Model-Based System Development for Asynchronous Distance Learning

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ABSTRACT

The innovation and diversification of development in multimedia technology and network infrastructures have brought a significant impact to education, especially for distance learning. This paper presents a model-based asynchronous distance learning system development that consists of a presentation semantic model called the multimedia augmented transition network (MATN) model and an asynchronous distance learning system called the Java-based Integrated Asynchronous Distance Learning (JIADL) system. The MATN model is powerful in modeling the synchronization and quality-of-service (QoS) for distance learning multimedia presentations. The JIADL system can support diverse asynchronous distance learning services by integrating RealPlayer and Java technology to augment the superiority of both models. A course sample is used to illustrate and validate the effectiveness of the system. How to use the MATN model to model the diversity requirements of a distance learning multimedia presentation is also discussed. Furthermore, the initial experimental results show that our system is cost effective and has a wide range of applications.

Keywords: multimedia augmented transition network; distance learning; Java media framework

INTRODUCTION

The recent advances in multimedia technology such as the high-speed communication networks, large-capacity storage devices, digitized media, and data compression technologies have drastically changed the way learners communicate with their instructors and with each other, especially in distance education. With the innovation of new network and Internet infrastructures and the development of multimedia technology, the distances perceived by the learners have been virtually diminished and distance learning has become one of the most interesting new directions for education.

Multimedia information has been used in several applications including education, computer-based training (CBT), manufacturing, medicine, entertainment, video conferencing, etc. In particular, distance learning has become the mainstream of computer-based training and education. For example, there are 247 articles with the distance learning subject published on IEEE/IEE Library in 1997 and 1999 (IEEELibrary), and different surveys show that there are one million students taking distance learning classes via the Internet and predict that the number of college students enrolled in online courses will reach 2.2 million by 2002 (Syed, 2001). Moreover, the seamless integration of the overwhelming World Wide Web (WWW) and the emerging Java technology further endorses the universal accessibility to diverse distance learning services. The former provides a cross-platform consistent visual user interface for accessing information whereas the latter allows the application code (applets) to be downloaded over the Internet and run on any Java-compliant Web browsers.

In general, distance learning services can be delivered in three ways: synchronous (real-time), asynchronous (on-demand) and hybrid of both. Synchronous distance learning systems provide live lecture contents as in the traditional classroom. Asynchronous distance learning systems offer archived lectures by using Web and/or streaming technologies and try to provide the most of the capabilities and experience that an in-class participant can have to a remote participant. Hybrid systems supply complementary services to those listed above.

For the asynchronous systems, an early development is to use television to broadcast courses (Egan, 1993). The main drawback of this type of television instruction is the lack of interaction between the students and the instructors. Later, the Web is used to support asynchronous activities. One example is to develop the online programs using Web pages to access course materials, announcements, and other information for a course. Another example is to provide the online activities that include forums, chat rooms, and emails. Also, the students can submit their assignments online in multimedia formats and receive online reviews of the assignments in the same formats from their instructors.

Maly et al. (1997) proposed a synchronous distance learning system. In their system, a virtual classroom is developed to allow the students to have a conventional classroom experience through a workstation since the students and the instructors interact with video conferencing. Such an environment incorporates an X-Windows-based group-collaboration system called XTV (Abdel, 1994) so that any participant can take control of a window to multicast his/her inputs to the distance participant. Under this environment, those tools such as Netscape and PowerPoint can be shared through a window-sharing engine. However, there are two disadvantages in such an environment, namely speed and bandwidth. In other words, an extraordinary load is put on the reliable multicast protocol and the environment works only on high-speed networks. Another system proposed in Saini (1999) studied how to immerse the students in a virtual environment that provides them with feedback. In their system, the student interactions are computed and the system reacts like an educational game. However, the issue of how to share a virtual world among the students is not discussed.

