Implementation and testing of the requirements for the bandwidth of the eLearning system

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Abstract **-** In this paper elements of eLearning system developed at the Silesian University of Technology have been presented. The main idea of the system is to provide distance lectures for students including persons with different disabilities. The system uses audio, video and text messages transmission and in this part it is similar to videoconference. Additionally system is prepared to handle special channels with data for handicapped persons. The teacher can present the lecture in traditional way and transmit the presentation to remote students using the Internet. The system consists of three parts: streaming server, control application and presentation application. In this paper the short description of the system has been presented with description of testing of requirements for the bandwidth.

Key-Words*:* - eLearning, distance learning, videoconference, webcast, handicapped persons

I INTRODUCTION

THE Internet is now widely used as communication medium for personal, commercial and educational purposes. In education it has opened new possibilities for enlarging the number of students that can reach the opportunity of learning [1]. In recent years a lot of work was done for developing eLearning systems that allow to give lectures remotely using Web technologies. Internet educational platforms appeared more than 15 years ago [2]. The web conferencing technologies integrate presentation, collaboration and communication on one platform. Providing synchronous on line learning space they offer possibility of emulation of traditional classrooms [3]. Systems based on the web conferencing technologies are dynamic and so they can be called active learning systems. Using such system motivates teachers and students to take an active part in the educational process. These systems allow to contact the teacher remotely in real time using audio or video transmission. In some systems it is also possible to provide a kind of real time discussion between learners with multi-party video interactions or at least instant messaging tools [4]. The role of modern teacher has changed. He is now not only the source of knowledge but also activates discussion and stimulates creativity and critical thinking [2].

ELearning systems are especially attractive for persons with disabilities who have serious problems with attending to regular scholar courses. The possibilities of delivering educational materials to this group of persons have been significantly improved by Internet technologies. Different user interfaces, adapted to individual kind of perception possibilities allow to present the same information through several media types [5]. The Internet also increases the communication possibilities between persons with and without disabilities. It is very important that the learning system accessible for disabled persons must be built with accessible workspace, navigation, interaction and content [3]. At the Silesian University of Technology the work has been started to develop the system for remote lecturing accessible for people with different disabilities. The system consists of three main parts. This paper provides the short overview of the whole system and presents some details about two elements of the system – the server and presentation application.

II E-LEARNING SYSTEM ARCHITECTURE

In eLearning system developed at the Silesian University of Technology a teacher keeps control of the progress of the lecture. He has the possibility of presenting material in the real classroom with simultaneous transmission to remote students. The system has three main parts: web server, control application and presentation application.

Using the web browser application students can connect to the server and take an active part in the lecture that is currently transmitted. Making the connection one can receive the presentation slides, audio and video streams with possibility of turning them on and off and adjusting their quality to the Internet connection bandwidth. For example for fast connection, above 512 kb/s, student can receive audio and video streams with high resolution and quality. For slower connections student can switch the video off or choose low quality/resolution version.

Manuscript received November 23, 2010.

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The architecture of eLearning system has been presented in Fig.1.

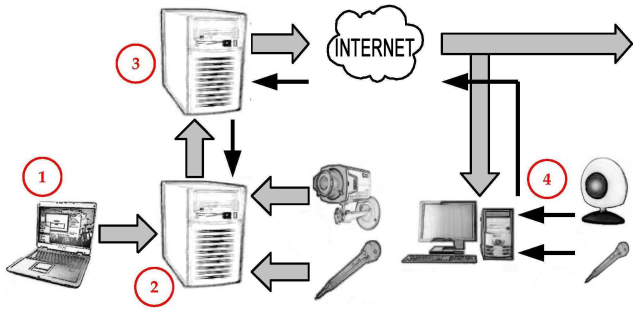

Fig.1 Architecture of eLearning system

During the lecture the teacher uses two parts of the system. One part is the presentation application usually installed on the teacher's notebook (computer labeled 1 in Fig.1). Second part is the control application intended for supporting lecturer during presentation. A computer with the control application (number 2) should be connected to such equipment as video cameras, microphones located in the classroom and also to the teacher's computer. It is also possible to use presentation and control application on the same computer. Control application takes slides from presentation application, adds the audio and video streams from microphones and cameras and sends everything to the web server (number 3). The main goal of the server is transmitting the lecture data streams to remote students' computers (number 4) through the Internet. A student's computer should have a client application as the plug-in to the browser. This application is stored on the server and is automatically loaded from the server during first logging on the eLearning system.

