them for collaborative and distributed usage. A concept for extending existing virtual knowledge spaces for the means of the technological disciplines ("ViCToR-Spaces" - Virtual Cooperation in Teaching and Research for Mathematics, Natural Sciences and Engineering) is presented. The integration of networked virtual laboratories and remote experiments will be described.*

## I. INTRODUCTION

Focusing on the social aspects of communication, coordination and cooperation, cooperative knowledge spaces possess a high potential to support the learning, teaching and research processes at universities by the means of new media and new technologies. "ViCToR-Spaces", currently under development at Technische Universität Berlin, focus on the enhancement of virtual cooperation in teaching and research in the fields of mathematics, natural sciences and engineering presenting novel collaborative working environments for knowledge acquisition and research as well as supporting natural forms of scientific and technological cooperations.

Cooperative knowledge spaces use a generalized "room metaphor" [5] as a guideline. They provide a virtual meeting point where interaction, communication and collaboration take place. The environment as a whole is defined by the combination of its dynamically linked objects, i.e. members, documents, tools and services [7]. Hence, the design of those components and the way they are linked is the key issue to successful cooperation and knowledge acquisition.

Experiments play a vital role in natural and engineering sciences, thus their presence in form of virtual and remote laboratories in a cooperative knowledge environment is strongly desirable. We will have a closer look at cooperatively performed

experiments in section III, explaining why they are so essential to ViCToR-Spaces

## II. THE CONCEPT OF VIRTUAL ROOMS

Most community-based systems follow a room-based approach as it supports synchronous as well as asynchronous and mixed scenarios of cooperative learning [12]. These systems are composed of multiple rooms offering different functions. The function of a room derives from the number and character of the room's users, the attached tools and the assigned rights in the room. Different combinations of these components form different types of rooms. Following this principle, it is possible to design and create rooms for work groups, rooms with teaching material or laboratories with special virtual equipment according to the respective requirements. The users of such a system can decide on their own if they want to work in cooperation with other users or if they just want to solve tasks and study in their own work rooms. In addition, there is the possibility to build rooms as a mandatory element of a lecture series. Students will have to pass some of the rooms (e.g. a laboratory) on their way through a seminar before the successful completion of the lecture series is accepted.

Special function rooms such as room solely for teaching material or for a laboratory provide a clearly arranged structure of offered learning units in contrast to rooms containing all material of a complex lecture series. For example, a course consisting of a lecture, a seminar and a hands-on experiment can be distributed over three different rooms, which are presented in sequence or in parallel.

By assembling rooms with different functions in sequence or in parallel, a whole virtual university with lecture, seminar, workshop or laboratory rooms with virtual and remote labs can be built up.

By this means, a user can be virtually supported in all phases of a course, scientists from different institutions and locations can discuss their research achievements and approaches or perform experiments in virtual and remote laboratories - all in one virtual building.

The “ViCToR-Spaces” room concept does not provide the rooms in a hierarchical structure as it is characteristic for currently deployed cooperative knowledge spaces [6, 7]. We are not designing a static root-to-leaf structure but rather a dynamic, heterogeneous network, known in philosophy as a rhizome [4], such that each user will obtain a different view on the room structure of the system - according to the rooms which the user is interested in and related to.

The user can be assigned to certain rooms supporting their individual profile, e.g. to the rooms of a course the student is attending in this semester. Additionally, users can delete and add rooms constructing their individual network of rooms. The different perspectives of the users provide many different views on the room structure. The rooms define a new way of knowledge management.

The room will be built in a successive way. Thus, the function of a room will be constructed from three components as already mentioned above:

- room related rights
- specification of the room users
- used tools and communication interfaces

These room components will be elaborated in the next three subsections.

#### *A. Room-Related Rights*

Unlike a physically existing room a virtual room can be built and completely deleted in short time. It is obvious, that not every user can be allowed to change or delete every room in the system. Room related rights are needed. On the one hand, they refer to creating, deleting and changing a room. On the other hand, they define pre-conditions for the access to the room.

For rooms that can or should only be used by a limited number of users, access can be controlled by bookable timeslots. Every user is assigned to limited time slots to accomplish an experiment in a laboratory.

As another precondition for the access to rooms a special test room can be added upstream such that the users first have to successfully complete the test before entering the next room. Following this principle, i.e. the serial operation of completing a test, booking a timeslot and finally accomplishing the hands-on experiment an artificial bottleneck is created. This is especially important in cases of special laboratories where users need previous knowledge for accomplishing a certain experiment.

#### *B. Specification of Room Users*

In most “real life seminars”, three or four students form a work group to solve the tasks of the seminar

together. In this case the room should “know” the identity of the group members to restrict the access to the room to this user group alone. All participants have equal rights in the room concerning the modification of the room. The users' own work room would represent such a user-restrained room. Only the user himself can access his own work room.

There are also rooms that only should be accessed by a certain number of users e.g. in remote laboratories. In this case only the number of users who have access to the room is restrained without specifying certain users.

