Pedagogically Enhanced Video-on-Demand Based Learning System

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Abstract - Recent developments in streaming video and information technology have made it possible to design video-on-demand (VoD) based learning systems that allow on-campus and off-campus access to learning material available in video format. The wide-spread approach to computer based and distance education is to present mainly text based material as web pages or as other graphics enriched text presentation forms through the World Wide Web or CD-ROMs enriched with video clips. An alternative but as yet not widely explored approach is possible where video presentations can be made the central media for the coverage of the concepts but this time, the additional material in the form of text, graphics, visualization models, presentation slides and other document forms may be inserted in the presentation project in support of the video presentation. This paper describes the design of a Pedagogically Enhanced Video-on-Demand (PeVoD) system for the implementation of a complete Computer Assisted Learning (CAL) or Asynchronous Distance Education (ADE) system. The main objective is the provision of a pedagogically enhanced learning environment that will allow the traditional VoD systems to include synchronized "html" based pages for additional clarifications on the subject material. Furthermore, all the other features of a dynamic web page such as, animation, flashing objects, color, forms, special icons, dynamic links, graphics, sound can be used in conjunction with the VoD based video material presentation. The system incorporates a number of novel features including the facility for student interaction with the learning material. Other features include communications facility between the learners, learners and the instructor, threaded discussions, chat and discussion forums. These help create an environment for active and student centered learning system.

I. INTRODUCTION

Fast developments in streaming video and information technology have resulted in the development of many local or remote applications in education. Computer based education systems have been developed to meet the needs of both the on- and off-campus learners. Many universities have both the course web pages as well as extended programs for distance education. A number of different techniques are being employed at universities and organizations providing computer based and distance education. These include the use of the web technology, interactive TV, digital video, videoconferencing and a hybrid approach utilizing a number of these technologies. In recent years increase in the bandwidth of distribution and access networks, as well as availability of mass storage devices have made the use of real-time and stored digital video possible [4, 6]. The wide-spread approach to computer based and distance education is to present mainly text based material as web pages or as other graphics enriched text presentation forms through the World Wide Web or CD-ROMs enriched with video clips. An alternative but as yet not widely explored approach is possible where digital video presentations can be made the central media for the coverage of the concepts. In this case, additional material in the form of text, graphics, visualization models, presentation slides, sound and other document/object forms may be inserted in the presentation project in support of the video presentation [1-2].

Distance Education (DE) made through computer systems can be classified as Synchronous DE (SDE) and Asynchronous DE (ADE) [5]. SDE must be handled in a way that all the learners and the instructor must be online and a "meeting time" must be arranged. If the SDE is supported with the online video streaming technology or the interactive TV (ITV) [7], it becomes nearly class education quality with many advantages. On the other hand, SDE sessions must be announced in advance and a given session must be presented during the period allocated to that session. The quality and the efficiency of the online course depend on the instructor's performance capabilities. Since each learner has different capabilities, computerized SDE may not be the best choice at all [5]. ADE is the alternative choice for computerized DE and could be applied at any time on the request of the learner [3]. Video sessions supplied for the ADE course could be more effective than the SDE online courses since it may be built up on a scenario to fit its requirements. Furthermore, a learner could pass over difficult topics several times for revision. The disadvantage of the ADE is that, since it is served on the request of the learner and on a peer-to-peer basis [8], there will not be any online instructor to answer the learner's questions. This may be remedied by the use of discussion forms and announced chat times with the instructor.

In this paper, the use of the Video on Demand (VoD) technology [8-10] for computer based and distance education is studied. In order to provide an active learning environment as well as a learner centered approach, a number of enhancements are proposed for the delivery of the course material and the general learning environment. This results in a system that is labeled as Pedagogically Enhanced VoD

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System (PeVoD). The main idea is that a learner usually relates new material to his/her existing knowledge. This, (s)he does in two ways: first, by reminding him(her)self of the pre-requisite topics for the concepts presented and second, by note taking or jotting down information. It is envisaged that if the topic and concept related learning material can be made available to the learner, (s)he will use them to establish the necessary foundation in the pre-requisite concepts. For this, the instructor can decide with the help of students the additional learning material necessary for understanding the concepts to be learned during that session. Further, other related material may be linked and synchronized to the video clip. These materials may include relevant notes, information sheets, sample solutions, simulations, graphs, sound, and other multimedia objects for helping the learner in his/her task. The issue of note taking can be provided by allowing the learner to be able to have a similar facility with which (s)he may add notes, links and documents in addition to those of the instructor to the video clip. The PeVoD system is proposed to provide all these features.