III Technologies Considered for Creating Elements of the System

Streaming server with client application should cooperate so they need to use the same technology. Because communication between parts of the system is performed with universal XML-based messages presentation application could be written in quite different technology. XML is often used for such purpose [6, 7] as a tool that is very independent on a platform. For the elements of the system three technologies have been considered.

A. Java applets with JMF

Applet is a small program written to run in the web browser environment. It is loaded from web server as intermediate byte code and executed in virtual machine that allows to run the same code on different hardware platforms and in different operating systems. Java applets allow to perform operations that are not possible in standard web browser. For safety reasons unsigned applets can not get an access to local resources as file system, hardware devices etc. These restrictions can be released with signing the applet. It is important that Java applets work with all popular web browsers.

JMF is the universal Application Programming Interface created for writing multimedia applications in Java programming language. Applications written in JMF can be executed on different hardware platforms and under control of many popular operating systems. JMF packet operates with many compression formats as MPEG-1, H-263, JPEG, Indeo, MPEG Layer3, GSM, G.723.1. Packet can be downloaded from Sun Microsystems' web site free of charge.

B. ActiveX with Windows Media Services

ActiveX is the set of technologies, protocols and programming interfaces, built by Microsoft and intended for creating and sending executable programs through the Internet. It is used for creating multimedia elements and interactive applications on web pages. ActiveX technology allows to run any executable program which can access the system resources so it is less safe than Java applets. The main drawback is that ActiveX technology works only in Windows systems and is not supported by some popular web browsers.

Windows Media Services (WMS) is the part of the Windows Media Server. It allows transmission of the multimedia data in local networks and in the Internet. Other parts of Windows Media Server are:

- Windows Media Player – multimedia player,
- Windows Media Encoder – multimedia encoder,
- Windows Media Software Development Kit – the packet for building applications.

Client devices can be either end-user computers equipped with Widows Media Player, or computers with Windows Media Services running, used for distribution or buffering the multimedia data during transmission. Clients can also be applications created with Windows Media Software Development Kit. It is possible to transmit multimedia files or live video streams. It is also possible to define the play lists on the server grouping different media types into one stream. Data transmission is provided with UDP/TCP protocols. Communication with client applications can use one of the protocols: RTSP, HTTP or MMS. Data can be sent to a single user (unicast) or simultaneously to many users (multicast).

C. Adobe Flash

Flash is the technology created by Adobe Systems Inc. It allows to create interactive WWW sites with multimedia

content based on vector graphics. Playing the Flash files in the web browser is possible with the plug-in. There exist plug-ins for different browsers executed in different operating systems, which makes Flash very universal and portable technology. From version MX2004 Flash has also became the programming environment with ActionScript language extending the possibility of interactions with a user. This version also was the first that allows for playing the video clips stored on the server and sending video data acquired on user's computer.

Flash Media Server is created by Adobe multimedia server that works together with Flash Player. ActionScript language is used for programming the working modes of the server. It can be used for different functionality as video on demand, live video transmission from server to end user, acquiring video on client's computer and sending the stream to the server or to other users. Client applications communicate with the server using RTMP Protocol (Real Time Messaging Protocol). This protocol allows to send the multimedia streams in both directions between server and users. It also allows for remote execution of procedures stored on the server by client, or running procedures placed on client's computer by the server. For the synchronization purposes or to triggering of execution of the procedure on many users' computers the special feature called SharedObject can be used. ActionScript objects are sent with the usage of Action Message Format (AMF) protocol.