A third possible type of room user specification is the access to a room by all users.

#### *C. Tools and Communication Interfaces*

As a third function component the room can be previously filled with tools and communication interfaces, according to the room function.

Communication interfaces are important elements in virtual, cooperative work. In our room concept we provide chats, discussion forums, email and a VoIP function. Not all interfaces need to be attached in all types of rooms. Small groups can manage a clear information exchange in a chat or VoIP session. In larger groups such communication sessions can get unmanageable. In turn, smaller groups might not require a discussion forum.

Shared Whiteboards provide a consolidated graphical work area for all room users. All participants are able to work with the same set of objects on the board. Similarly to a chat client the written and drawn objects are shown identically on all participants' boards. Shared Whiteboards can be used both in synchronous and asynchronous manner. Geographical and chronological distances are bridged with version-controlled sessions and documents. Scientists from Berlin and Shanghai can thus work cooperatively on scientific problems.

Virtual und Remote Labs are mainly used in education for engineering and natural sciences. These installations are an important issue for providing access to laboratory equipment independently from time or financial means. As in both laboratories parameters can be manipulated, controlled and read off different measurement instruments can be attached and combinations of virtual and remote labs for the same physical effect can exchange parameters and other information. In this way, output from a virtual experiment can be verified by the physically existing experiment. Experiments - be they virtual or remote - integrated in a virtual knowledge space can exchange any kind of information.

### III. EXPERIMENTS IN VIRTUAL SPACES

Experiments form an important part of learning, teaching and research within the technological disciplines. Integrated into a cooperative knowledge space, they provide better access to experimental setups for all students, independent of limitations in time, budget or access to classical laboratories- thus forming one of the most important parts of the ViCToR-Space concept.

To enhance access to experimental setups, there are two principle alternatives [9]: Virtual laboratories use the metaphor of a “real” scientific laboratory as a guiding line [8, 10]. The software design focuses on emulating scientific hands-on experience in virtual spaces. In theoretical fields such as mathematics and theoretical physics, virtual laboratories have revolutionized education and research as they allow an intensive experimental access to abstract objects and concepts. They are capable of building bridges between the theoretical fields and experimental sciences.

Complementary to virtual laboratories, remote experiments are real experiments, remotely controlled by the experimenter from outside the laboratory [11]. They are based on a technology which allows true experimenting from a remote location at almost any given time. The different approaches have a number of similarities, and enrich each other through their differences: remote experiments allow the investigation of real objects including hands-on measurement experience, which does obviously not hold for virtual laboratories. On the other hand, virtual laboratories are capable of constructing an experiment, whereas this kind of flexibility is hard to imagine or implement in remote experiments.

#### A. System Architecture

As said in [3], ViCToR-Spaces, in its first prototype, will be built on top of the CURE system developed at FernUniversität Hagen. Nevertheless, many concepts similar to those in CURE can be found in other room-based platforms for collaborative learning, e. g. sTeam [7]. CURE (“Collaborative Universal Remote Education”) is a web-based platform for collaborative learning which is based on combining the room metaphor with WIKI concepts and communication tools [6]. CURE is implemented as a set of Java Servlets. The implementation strictly follows the “everything is an object” philosophy. I.e., rooms, documents, users etc. are realized as plain Java objects to which a simple, but efficient persistence mechanism backed by a DBMS has been added. Basic operations in CURE are made available to external applications through a SOAP-based Web Services interface.

The core concept of CURE - and hence of ViCToR-Spaces, - is the room metaphor [5]. A virtual knowledge space as defined by CURE is subdivided into virtual rooms. In CURE, rooms are arranged in a hierarchical, recursive, tree-like structure. The root of this room structure is a so-called entrance hall which a user sees first after logging in; the other rooms are arranged “below” this root. Each room offers communication channels such as chat, threaded discussions, e-mail or instant messaging among group members as well as documents provided as a Wiki page or created by external applications and integrated into the room. The communication interfaces and user awareness features are always tied to their room as well as documents are always associated with the room there are created in. It is possible, however, to simply move or copy documents from one room to another. Managing different versions of documents is essential for cooperative work. CURE’s version control allows branching and is able to detect versioning conflicts in documents edited concurrently. Being geared towards mathematicians, natural scientists and engineers, ViCToR-Spaces unconditionally has to support formulae not only in documents, but in all components, most notably communication tools. CURE allows rendering formulae as PNG images.

Cooperative work requires an appropriately flexible rights management for group workspaces and documents. CURE supports this through its concept of virtual keys. The user who created a room may pass on one or more of these keys to one or more of the other users. Keys may be associated with three groups of rights: room related rights, communication and document related rights, and key related rights. Consequently, groups are defined implicitly by ownership of a virtual key to a room.

