AUTOMATIC CONTROL LEARNING MANAGEMENT SYSTEM BASED ON WEB SERVICES AND SEMANTIC WEB

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Abstract: Although interconnected computers are beginning to play an ever more central role to automatic control education, the software used today differs significantly from university to university, from platform to platform. Therefore a unified approach to computer-assisted learning has been sought and a system using semantic web and web services has been developed. This paper describes the architecture of such system designed at Czech Technical University and its advantages over the current Learning Content Management Systems.

Keywords: remote control, semantic networks, wide area networks, control education, learning

1. INTRODUCTION

The recent spread of the use of computers in general and the continuous growing reach of the Internet in particular is changing the way automatic control is taught. Many new learning content management systems (LCMS) have emerged from the need to allow easier management of the content stored within these learning systems (sometimes also referred to as e-learning systems) (Grabowska, 2004). While in areas such as psychology, history or law the tools offered by these systems are sufficient to support the educational process, in the case of automatic control it is not often so. It is mainly due to the rather abstract nature of control engineering and the higher need to experiment, to have experience with hands-on activities, to use trial and error techniques and other approaches (Dormido, 2003; Gentil and Exel, 2004).

Although there exist many computer-based systems today (Gillet, 2004) which allow many of the above mentioned approaches and techniques to be carried out, the interoperability of these systems is often very limited, if not impossible.

Therefore a unified approach to incorporating access to virtual labs, simulation tools, modelling and remote control environments as well as the traditional educational content has been sought.

2. CURRENT LEARNING CONTENT MANAGEMENT SYSTEMS

There exist many currently available learning management systems of different quality and functionality today, some of them being WebCT, Thinq, Pathlore, GeoLearning, Click2Learn and KnowledgePlanet. However it must be noted that the content that is stored inside of these systems is to a large extent "trapped". It is very difficult (and often impossible) to access the content other than through the supplied user interface, which in many cases may not be suitable, especially for the needs of automatic control engineering education. Although LCMS developers and the e-learning community have invested significant energy into the standardization of the content format and its portability among different LCMS (known as Shareable Content Object Reference Model – SCORM), this effort only makes it possible to transform the content from one LCMS to another; it does not allow other systems (not LCMS) to connect to the content from the outside and therefore the content still remains "trapped" (Tamáš and Šulc, 2004b).

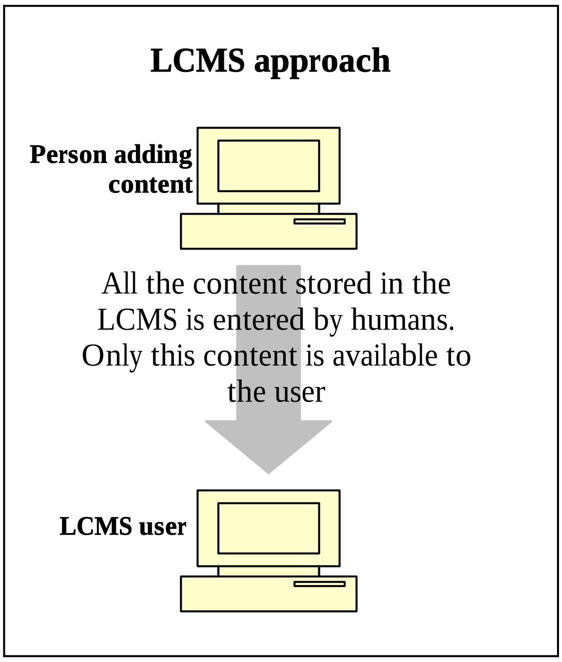

Fig. 1. LCMS approach to content management. The extent to which content is transferred from the system to the end user is limited by the capacity of the person(s) creating and updating the LCMS content.