IV Streaming server for eLearning system

Streaming server is the point for accessing the lectures given at the school with usage of the eLearning system. It receives streams with slides, audio and video data from control applications and transmits them to remote students. The main features of the server are as follows.

Streaming server is prepared to operate with many lectures simultaneously so there can be just one server for more than one classroom. Many control applications can connect to the server with the possibility of separate transmission of every lecture to different group of students. A student who wants to take a part in the lecture through the Internet can make a choice from the list of currently available lectures.

The internal implementation of the server allows for simultaneous transmission of many audio and video streams. The server can also transmit many streams with slides to the end-user. This feature can be used if the control application delivers more than one stream with presentation slides of different quality or resolution.

Changes of slides in a presentation do not happen with constant frequency. For preventing unnecessary usage of the network slides are sent only while changing their content. Such approach can be problematic while connecting remote student between transmission of the slides and in the situation of loosing one slide due to transmission delay or network error. Communication method must be reliable to deliver the newest slide to the client independently of the situation.

Streaming server does not have any graphical user interface. It is intended to work as the background process without any interactive mechanisms. Configuration of the server is stored in the XML file. This file contains only the basic set of parameters, essential for starting the server program. Other configuration parameters are sent to the server by control application. Due to such approach the administrator can set most of the parameters of the server and control application from one place. Lack of user interface causes the need to log the events from server's work. The server program generates the text file with messages reporting its own activity and errors.

Streaming server has the access control mechanism built in. A teacher can set the password for every lecture. Only these students who know the password are authorized to get the access to the system during lecture.

Taking part in the lecture remotely is not limited to observing only. The server can send the audio and video streams from the teacher to students and also receive streams sent by students and deliver them to the teacher. Student can choose the quality of audio and video streams according to his network bandwidth. Thanks to text messages students can ask the lecturer some questions, and answer his questions. If the student has the microphone that is connected to the computer the audio channel can be used for the same purpose. It is also possible to use the web camera for video transmission. The teacher can allow for or reject the reverse transmission channel activation depending on permission of receiving questions from remote students during lecture. He can also choose the preferred method of the transmission.

The streaming server works in close cooperation with the control application. It receives the configuration data and sends the information about students connecting to and disconnecting off the eLearning system. The server assigns the unique identification number to every connecting client to enable the control application distinguish between all remote participants of the lecture. Data channel between control application and the server is responsible also for transmitting the text messages from students to the teacher containing information about the sender of the message.

V Client applet

To connect properly to the eLearning system student's computer should have the client application installed.

A. Functions of the client application

The application has been created as the Java applet to be executed in the web browser environment. Such approach minimizes the administrative job on client's computer and allows for upgrading the program to a new version without any installation. The main purpose of this application is to receive the data stream with the presentation of the lecture. Applet also allows to receive audio and video streams if the teacher configured the lecture to be performed with microphones and cameras installed in the classroom. A student can make a choice between slides transmitted with different quality and resolution to effectively use available network bandwidth. Also the quality of audio and video streams can be chosen for the same purpose.

The student can ask the teacher some questions using text messages, audio and video channels. Methods of transmission are set during configuration of the applet. The teacher decides what method he wants to use. The same applies for questions asked by the teacher.

Client applet is able to acquire audio data using sound card with microphone connected to it. It can also record the video stream from web camera connected to the computer using USB. Both audio and video channels can be configured. The student can choose the audio quality and codec used for data compression. For the video channel the codec, quality and resolution can be configured.

B. Security considerations

As mentioned above the client application has been implemented as Java applet. Because of security reasons applets have limited possibilities (i.e. can not connect to computers others than the server they are loaded from, can not read files from hard disk, can not receive data from microphones or video cameras). Client's applet uses microphone and web camera. In case of using different computers as the server of eLearning system and as WWW server where the installation version of applet is stored, to disable restrictions the applet must have digital signature.

VI Control application

The control application is the main part of the system. It centralizes all other elements. It has been written using Java Media Framework technology in Eclipse environment. Such choice made many help documents available for the programmer.