This paper is organized as follows: in section 2, architectural design of the VoD system, the general system configuration and components are described. In section 3, pedagogical enhancements to the system are described. Implementation of pedagogical enhancements are described in section 4, while, section 5 investigates the practicalities. The final section includes the conclusions.

II. Architecture of the VoD System

A Video-on-Demand (VoD) system necessarily comprises one or more VoD servers and a number of clients operating in the client-server mode. As the name implies, a VoD system provides either a facility to download or stream and play requested video files from a server. The latter is referred to as streaming video. It is the preferred method due to its advantage of allowing starting of the playing of the video after buffering the minimum number of necessary video frames while downloading the remainder of the video file. In VoD systems a method of organizing and announcing the list of available video files is necessary. A user at the client machine can then access the video server for available titles and download and play the selected video clip on the client computer.

Different architectures may be used in order to provide this service. The technique proposed by Rousseau and Duda [1] has been adopted and extended in this work. The proposed technique necessitates the use of a mediation server for service access and a content server for multimedia content delivery. The general scheme which includes these servers and the different types of clients are depicted in Fig. 1. Here, one mediation server and three content servers are depicted. The mediation server allows the registration, request, negotiation and authentication for services from the VoD system. In short, it mediates between the content servers and client applications. The content server provides storage and streaming for the video clips and files which can be selected, downloaded and played on the client terminals. The distributed nature of the design allows the installation and maintenance of VoD

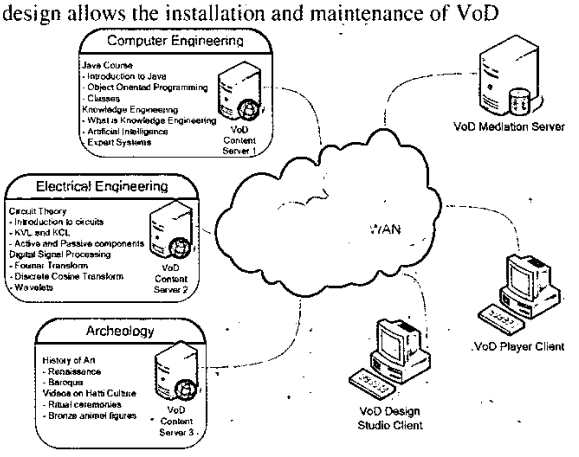

Fig. 1. Distributed VoD client-server architecture.

learning material for different faculties or even individual departments. Another advantage of this system is load and content distribution. This allows speedier access since only the relevant content is accessed on any server; this results in minimization of irrelevant traffic load on the VoD system. It also alleviates the mass storage problem encountered in many VoD systems.

A *VoD Player* client and a *VoD Design Studio* client are shown in the diagram. The player client is typically the computer of a learner. The number of clients simultaneously accessing the VoD system is a design parameter and is based on the server configuration and capabilities. The design studio client is a VoD Editor client, typically accessed by faculty members who are expected to create multimedia lecture sessions for their online-courses. An additional client would be a management client, who would maintain the VoD system.

III. Pedagogically Enhanced VoD (PeVoD) Learning Environment

Standard video-on-demand systems offer nothing but the plain streaming video to the clients. Everything related to the course is assumed to be within the video session. Lectures are recorded on video tapes, digitized, (or are alternatively recorded in digital format), compressed and stored on video servers. Sessions of lectures are indexed and users are expected to download and play the video clips. This system is a fully asynchronous learning environment. It can be used as local (e.g. campus based) and distance learning platforms.