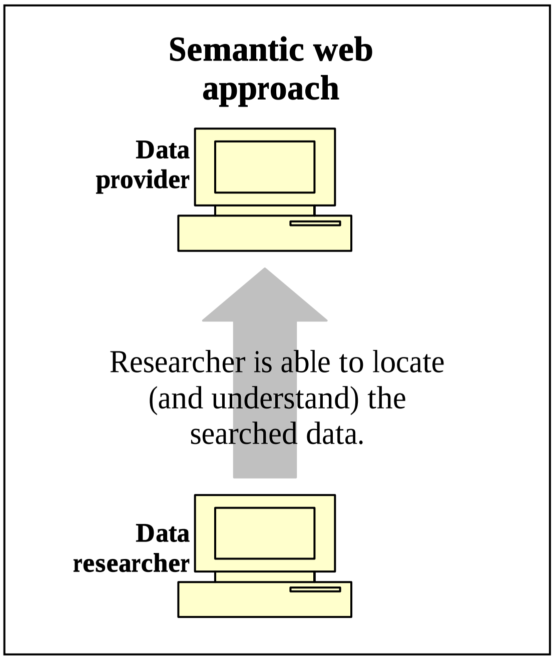

Fig. 2. Semantic web approach to content management. Content is stored on many Web servers across the Internet and the researcher is able to locate the desired information using sophisticated queries.

It is also necessary for the teachers or special personnel to enter the data to the system manually. The system does not make any use of the data available on the Web, as shown in Figure 1.

Also to be noted is the relatively high price of these systems.

3. SEMANTIC WEB BASED LCMS

From a point of view of the available content, the biggest limitation of the LCMS is the fact that only content manually entered in the system makes part of the learning process that the users can experience. Even though today's LCMS are almost always Internet-based, they do not make any use of the relevant content which is already published elsewhere on the World Wide Web (the Web). Partially the reason lies in the fact that it is very difficult for a computer application to gain a deeper understanding into the content available on the Web today.

Semantic web (World Wide Web Consortium-SW, 2004) aims at describing the data published on the web in a way that will allow computer applications to better understand them. Figure 2 shows basic Semantic web architecture.

The efforts currently being undertaken at the Department of Instrumentation and Control Engineering of Czech Technical University focus on building a Learning Content Management System that makes use of the semantically described data available on the Web today and in the near future for the purpose of automatic control engineering education both at our institution as well as in other countries (Tamáš and Šulc, 2004a). Special attention is given to the usability of the designed system in the developing countries as one of the authors has several years of hands-on experience with development education in Africa.

The currently designed system consists of the following parts:

- Semantic Web Browser
- Content Publisher
- Spidering Engine

The Semantic Web Browser (SWB) is similar to the normal web browser, with the difference that it navigates through local or web-based XML documents and transforms them using specially created XSLT transformations. These transformations have been created so that a simple HTML document can be displayed from the "raw" XML data. It is planned to expand these transformations in the future so that much richer user experience can be achieved. This will be done once more automatic control-related documents are described in XML.

The Content Publisher (CP) is a tool that helps transforming content in a form suitable for the Semantic web-based LMS. This word processor-like tool allows the content-creator to go through an already existing document and enrich it with the necessary semantic metadata using the mouse or the context menu. To simplify the content creation even more, efforts are currently undergone to incorporate this tool in Microsoft Word using the Smart Tags technology to make it possible to create semantically described content from the word processor that many scientists use today.

The Spidering Engine (SE) searches through the web looking for semantic web pages of interest. It can also be ran on the background to index pages with interesting content. The search criteria can be changed by the user of the system to reflect the area of interest.

4. WEB SERVICES AND SEMANTIC WEB BASED LMS

With more experience gained during the design and implementation of the semantic web based LCMS it became obvious that using the semantic web approach did not allow incorporation of more sophisticated and necessary learning content specific for the automatic control area, such as access to virtual labs, simulation tools, modelling and remote control environments. Since these environments consist of more than mere text, graphics, animation, video or sound (which can – with smaller or higher degree of difficulty – be described semantically) and include the element of interactivity, other unified approach has been sought. The aim was to make sure that the designed LCMS would allow not only passive "consumption" of content, but such that would enable also interaction through open standards-based architecture.

Web services have been chosen as the preferred choice mainly for the wide-spread adoption, the high potential and the fact that they are based on open standards (Tamáš and Šulc, 2003). The name of the system was at that stage changed from LCMS to Learning Management Systems (LMS), mainly due to the fact that the system no longer contained plain content, but it also started to allow user interaction.

4.1 Closer look at the LMS architecture.

The parts of the designed LMS and the implementation methods are shown in Table 1.

The Syllabus and the Virtual labs have been placed at the core of the designed system. They represent the virtual counterparts of the real educational process parts: the lectures and the exercises (labs) respectively.