In this paper, we present a project that aims at digitizing and distributing video tapes recorded in a synchronous distance learning classroom to improve curriculums, to provide another channel for learning, and to complement synchronous/asynchronous learning. In order to broaden the functions and the effectiveness of such service, a number of interactive and cooperative services are integrated by mainly applying Java technology, which results in the paradigm of Java-based integrated asynchronous distance learning (JIADL) system. Unlike most related work in the literature, we integrate RealPlayer and Java technology so that the superiority of both models can be augmented in the JIADL system. This project is supported by the Ministry of Education, R.O.C. and implemented at National Kaohsiung First University of Science and Technology (NKFUST).

However, due to the variety of media data (such as video, audio, text, and image data) that needs to be transmitted and synchronized for multimedia presentations, a distance learning system development involving multimedia data becomes more complicated than the traditional system development. In addition, for a multimedia system to be useful, reliable, adaptable and economic, it must be based on a sound data model so that this model is a valuable communication tool between the system developers and the users. Hence, it will be of great benefit to have a presentation model that can represent and model the different requirements for multimedia data in a distance learning system.

Towards these demands, a model-based distance learning system that consists of a presentation semantic model called the multimedia augmented transition network (MATN) model to model the distance learning multimedia presentations for the JIADL system is proposed in this paper. A MATN has a finite set of nodes (states) connected by labeled directed arcs. A labeled arc represents the transition function, where an arc represents an allowable transition. The multimedia input strings that can capture the temporal relationships of the media streams and model the concurrent and optional displaying of the media streams in a distance learning multimedia presentation are used as the inputs for the MATN model. In addition, the synchronization and quality-of-service (QoS) of each presentation are maintained by a condition/action table associated with a MATN. In the condition/action table, a set of conditions for the synchronization and/or QoS is checked for each input symbol. Each condition has its own set of actions. When a certain condition is satisfied, then the corresponding set of actions is activated.

An example course is used to illustrate how a distance learning course can be modeled by the MATN model in the JIADL system. The MATN model is powerful in modeling the synchronization and quality-of-service (QoS) for distance learning multimedia presentations. In addition, our initial experimental results show that this JIADL system that is based on the MATN semantic model is cost effective and has a wide range of applications.

The remainder of the paper is as follows. The next section briefly describes the kernel technologies employed in developing the JIADL system.We then introduce the multimedia augmented transition network (MATN) model, the JIADL paradigm and its components, and how to use the MATNs to model distance learning multimedia presentations in the JIADL system with an example course. The multimedia input strings and the condition/action tables used in the MATN model are also presented in this section. Finally, the conclusion to this paper follows.

INFORMATION TECHNOLOGIES FOR JIADL

Java-Centric Computing

The Java programming language, initially designed for small consumer devices, became more prevalent when it was coupled with the WWW for developing distribution applications including distance learning. For example, the Virtual Laboratory at the University of Catania is developed in Java to support remote users to access tutorials, perform simulations, and control an educational industrial system (JavaJMF). Reed and Afjeh (1998) designed and implemented a Java Gas Turbine Simulator to provide an interactive environment for constructing and analyzing gas turbine systems. De Santo and Chianese (Arcelli, 1998) proposed a Distributed Learning Environment Support Tool employing Java language in an intranet environment (Stefano, 1997). The JavaGram application developed at Clemson University allows the students to turn in their homework diagrams such as the signal flowcharts in signal processing classes (Patterson, 1998). The GVA system presented in Min (1998) is a Java-based multimedia distance education system, which provides a distance lecture environment and a study environment.

Java has a number of distinct features such as architecture neutrality, concurrency, distribution, user interaction, persistence, mobility, security, and interoperability, which make it popular in many applications. Moreover, accompanied with a comprehensive set of APIs, Java offers a potential framework for efficiently developing a wide range of applications including image processing, multimedia, database management, electronic commerce, information security, telephony, embedded systems, to name a few. A Java industry era is expected to emerge in the near future.