The proposal in this project is that, a number of pedagogical improvements can be added to this static learning environment to make it a much more powerful learning environment. These include the following:

1. The use of additional learning material which can be synchronized to the video session,

2. Allowing the learners to interact with the video session and the learning environment,
3. Allowing the learners to communicate in real-time and in non-real time formats with their peers as well as the instructor,
4. Provision of a threaded discussion forum for creation of a class-environment.

It is believed that the addition of the above features to a standard VoD system is adequate to make it a more interactive learning environment allowing *active learning* for the students. This extended VoD system is called the Pedagogically Enhanced Video on Demand (PeVoD) system in the rest of this paper. In short, the PeVoD system is an asynchronous distance learning (ADL) environment that offers multimedia, i.e. text, sound, video, graphics and animation enriched courses to be presented over intranets or the Internet with its own client-server applications.

A. Desired Features

1. Use of additional learning material

Stored video or VoD systems are useful but are rarely used on their own for distance learning (DL). There is a need to provide video as part of a complete DL environment. This environment may have different forms: One approach is to provide video clips when and where necessary for demonstration purposes within a text based learning environment. This is the approach taken in most of the web based DL systems. In the PeVoD system, the video session covers the main event or a presentation on the topic. Additional learning material may be added as text or multimedia appendage to the video session. The problem is that this additional material must be synchronized to the video in order to be displayed at the most relevant time during the video presentation. This necessitates the provision of two main windows for presentation: first, the video screen and second, a multimedia presentation space for the additional learning material. It is proposed that the most suitable window for the additional learning material is a browser window attached to the video window. In this way, the instructor responsible from delivery of the DL package may utilize the browser window space for placing additional learning materials. Each additional learning material will be synchronized to the video at the time of its addition. These materials may include:

- prerequisite material necessary for understanding the concepts discussed in the video session,
- related supplementary material that may help consolidate understanding or provide additional samples for discussion,
- summary of important topics,
- additional solved examples,
- visualization, simulation and virtual reality,
- graphics, plots, documents and tables with related information on the discussion topic,
- links to other source materials on the subject, etc.

The additional learning material that can be added and synchronized to a video session may come in various formats including HTML, XML, DHTML based mark-up text, virtual reality modeling language (VRML) based visualization material, hyperlinks, ActiveX® components such as Microsoft® Office® components, Macromedia Flash® and Adobe Acrobat®, music, sound, etc. These materials can be used to annotate the video based course material in order to bring the related content to the attention of the learner. In this way, the learner gains two important advantages:

- reference to additional material on the topic; hence, gaining an insight to the pre-requisite or more advanced topics related to the issues discussed in the video clip,
- access to additional content for visualization and learning.

2. Learner interaction with the learning environment

An extension of the idea of adding synchronized learning material is that each learner could also make notes and add further links to the video material in addition to those that are created by the instructor or the author. This allows personalization of the video clip. Implementation of this idea necessitates the use of indexing and relating additional content material based on user profiles. PeVoD allows user content additions to a VoD based project. The user additions are added to the project by blending synchronization cycle of the current project with the user contributed materials.

3. Learner communication in real and non-real time

In a class environment, usually the instructor-student communication is encouraged. Student-student communication is allowed in special sessions, in tutorials or group meetings. By allowing both the instructor-student and student-student communication at the same time, additional synergies can be activated; hence increasing learning. The PeVoD system aims to provide both through a real-time chat facility. Instructor "presence" during learning sessions may be achieved by advanced scheduling of instructor contributed sessions. However, the most useful feature is that the students can use the asynchronous learning environment at their convenience, while having the capability of:

a. setting up chat sessions about the video lecture topics with other students who are on-line at the same time,
b. sending their enquiries by e-mail to the instructor or their peers in an off-line manner.

4. Provision of threaded discussion forum

A discussion forum is proposed to be included in the PeVoD system in order to allow threaded discussions to be made on the presented material. This is expected to increase the class interaction.

The features described above are included in the PeVoD design in order to provide a *learner centered* educational environment.