Control application is responsible for collecting the audio and video streams from classroom infrastructure as video cameras and microphones. It adds pictures with the slides from presentation application and prepares all the streams for the server that broadcasts them to remote students. Audio streams can be originated by microphones or files. Also video streams can be obtained from files as well as from cameras. The number of audio and video streams is not limited and can be configured. Because there can be only one computer with presentation application, number of streams with the slides is set to one.

Incoming multimedia streams can be configured separately. Audio and video stream can be acquired with some set of quality parameters and later transformed with different set of parameters forming outgoing data stream. The transformation is performed using codecs which are installed in the system. Administrator can set parameters of incoming streams according to hardware used and parameters of outgoing streams according to requirements of remote students. Stream of pictures with slides is always received with fixed resolution and splited into many streams with different set of parameters allowing remote students for choosing the quality according to bandwidth of their connection.

Server does not have any user interface so control application is responsible for setting the parameters of that part of eLearning system. The administrator can configure IP addresses and TCP port numbers used by the server for multimedia transmission. Parameters can be saved into file for later usage and if not set the default settings are send to the server during first startup. All parameters of eLearning system are saved in XML file which structure is defined in XSD file.

The teacher has the possibility of asking remote students questions using multimedia streams or text messages. Student can select transmission methods he wants to use according to his Internet connection speed. The reverse questions are also possible. It means that student can ask teacher questions. The teacher also can make selection within available communication methods. The teacher can grant or reject the question.

The user interface of control application is clear with large buttons developed for using with both mouse or touch panel mounted on the monitor. Comfort of usage is important during the lecture because the teacher cannot afford to waste the time for using the system but should pay attention to the lecture process.

VII Presentation application

During the lecture the teacher usually uses the multimedia projector for displaying slides but sometimes uses also blackboard or whiteboard for drawing some details about presented topics. A good example of such lecture which requires both the slides and the classical writing on the blackboard is the presentation of the genetically optimized hybrid opto-electronic pattern

recognition system [8-10]. To achieve the goals of efficient supporting such lectures, the presentation application concatenates both functions. It allows for displaying slides in the background and to draw additional figures on the slides or on white screen as the virtual whiteboard. The input device can be the mouse, tablet or interactive whiteboard from which the last seems to be the most comfortable. The lecturer can switch between slide and whiteboard modes using only one icon on the presentation application task bar.

A. Integration of the eLearning system

Presentation application is intended to be used separately as stand-alone program or with close cooperation with the rest of eLearning system. It is connected directly to the control application. Communication is bidirectional. Control application itself or streaming server through the control application sends administrative messages to the presentation application. An example of such message is the information about readiness for getting slides from the presentation. Administrative messages use XML format. Every message is controlled for conformity with the template stored in XSD file. Usage of XML format makes the messages understandable and allows to extend message content for additional functionality very easily.

Presentation application sends pictures with slides to the control application. It analyzes the pictures and re-sends the current slide with modifications if the teacher makes any additional marks or drawings on it. Slides are sent using JPEG format encoded on three bytes with 8-bits color depth. Format is compatible with Windows BGR style (TYPE_3BYTE_BGR). Transmission between presentation and control application uses TCP protocol. Messages use XML format and are controlled for conformity with template stored in XSD file.

B. Application requirements

Presentation application has been written in C# with Visual Studio 2005 environment. In this environment the regions can be defined. The regions allow to divide program source into logical parts, grouping together functions responsible for similar functionality. To run the application user needs only the .NET framework 2.0. It does not need any installation, user can start the application with executing the program file only.

VIII Methods of transmission

The eLearning system uses different kinds of the data transmission for different purposes. In this section there are described methods for transmitting the audio and video streams and slide pictures.

A. Audio and video transmission

Voice of the teacher and image from the classroom are transmitted in continuous manner. For real time participation in the lecture this data should be received on student's computer as soon as possible. Short-term degradation of voice and image quality is not critical, as the presentation can be still comprehensible. Streaming media is the best choice for such kind of transmission. This technique is based on transmission of the series of packets containing digitally encoded audio and video data. Packets are sequenced and they should be processed and decoded in the receiver in order they were generated in the transmitter. Encoding in the server and decoding in student's computer is performed by codecs.