Streaming Archived Lectures

To transmit the archived lecture contents, the Java Media Framework (JMF) from SUN (JavaJMF) and RealPlayer from Real Networks (RealPlayerJava) are two commonly used approaches. JMF provides a platform-neutral framework for building media players and supports a variety of media content types, including the high-quality MPEG-1. It specifies a unified architecture, messaging protocol and programming interface for playback, capture and conferencing of compressed streaming and stored timed-media including audio, video, and MIDI across all Java enabled platforms. On the other hand, the RealPlayer G2 supplies an efficient service for playing streaming video (RealVideo) and audio (RealAudio) objects. Choosing MPEG or RealVideo for delivering archived lectures is a tradeoff between network infrastructures and constraints on efficient compression. Recently, RealPlayer for Java, a wrapper around the RealSystem G2 released by Real Networks, provides a comprised solution that allows the ability to play G2 objects via the JMF API (RealPlayerJava). By utilizing RealPlayer for Java, the goal of delivering archived streaming contents efficiently can be achieved without loss of the salient features of the Java computing model.

A MULTIMEDIA PRESENTATION MODEL FOR JIADL

Benefits of Having Semantic Models

In any software system design, it is necessary to have a conceptual model of that software system provide a high-level view of the system once the initial analysis of the user's requirements for the software system have been identified. Such a conceptual model is a valuable communication tool between the system designer, software developers, and users since the involving components, functionalities, and relationships of the system are documented in this conceptual model.

A data model is a symbolic or abstract representation of a system, which can highlight the important facts by efficiently eliminating uninteresting details. Symbols, arcs and notations are used to represent functions, objects and relationships for a system. For a trivial and small system, a conceptual model may exist only in the mind of the developer responsible for establishing the specifications since the developer understands the details of each function or component together with the limitations, conditions, and actions. However, this does not work for the non-trivial systems such as a multimedia system.

A multimedia system may involve different media types such as videos, audio, images, texts, graphics, and animations. To provide a better multimedia system, several factors need to be considered. For example, the temporal relationships among media streams need to be modeled. Synchronization and QoS need to be maintained in order to have a high-quality presentation. User interactions should be provided so that the system allows two-way communications between the user and the system. User loops also need to be provided so that the users can continue watching the same part of a presentation more than once.

In such a non-trivial system, the system to be modeled is usually complex and many situations need to be considered and handled. A mental model is not suitable since the model in the developer's mind normally is incomplete and imprecise. Therefore, it is necessary to establish an explicit and precisely defined data model at an early design stage so that the system can be understood.

The MATN Model

The benefits of using a semantic model for a software system were presented in the last subsection. Specifically, there are several factors that need to be considered for a multimedia presentation in a multimedia system. In order to model the complex multimedia presentation, we proposed to use the multimedia augmented transition network (MATN) model as the underlying data model for the distance learning multimedia presentation in the JIADL system.

A MATN can be represented diagrammatically by a transition graph. The MATN consists of a finite set of nodes (states) connected by labeled directed arcs. An arc represents allowable transition from the state at its tail to the state at its head, and the labeled arc represents the transition function. An input string is accepted by the grammar if there is a path of transition that corresponds to the sequence of symbols in the string and leads from a specified initial state to one of a set of specified final states. Multimedia input strings are used as the inputs for the MATN model. The multimedia input strings have the capabilities to capture the temporal relationships of the media streams, and to model the concurrent and optional displaying of the media streams in a distance learning multimedia presentation.