The Syllabus is located in the Semantic web part and serves as the main study material for the students and contains the necessary theory. Closely associated with the Syllabus are the Lecture notes. They serve as a guide to the weekly lectures carried out as part of the course. Assignments are also located in the Semantic web part as they only represent instructions given to students for their homework and therefore do not need to have any web services functionality.

Student presentations (which may include reports, research texts, measured data and other materials) can be uploaded and become a permanent part of the learning management system, thus bringing new content. This content is valuable mainly for students who will come in the next years as it may provide them with additional information which was previously not included in the system. This tool is advantageous also from the point of view of the lecturer as it provides him/her with a very valuable feedback about the level of understanding of the studied material. The student presentations have been placed partially outside of the semantic web part of the system, as not all the uploaded content has to be semantically described.

The Virtual labs have been placed mostly in the web services part of the system, but partially also in the semantic web part. Closely connected to the Virtual labs are the Modelling, Lab Remote Control and Simulations tools. They represent the different tasks the student can undertake while working with the Virtual labs. Modelling refers mostly to using Matlab to study the behaviour and control various systems. Lab Remote Control and Simulations refer to running experiments on real remote systems and simulating them respectively.

The results of experiments ran using published web service methods (both running on real plants and simulated) are described semantically and published on a web server, allowing others to locate this data through a semantic web browser. This is a very advantageous approach as no extra work is needed on the side of the experimenter and the results of his/her work are made available immediately to other students and researchers interested in the studied phenomenon. This feature can be switched off for the purpose of evaluating students' work and preventing undesired cooperation among different groups of student.

Internal mail is in this case implemented as a simple web service in order to avoid further complexity of the system (which would be unavoidable if POP3 or SMTP protocols were used) and to allow the users of the system to exchange e-mail messages related to the studied material.

Search function has also been implemented as a web service. However it is also possible for the client connecting to the LMS to implement its own search algorithm that would fit the needs of the user of the system. As most of the data stored in the LMS is semantically described, the search can allow sophisticated queries like "Show me all the results from experiments ran on real plants in our university that were collected no longer than a year ago".

Quizzes in this system have been implemented as a web service and allow students to test their level of understanding the studied material. They also provide feedback to the lecturer and allow for necessary adjustments in the course program if necessary.

Calendar is a standard feature in most of the available LCMS and allows teachers and students plan their activities in a common virtual "space". In this system, web services are used to interact with the calendar and produce and publish semantically described data in the semantic web part (in the case of the Calendar using the iCalendar RFC2445 W3C standard). The same is valid for Chat and Discussion tools. Therefore these three tools are located on the boundary between the semantic web and web services parts of the system.

Table 1. Different parts of the LMS and their implementation methods

LMS part	Semantic Web	Web Services	SW and WS
Syllabus	X		
Virtual labs			X
Remote Experiments		X	
Simulations		X	
Student Presentations	X		
Assignments	X		
Internal Mail		X	
Search		X	
Quizzes		X	
Calendar			X
Chat			X
Discussion			X

4.2 Available LMS Web Services.

The designed system has a modular architecture and as such allows for easy addition of new tools and features. However, some basic functionality has already been implemented in most of the above-described tools to serve as a proof of concept and for testing purposes. It can be found at pc-305c-5.fsid.cvut.cz/lms.

Each tool of the LMS has been implemented either as web service, semantic web page or combination of both, as shown in Table 1. This allows easy manageability and placement on different computers, should the load require so. Links to available web services are provided both in the HTML version on the LMS homepage (for programmers when designing clients) as well as UDDI for programmatic access. In the second case clients will continue to operate even when the hosted web service is moved to another computer.

The web services, methods and their descriptions that have either been already implemented or are under development are listed in Table 2.

4.3 Available LMS client.

The designed system can be used either using custom-made client software or using a web browser with necessary plug-ins. To show the functionality and potential of the system, simple custom-made client software has been developed. The client software is called ACES (Automatic Control Education Software) and is currently available for download in beta version at pc-305c-5.fsid.cvut.cz/aces.

It consists of a semantic web-enabled browser, web services browser and a special set of custom made controls. The semantic web browser creates browsable HTML pages from semantic web XML documents using the XSLT transformation. The web services browser is a specially designed browser that uses the UDDI to locate the relevant web services and allows easy navigation through them. In cases where a known web service is recognized, the set of custom made controls is enabled allowing the user to interact with the selected web service.