B. The PeVoD System Components

The desired features of the PeVoD system have been enumerated above. In this section, the client-server architecture of the PeVoD system is described in more detail. The VoD system is shown to have the client-server architecture in Fig. 1. The PeVoD system is based on the

standard VoD system but additionally incorporates the following features and components:

TABLE I

PEVOD CLIENT-SERVER APPLICATIONS AND COMPONENTS

	Client-Server Applications	Software Component
Client Side	Student/Learner Client	PeVoD Player
	Project Editor/Instructor	PeVoD Project Editor
	Database and Content Admin	Web access to server resources
Server Side	VoD Mediation Server	User and password databases, Video Project databases, Content server IP databases
	VoD Content Server	TCP, UDP and FTP Servers, Video Library, Supporting materials

1. A distributed server architecture (see Fig. 1): allows multiple video servers to be present in the system,
2. Multiple client types: includes access for the normal PeVoD Player, the PeVoD Project Editor, and the System Manager clients.

The different client and server types available in the PeVoD system are listed in Table 1. Both the server side and the client side applications and their software components are given in the table.

The details about the software components are described in the next section.

IV. IMPLEMENTATION OF PEDAGOGICAL ENHANCEMENTS

Implementation of the suggested pedagogical enhancements is described in this section with reference to the client and server side application software components.

A. The Client Side

The client side components include the PeVoD Player and the Project Editor software units. These are depicted in Figs. 2 and 4 respectively.

i) The PeVoD Player

The list of requirements from pedagogically enhanced VoD player (PeVoD-P) system has been described in earlier sections. These are shown in the figure below which depicts the different panes of the application display window. These include the video display, discussion forum, and the chat panes as well as the "html" based display pane for displaying the additional learning materials.

The PeVoD Player is capable of authenticating the users on the Mediation Server, streaming the course video in its video screen and browsing the "html" pages in its embedded "html viewer" as shown in Fig. 2. The presentation of the ADE course is handled after the processes of authentication and selection of the preferred video transmission protocol are carried out. When the user requests the list of available courses, the PeVoD Player connects to the Mediation Server and gathers available course titles. After selecting the desired

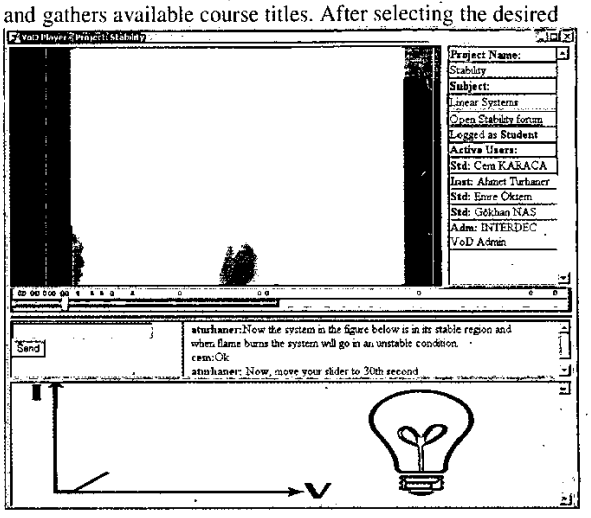

Fig. 2. The PeVoD Player

course, the PeVoD Player gathers the Content Server data about the server on which the project is located. After this step, the PeVoD Player connects to the Content Server and downloads the supporting "html" pages and their bounded objects by an FTP process and makes another connection to the Content Server with the preferred transport protocol to stream the selected course video. After that point the session starts and the course video will be streamed. The learner has full control on the streaming video such as pausing, stopping, forwarding or reversing. Details of the PeVoD Player are shown in Fig. 2. The browser window is used to display the supporting material.

Fig. 3 depicts a number of enhancements implemented on the PeVoD Player software. These include the buffering progress bar (4), the scroll bar (3), and the symbols (1) and (2) for the synchronization points on the video bar. The progress bar (4) shows the amount of video buffered so far and the video scroll (slider) bar (3) shows the amount of played video.