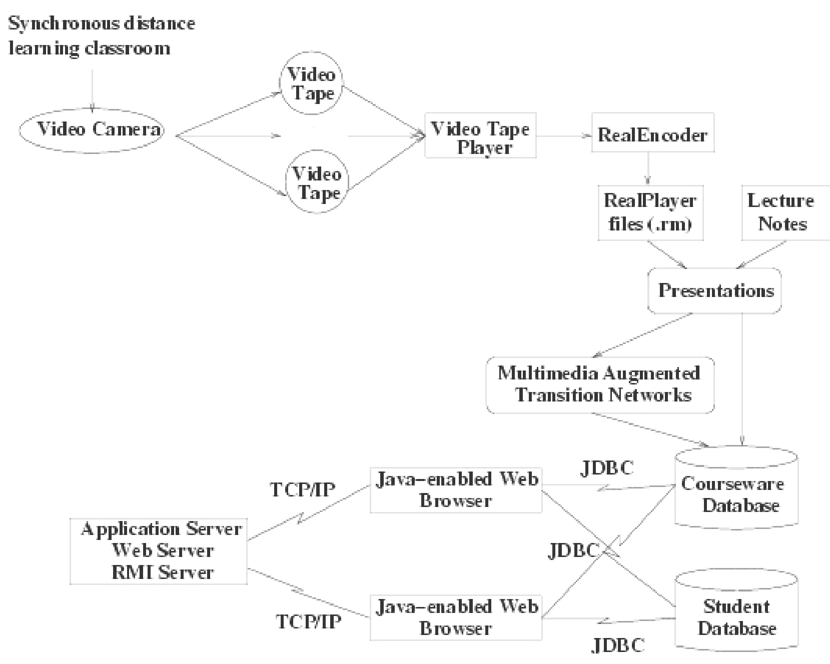
Conditions and actions in the arcs in MATNs maintain the synchronization and quality of service (QoS) of a multimedia presentation by permitting a sequence of conditions and actions to be specified on each arc. The conditions are to specify various situations in the multimedia presentation. A condition is a Boolean combination of predicates involving the current input symbol, variable contents and the QoS. A new input symbol cannot be taken unless the condition is evaluated to true. More elaborate restrictions can be imposed on the conditions if needed. For example, if the communication bandwidth is not enough to transmit all the media streams on time for the presentation, then the action is to get the compressed version of media streams instead of the raw data. In this way, synchronization can be maintained because all the media streams can arrive on time. In addition, QoS can be specified in the conditions to maintain synchronization. The actions provide a facility for explicitly building the connections among the whole MATN. The variables are the same as the symbolic variables in programming languages. They can be used in later actions, perhaps on subsequent arcs. The actions can add or change the contents of the variables, go to the next state, or replace the raw media streams with the compressed ones, etc. If a condition is matched, then the corresponding action is invoked. Different actions can generate different presentation sequences which are different from the original sequence.

The JIADL Paradigm

The high-level architecture of the JIADL paradigm is outlined in Figure 1. The archived lecture contents are converted into RealVideo files by RealEncoder in advance and are stored in the Courseware database. Mobile learners may download the system applets from Web Server and retrieve the courseware of interest via the JDBC mechanism. The student database keeps records of students' learning progress and personal registration information. RMI Server supports the collaborative learning in chat rooms. Currently, the platform for Application Server, Web Server, and RMI Server is on NT4.0.

There are three subsystems in the JIADL system. An example course offered by the Center of General Education at

Figure 1: The JIADL paradigm



NKFUST, Science and Technology had been experimented on the JIADL Paradigm. The lecture was broadcast in live video from NKFUST to four neighboring universities via three ISDN-dedicated lines at 384K.