Internet hasn't been designed for real time data transmission. The transmission protocol used for streaming data is UDP. Unfortunately it has some drawbacks. Packets forming the data stream can be delayed, lost, or transmitted through different paths causing change of order in packet sequence. The buffering is the answer for this kind of problem, new packets are not displayed immediately but they are stored in receiving computer for the short time before further processing. If the delay of transmission occurs, there is some number of packets in the buffer that can be displayed avoiding dropouts of the image. The price for smoother video is short delay of transmission.

B. Transmission of the slides

Slides have different requirements than the voice and video acquired from the classroom. They appear with much lower frequency than video frames but must have better resolution and quality. They must be transmitted using the reliable data channel. Slides must be always visible on student's computer, even if some packets are lost. While connecting to the system a student should see the current slide immediately with no need to wait for changing the slide by the teacher. If the student has slower Internet connection there is a possibility of sending by the server the series of slides while the student's computer is capable to receive only the first. In such situation the student should get only the last slide from the series. These problems can be solved by implementation of the buffer in the server that holds slide which was sent last.

Because of special requirements of this transmission the method of communication has been developed. Because of the need of reliability TCP has been chosen as the protocol for data transmission. It allows to send slides to every remote student with the speed of transmission adapted to student's Internet connection speed. Because of high resolution of pictures with the slides transmission generates large amount of data. It is

possible to reduce the bandwidth needed with using of some method of picture compression for example with JPEG algorithm.

IX Tests of requirements for bandwidth

The server is the part of the system that sends many streams of data to remote students. When the number of active students increases, wider bandwidth and more computational power is required. The research was performed to determine the minimal bandwidth needed for proper transmission to varying numbers of students. The tests were executed with the use of two computers. One of them worked as a server while the second simulated remote students' computers. The Karen's LAN Monitor was used as the program for measuring the amount of transmitted data.

Audio data transmission was tested for three different quality settings and compression methods. The stream with the best quality had 44100 Hz sampling frequency, 16 bits of data in mono and MPEG compression algorithm. Parameters of medium quality stream were 22050 Hz, 16 bits mono, MPEG, and parameters of the lowest quality stream were 8000 Hz, 8 bits mono, GSM. The results for different number of active clients are presented in Table 1.

Table 1. Audio transmission bandwidth [KB/s]

	Audio stream quality		
No. of clients	High 44100	Medium 22050	Low 8000
1	8,24	4,04	2,51
2	16,36	8,21	5,01
3	24,6	12,33	7,52
4	32,88	16,47	10,05
5	41,03	20,18	12,53
6	49,28	24,72	15,07
7	57,44	28,89	17,62
8	65,69	33,02	20,05
9	74	37,1	22,57
10	82,16	41,23	24,99

For all audio quality the transmission bandwidth required increases linearly with the number of active clients as shown in the Fig 2. Solid line represents the high quality, dashed line medium quality and dotted line the lower quality of audio stream.

Video transmission was tested with the same quality settings but with different content of the stream. The first stream had slow changes in the picture, and the second had fast changes. Both streams had resolution equal to 352x288 pixels with 30 frames per second and both were encoded using H263 compression method. The results for different number of active clients are presented in Table 2.