#### B. Integration of Remote and Virtual Labs

At the core of our concept to adapt CURE for the special requirements of mathematics, natural sciences and engineering there is the integration of experimental settings. Experiments play a vital role in these disciplines, thus their presence in ViCToR-Spaces is strongly desirable. As a rationale, virtual [8] and remote [11] laboratories must be treated and integrated uniformly (i.e. as a “black box”) wherever possible. Experiments - be they virtual or remote - are to be held in a so-called “warehouse”. There is only exactly one instance of each experiment present in the virtual knowledge space. Using links, experiments can be integrated into each room. Quality of experiments uploaded to ViCToR-Spaces is assured in a two-stage process: First, they are uploaded to what might be called a “submission hall”. There, they are checked automatically for technical correctness, and propriety of their semantic classification. This is to

prevent, e.g., an experiment on electronics to be classified as an optics experiment, rendering it undiscoverable for an electronics teacher. For providing this automatically, developers of experiments must provide them with appropriate metadata (s.b.). If the automated checks are passed, a human user assesses the experiment for scientific soundness. It is up to him/her to finally transfer the experiment from the “submission hall” to the “warehouse”, where it is made available to other users.

### *C. Java Web Services and Modularization*

#### **Service Broker and Java Web Services**

In order to provide “lab services” we will implement a “service broker” in the current knowledge space system for java web services. The Service broker will manage different tasks between the integrated components and the system. As one task we will provide the communication between the different laboratories - virtual and remote labs - as web services. The labs will be able to exchange information with each other. In case there is a virtual and a remote lab investigating the same physical effect the devices are considered to exchange measurement results to e.g. prove the effect from the virtual lab in the real experiment of the remote lab. Also, we will supply web services between the knowledge space and the laboratories - for example to assign a laboratory to a certain group of users while in use. As another implementation there will be a time booking system for remote laboratories. A time slot reservation will be communicated to the knowledge space system through a web service routine. The web services will also be used for saving the measurement results in the knowledge space. All offered services will be registered in the service broker integrated in knowledge space system.

#### **Use of Metadata Standards**

Over the last years many different types of virtual or remote laboratories have been developed in almost every university or research institute. One of the main aims of our project is to integrate these software laboratories in our knowledge space system in a way of a “black box”. This will provide reusability and interoperability as well as a modularity for both integrating our components in other systems and components from other institutions in our system. We will use approved e-Learning standards to assure interoperability and reusability. In the last years only a few standards have been established. For our project we shortlisted the Dublin Core metadata element set, Learning Object Metadata (LOM), and the Sharable Content Object Reference Model (SCORM).

In our project we will decide which standard works best for our requirements and the components to be integrated and the virtual knowledge space system. The

corresponding standard will then be combined with a semantic description to create ontologies between the integrated components and other appropriate documents:

#### **Semantic Description of Objects and Ontologies**

In the current knowledge space system different types of documents can be integrated and made available for other users. Our further developments will provide these documents, our integrated remote and virtual labs and other possible components with a semantic description using RDF, XML and/or SPARQL. As e.g. SCORM 2004 already uses XML binding for the metadata description (defined in the Content Aggregation Model [1]) and for building sequencing rules (defined in the Sequencing and Navigation Book [2]) we will combine such types of standards to derive an e-Learning object with completely machine readable semantic descriptions. Furthermore we will build ontologies between the corresponding components and documents. Users will be able to find respective documents or remote experiments in the system after e.g. completing a virtual experiment in a laboratory.

Semantic Web technologies form the basis to achieve these goals: The Semantic Web aims at augmenting the existing World Wide Web with machine-readable semantics, making the content of today's Web accessible to intelligent queries and machine reasoning. Taking a more abstract perspective, Semantic Web is concerned with the semantically meaningful and well-defined description of abstract resources, for instance documents, graphics, data streams etc. which allow machines to access and deal with abstract resources. In contrast to standard (i. e. not semantically annotated) resources, semantically annotated resources can be integrated automatically and processed dynamically (without deep and detailed prior agreements between the providers of different resources).

## IV. OUTLOOK

In the past years, the main focus in developing eLearning and eResearch technologies has been on stand-alone applications and solutions for specific tasks. Today, modern approaches in the design of the architectures required show that the integration and interconnection of independent, single components play a central role in providing diverse, comprehensive functionality and addressing a broad, heterogeneous user spectrum.

As a result, we face two serious challenges: First, research and applications are increasingly oriented towards semantic content encoding as a prerequisite for interconnectedness on a content level and towards integrative technologies for software components as “Web

Services/Semantic Web". Second, integration on a social, community-oriented level, that is, support of communication and cooperation structures and shared workflows, is becoming more and more important. Not realizing that communication and cooperation in a virtual world will even facilitate one's need for mobile and freelanced access to knowledge we currently face a knowledge landscape of widely spread developments and unequally distributed knowledge.

Crosslinking existing knowledge repositories and developments will open knowledge and technologies to students, teachers and researchers beyond geographical limitations by advancing the building of virtual communities.

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