As stated previously, the system can also be controlled using a web browser with necessary plug-ins. These plug-ins were not yet designed at our department, but due to the open nature of the solution anyone is free to design their own browser plug-in. This plug-in can connect to the chosen web service and interact with it based on the aims and educational intention of its creator. Unlike with other systems of similar kind, the user interface in this case can be designed so that it will fit the needs of each particular case and reflect user preferences.

5. ADVANTAGES OVER PROPRIETARY LMS

There are several different points of view at the advantages that this approach has in comparison with the proprietary learning management systems.

From the point of view of content, the biggest advantage is the fact that content is not "trapped" inside the system but is open to the users of the Web – partly through the semantic web pages and partly through the functionality of the web services.

From the point of view of user functionality, the described LMS based on semantic web and web services allows easy integration of tools such as modelling, remote lab control or simulation into the learning system. It provides the possibility to include the outcomes of the users' work into the system, which brings added value and allows students to learn from other students' learning process. This can significantly lower the load on the lecturer and can stimulate student cooperation resulting in quicker and more efficient learning.

Furthermore, the fact that the client software can be written by almost anybody significantly broadens the scope of the potential use of each web service – be it anything from a remotely controlled heat-exchanger experiment to a simulation of a coal-fired power plant. The educational setting of the Virtual lab can more closely reflect the intentions of the teacher or the experimental nature of the students.

Table 2. List of web services, methods and descriptions, which make part of the LMS

Service	Methods	Description
RemoteLabControl_HeatChamber	StartSession, SetSetpoint, SetP, SetI, SetD, Start, GetControlledVariableValue, GetSetpointVariableValue, Stop, GetResults, PublishResults, ResetToDefault, EndSession	Service providing remote access to a laboratory experiment Heat Chamber with PID Controller
Simulation_PIDControl	StartSession, SetSetpoint, SetP, SetI, SetD, Start, GetControlledVariableValue, GetSetpointVariableValue, Stop, GetResults, PublishResults, ResetToDefault, EndSession	Service providing remote access to a Matlab simulation running on the server.
Modelling_CustomSystem	StartSession, UploadCustomSystem, Start, Stop, GetResults, PublishResults, DeleteCustomSystem, EndSession	Service enabling the user to upload and run custom-made Matlab simulation.
Modelling_Stability1	StabilityFromTransferFunction, StabilityFromPoles	Simple service determining the stability of the given system.
Quizzes_ControlTheory1	StartSession, GetQuizz, PostAnswer, GetResult, GetFinalResults, EndSession	Service allowing the user to test his knowledge using quizzes.
Search	SetQuery, ExecuteQuery	Service allowing the execution of remote queries.
InternalMail	PostMessage, GetHeaders, GetMessage, DeleteMessage	Service providing access to internal mail
Calendar	PostEvent, GetEventsInDay, GetEventsInMonth, DeleteEvent	Service providing access to internal calendar
Chat	PostMessage, DeleteMessage	Service providing access to internal chat
Discussion	PostMessage, DeleteMessage, CreateThread, DeleteThread	Service providing access to internal discussion

From the point of view of manageability, being distributed this system does not have the single point of failure and therefore should be easier to manage over time. However, this has yet to be proven in the following months and years.

From the point of view of resources, there is a significant advantage in the fact that the system is based on open standards and modular custom-made client software and therefore does not require the acquisition of an expensive LCMS.

6. CONCLUSIONS

Learning Management System based on Semantic web and Web services principles represents a relatively new approach to learning with the support of computers and the Internet. Its biggest ambition is to overcome the difficulties in sharing content created for different Learning Content Management Systems. At the same time it aims at resolving the difficult implementation of more complex forms of computer assisted learning such as running remote laboratory experiments, simulations or modelling systems into a compact, open, standards-based learning platform. It does so by choosing semantic web standard with special automatic control related ontology for the storage of content and web services for the interaction with the remote real and virtual systems.
The experience gained so far is not yet sufficient to lead to final conclusions, however the feedback received so far both from the students and the academic community has been a positive one. The significance of the described approach to computer-assisted learning will be considerably higher once more content is available on the Web in the semantic web form. The potential of the system will also be evident when more automatic control-related web services are available from different universities and research institutions.

7. ACKNOWLEDGEMENT

This research has been supported by the Grant Agency of the Czech Republic No 101/04/1182.

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