- StudDBMS: Any students, including ones in the classes, can log into the JIADL system by registering it in advance as shown in Figure 2. The StudDBMS subsystem allows learners to query and modify personal information besides registration. As shown in Figure 2, students need to register into the system by giving personal information such as Stud ID, Password, Name, SSN, and so on. Three options are provided to let students register, query, or update their personal information.
- CourseDBMS: The CourseDBMS subsystem endows the lecturers or administrators to manage the digitized courseware. The control layout of the CourseDBMS subsystem is shown in Figure 3. Student ID and Password need to be specified in order for them to access the corresponding courses.
- CyberLearn: The CyberLearn subsystem is the kernel part of the JIADL paradigm which allows the student to browse the static lecture notes and the corresponding video lecture. After students specify their student ID, Password, and the course information, they click on the OK button in Figure 4 to activate the next window as shown in Figure 5. There are two options — Show_Outline and Show_Video. When the Show_Outline option is highlighted, the lecture notes will be displayed. The same situation applies for the Show_Video option. If both options are selected, both lecture notes and video (audio) lecture will be displayed synchronously. Therefore, the student can browse the static lecture notes and the corresponding video lecture by simply clicking on the Play button, which results in a RealPlay window popped out as shown in Figure 6. As we can see in this figure, both lecture notes