The instructor placed and student placed additional learning material are distinguished as descried above. This is also true for the way in which these are added. While the instructor places additional learning material using the PeVoD Project

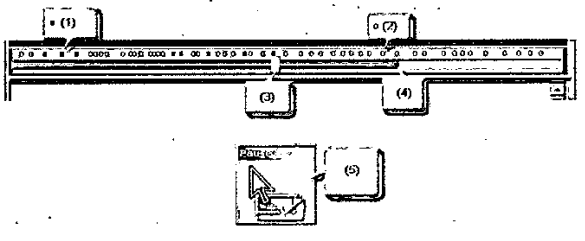

Fig. 3. PeVoD Player enhancements: video slider and "Pause and Drag" windows

Editor, students can use the Pause & Drag window (5) provided with the PeVoD Player as shown in Fig. 3. Any document or display object can be dragged and dropped into this window to append it to the video display list and synchronize it with the video at the time of the frame displayed at that moment. The additions made by the student with the PeVoD Player will only be seen by this student and stored in the students' local computer. Synchronization points on the scroll bar are indicated with symbols. The symbols "o" and "■" indicate the instructor and student placed additional learning materials respectively.

ii) The PeVoD Project Editor

The PeVoD Project Editor (PE) application window screen shot is shown in Fig. 4. The four main panes of the system are the video preview screen (1), project display pane (2), synchronization and timing ruler pane; also known as the content material addition/edition bar (3), as well as the "html" viewer/editor/code editor/display pane for the additional learning material. The PeVoD-PE is a handy tool for the design of multimedia based courses by instructors. Its main feature is the capability to include additional course materials as "html" pages synchronized to the course video. This editor is capable of DHTML editing and course previewing facilities. After the development of the course, the ADE project which includes video, html pages and their bounded objects such as images, animations or ActiveX® objects and the synchronization data is sent to the preferred Content Server and is registered on the Mediation Server on its appropriate branch of course. The "html" pages added to the course project will be identified as "tics" (2) in the PeVoD players' scroll bar and will be shown in the PeVoD Player's "html" browser pane when the scroll bar passes through these tics as shown in Fig. 2.

iii) The PeVoD Web Services

The PeVoD Web Services (WS) can be used either by the administrators to manipulate the projects and take statistics or by the students to view the discussions made on a topic. Both the students and the administrators must be authenticated before logging into the PeVoD web services.

B. The Server Side

i) Content Servers

Content Servers are supported with the designed applications to give the learners the selectivity of network application/transport protocols including FTP, TCP, UDP and Reliable UDP (RUDP) where RUDP is designed for the streaming purposes of videos on low bit error rate networks. The protocols mentioned above have different overheads and reliabilities.

ii) Mediation Server

The Mediation Server is supported with an SQL relational database management system (RDBMS) and a web server in order to facilitate web based discussion forums and storing important system related data.

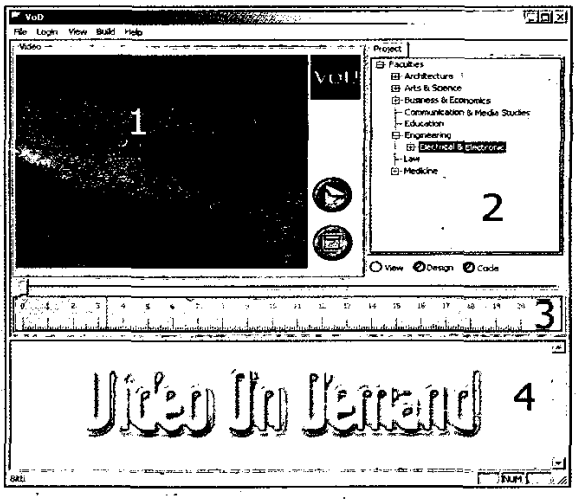

Fig. 4. The PeVoD Project Editor

V. PRACTICALITIES

Video centered CAL and ADE implementations, necessitate the availability of a powerful design tool to serve the needs of instructors in designing their course projects. A course project involves the creation and storage of a multimedia presentation project with video as the main component and additional learning materials added and synchronized with the video. To meet these requirements, the PeVoD system includes a Project Editor (PE) tool that can handle all the project related tasks, such as editing, creating, designing and posting the projects with their bounded content materials to the servers and registering these projects with the Mediation Server. In the absence of this kind of a tool, the project design process will be a tremendous work for the course instructors. The steps for creating a project are as follows:

i) PeVoD presentation project video must be converted in to a digital form by external tools in a variety of popular compression algorithms. After this step, instructors can use PeVoD Project Editor to publish their videos.