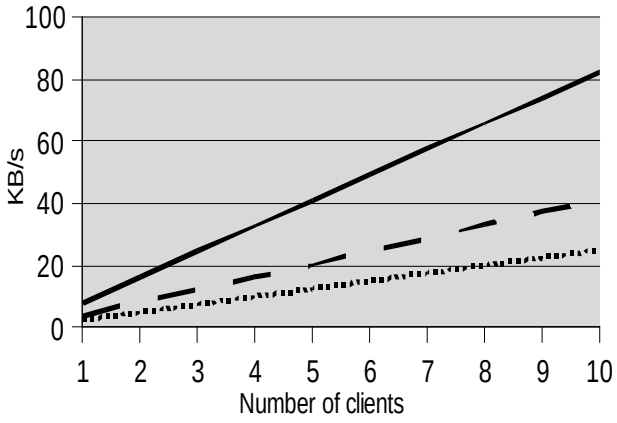

Fig.2 Transmission bandwidth of audio streams

Table 2. Video transmission bandwidth [KB/s]

	Video stream	
No. of clients	Fast	Slow
1	33,01	19,55
2	66	38,43
3	99,15	58,56
4	130,37	78,01
5	165,08	98,93
6	198,45	118,72
7	228,39	141,44
8	261,9	163,63
9	296,05	183,65
10	328,51	204,47

As for audio the transmission bandwidth for video stream increases linearly with the number of active clients. The chart with results is presented in the Fig. 3 where solid line represents the fast and dashed line represents slow changes in the video stream.

Third data stream transmitted contained the JPEG encoded pictures with presentation slides. Slides should be transmitted with better resolution and quality than the video stream but the transmission occurs only while changing the picture content. For testing purposes slides had high resolution equal to 1024x768 pixels and were compressed with JPEG algorithm, with the compression ratio above 90%. Table 3 presents the amount of data sent and bandwidth requirements for different number of active clients with the assumption that slides for all participants were transmitted within 5 sec period.

In the Fig. 5 the summary bandwidth needed for all data streams with the best quality audio and fast changes in video is presented. For the client side the bandwidth requirements for the best quality audio and video transmission together with slides sent every 5 seconds

does not exceed 75 KB/s. Since slides are usually transmitted every few minutes, such bandwidth is needed only during slide transmission, thus for the client computer the 512 kbps link should be sufficient. As it is presented on Fig. 5, bandwidth requirements for the server's Internet connection grow linearly with the number of active clients.

Table 3. Slides transmission

	Slides	
No. of clients	Amount of data [KB]	Bandwidth [KB/s]
1	146,45	29,29
2	286,4	57,28
3	421,03	84,21
4	563,53	112,71
5	707,97	141,59
6	828,57	165,71
7	990,46	198,09
8	1146,88	229,38
9	1269,76	253,95
10	1413,12	282,62