Figure 2: The control layout of the JIADL StudDBMS subsystem

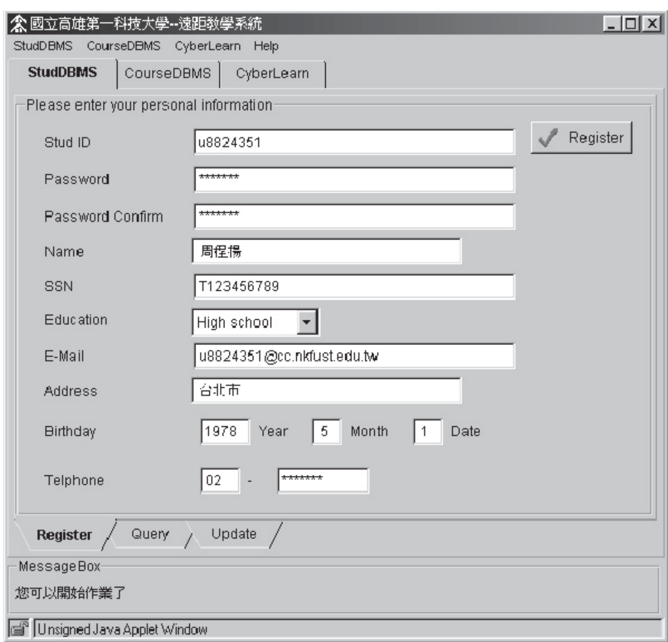


Figure 3: The control layout of the JIADL CourseDBMS subsystem

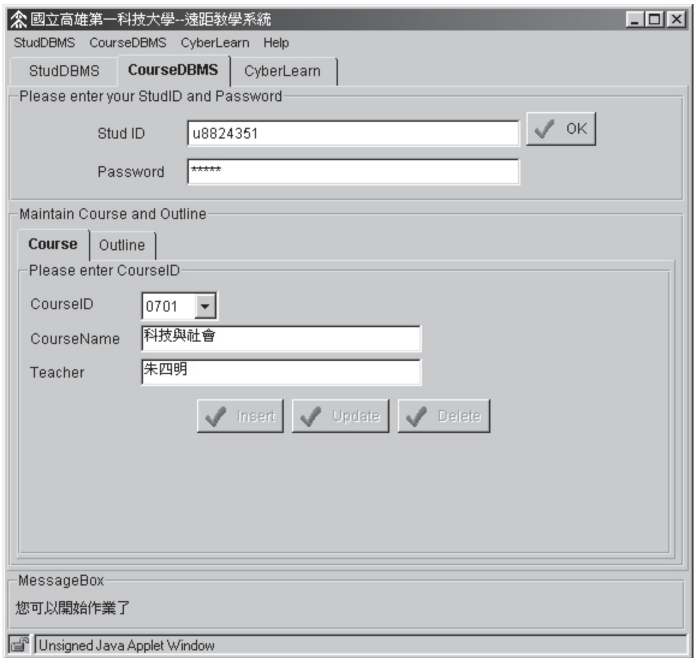


Figure 4: The control layout o the JIADL CyberLearn subsystem

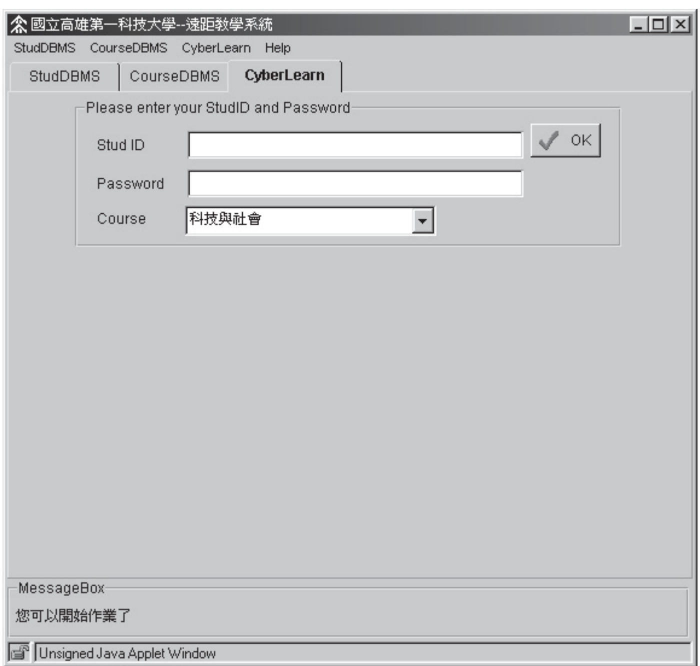


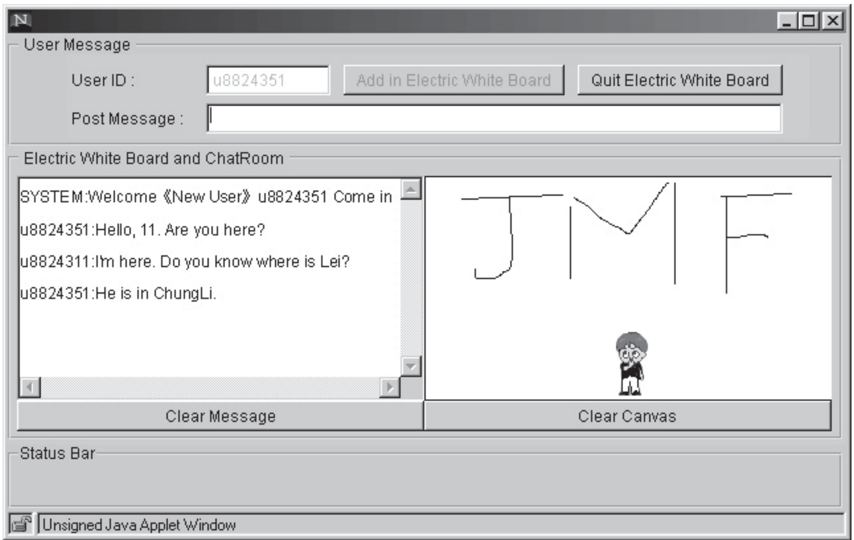
Figure 5: The CyberLearn subsystem

and video lecture are displayed since both Show_Outline and Show_Video buttons are highlighted in Figure 6.

Empowered by Real Player G2, the student is granted the capability of controlling voice and lecture progress. Further functionality like lecture clips can also be easily implemented. One important supple-

Figure 6: The archived lecture played by RealPlayer for Java.

Figure 7: The whiteboard subsystem.



mentary function for mobile learner is the Notes Area (the bottom area in Figure 5), in which the learner may write down the notes and send them via the SMTP protocol. The capability of attaching MIME objects from the local learning environment is incorporated. From the learning theory, learners of distance learning are not expected to sit still and stare at the lectures consistently. To improve the learning performance, an interactive multi-user chatroom and a collaborative real-time whiteboard are offered, which are based on the Java RMI-distributed computing model. Figure 7 depicts the layout of such services, where a number of vivid images can be added into the whiteboard.