ii) After authenticating him/her-self with the login facility of the PeVoD Project Editor, the instructor may select a category for the project in the range of courses displayed by the editor. If necessary, a new project title will be added to the appropriate category.

iii) With the addition of the new project to a category, the editor will start to play the video, at this point new "html" pages could be added to the project and they can be edited by the DHTML editing facilities of the editor. The editor also synchronizes the "html" pages to the video with respect to their "addition time". Addition time is the video playing time of the corresponding video frame.

iv) To complete the PeVoD project publishing operation, the instructor must use the "build" facility of the editor. This build facility sends the project and its bound objects to the desired. Content Server by an FTP process and registers

this project on the Mediation Server after successful completion of the FTP process. Once the projects are registered, the learners should be able to see them in the PeVoD Player project selection screen.

The learners using the PeVoD Player must also be authenticated through the Mediation Server by a login process. After the login operation, the users will be able to see the current projects registered on the Mediation Server. After the selection of the desired project from the list, the PeVoD Player gets the relevant "project information" from the Mediation Server. This information includes the Internet Protocol (IP) number of the Content Server where the project related data are located. After this step, the PeVoD Player connects to the related Content Server by an FTP process to download additional course related content data such as "html" pages, images and other objects. Further, it makes another connection using the preferred transport protocol for streaming the course video. After a little buffering, depending on the connection type or bandwidth, the course video starts to play back and the synchronized "html" pages are shown in the embedded html browser with their appropriate timings.

The learner at that point can also add his/her content material to the DE project by dragging the materials to the "Dragging Pane" of the player as shown in the Fig. 3(5). The user additions are stored in the user's local computer and are also synchronized to the course video. In the subsequent openings of the same project, the PeVoD Player will search for these additions and show them with their appropriate timings also.

VI. Conclusions

This paper proposes a complete learning environment based on a video-on-demand supported facility. The system allows the development of both locally and remotely accessed courses. In the case of locally accessed courses, a campus environment or a company's own intranet may be used to access the educational services. This mode of usage may be useful for providing students with additional course material to which they can access and study in an asynchronous matter in addition to their normal lecture based offerings. As such, the system becomes a Computer Based Training (CBT) aid for learning. In the second mode, the system may be developed as a fully fledged Asynchronous Distance Education (ADE) system in networking environments where access to video sources is supported by the available network access bandwidth.

A complete system design is given including the tools to be used. The proposed system has been implemented as a pilot within the Department. What distinguishes this proposal from standard VoD type applications is the availability of pedagogical tools and the creation of an active learning environment for the learner. It is envisaged that the powerful environment of a video presentation can still be enriched pedagogically, by associating the concepts presented in the video with additional learning materials. The PeVoD design incorporates a powerful Project Editor for the instructor to place the prerequisite, frequently asked or more advanced material related to the topic of the video presentation. The learner on the other hand, not only finds the video presentation that is repeatable an infinite number of times, but also can browse additional material related to the concepts presented almost at each video frame. In addition, the learner is allowed to "jot-down" any ideas, comments, additional links or material as additional content material in a similar manner to that of the instructor. This facility provides a unique way of interaction by the learner with the course material. Furthermore, the learners and the instructor can meet over any video presentation using the incorporated discussion forum, per-project threaded discussion list and the chat facility. These facilities allow a multitude of interaction possibilities between the learner-learning material, as well as the learner-learner and the learner-instructor pairs, hence creating an active learning environment. It is believed that the use of these tools and concepts in distance education or in computer assisted learning applications will enhance student learning in ways not envisaged before.

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