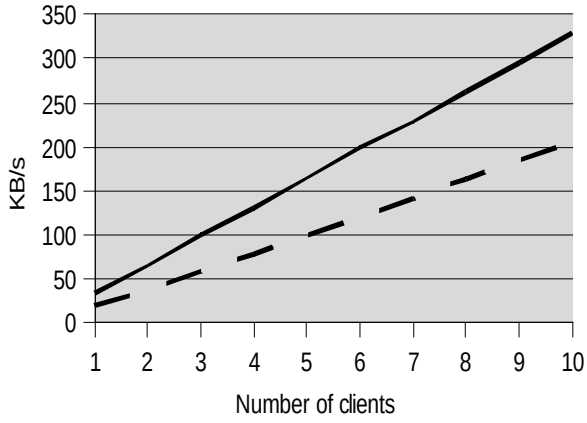

Fig.3 Transmission bandwidth of video streams

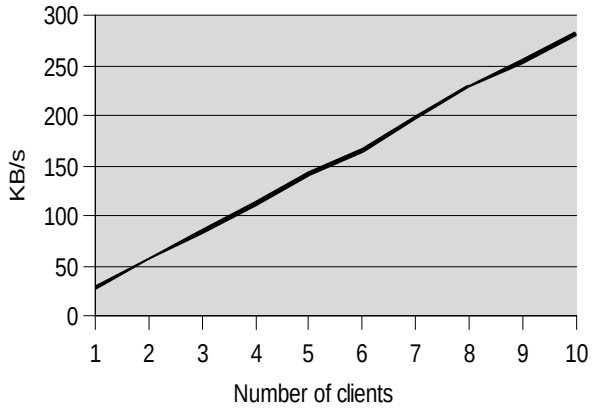

Fig.4 Transmission bandwidth of slides

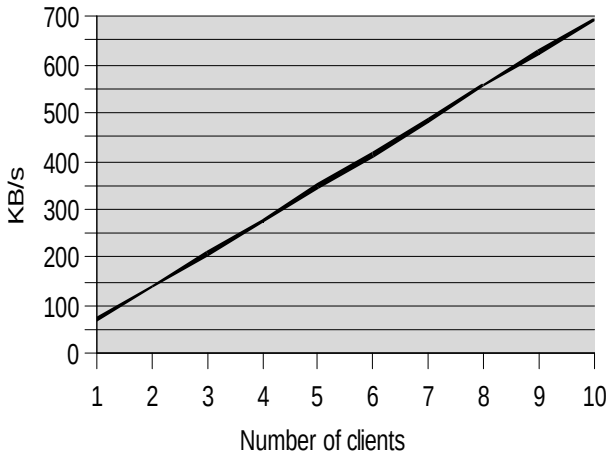

Fig.5 Summary of transmission bandwidth

X CONCLUSIONS

The eLearning systems are important for persons who cannot attend classical lectures. Systems with possibilities of multimedia transmission can be the challenge for handicapped persons' social integration because they offer not only the access to the knowledge but also the impression of participation in real lectures. Especially helpful can be the possibility of real-time video transmission between remote students and people in the classroom. During the lecture the additional streams can be also transmitted containing data destined for persons with different disabilities. The eLearning system developed at the Silesian University of Technology is prepared for transmission of such additional streams.

References
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[1] C.C. Ko, Ben M. Chen, K.P. Chan, C.D. Cheng, G.W. Zeng, J. Zhang, A Webcast Virtual Laboratory on a Frequency Modulation Experiment, Proceedings of the 40th IEEE Conference on Decision and Control, Orlando, Florida USA, pp. 3236-3241, 2001

[2] Rocael Hermandez, Abelado Pardo, Carlos Delgado Kloos, Creating and Deploying Effective eLearning Experiences Using .LRN, IEEE Transactions on Education, Vol. 50, No. 4, November 2007, pp. 345-351.

[3] Jason Morningstar, Saroj Primlani, Accessibility of Online Synchronous Learning Space: Challenges and Strategies, 21st Annual International Technology and Persons with Disabilities Conference, Northridge, 2006.

[4] Marc Eisenstadt, Does Elearning Have To Be So Awful? (Time to Mashup or Shutup), Seventh IEEE

International Conference on Advanced Learning technologies (ICALT 2007), IEEE Computer Society 2007, pp. 6-10.
[5] Helmut Vieritz, Olivier Pfeiffer, Sabina Jeschke, BeLearning: Design Accessible eLearning Applications, 37th ASEE/IEEE Frontiers in Education Conference – global engineering: knowledge without borders, opportunities without passports, Milwaukee 2007, pp. 1-6.
[6] Max Muhlhauser, Multimedia Software for eLearning: An Old Topic Seen in a New Light, Proceedings of the IEEE Fifth International Symposium on Multimedia Software Engineering (ISMSE'03), 2003, pp. 2-3.
[7] Martin Zimmermann, Towards Tailor-made eLearning Streaming Services: A Framework for Specification, Implementation and Management, Proceedings of the Advanced International Conference on Internet and Web Applications and Services (AICT/ICIW 2006), 2006, pp. 67-72
[8] K. Cyran, Rough sets in feature extraction optimization of images obtained from intermodal interference in optical fiber, Proc. SPIE, 3744, 1999. pp. 241-252.
[9] K. A. Cyran, L. R. Jaroszewicz, A. Mrózek, Optical fiber and genetically optimized computer-generated hologram for force detection and classification, Proc. SPIE, 4238, 1999, pp. 234-238.
[10] K. A. Cyran, A. Mrózek, Rough sets in hybrid methods for pattern recognition, Int. J. Intell. Syst., 16 (2), 2001 pp. 49-168.

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