USING MATNS TO MODEL DISTANCE LEARNING MULTIMEDIA PRESENTATIONS

A MATN consists of nodes (states) and arcs. Each state has a state name and each arc has an arc label. Each arc label represents the media streams to be displayed in a time duration. Therefore, time intervals can be represented by *transition networks*. In this *transition network*, a new state is created whenever there is any change of media streams in the presentation. There are two situations for the change of media streams:

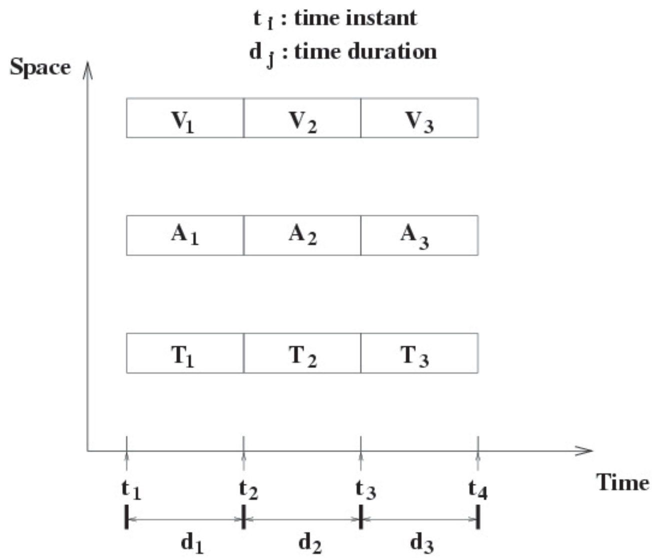
1) Any media stream finishes to display;
2) Any new media stream joins to display.

Figure 8 is a timeline to represent the multimedia presentation for Figure 6. In this example, part of the presentation is depicted for simplicity. There are four time instants (t_1 to t_4) and three time durations (d_1 to d_3). There are three occurrences of media stream combinations at each time duration:

1) Duration d_1: V_1, A_1, and T_1.
2) Duration d_2: V_2, A_2, and T_2.
3) Duration d_3: V_3, A_3, and T_3.

Figure 9 is a *transition network* for Figure 8. There are four states and three arcs which represent four time instants and

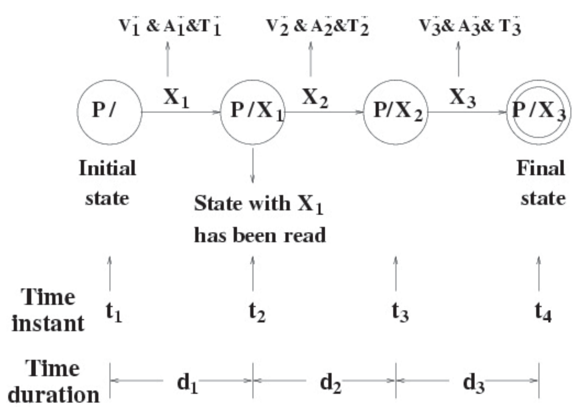
Figure 8: Timeline for the distance learning multimedia presentation as shown in Figure 6



three time durations, respectively. State names are in the circles to indicate presentation status. State name *P/* means the beginning of the *transition network* (presentation) and state name P/X_1 denotes the state after X_1 has been read. The reason to use X_i (i = 1, 2, 3) is for convenience purposes. In fact X_1 can be replaced by V_1^*& A_1^*& T_1^*. State name P/X_3 is the final state of the *transition network* to indicate the end of the presentation. State P/X_i represents presentation P just finishes to display X_i and the presentation can proceed without knowing the complete history of the past.

Each arc label X_i (i = 1, 2, 3) in Figure 9 is created to represent the media stream combination for each duration as above. For example, arc label X_1 represents that media streams V_1, A_1, and T_1 display together at duration d_1. A new arc is created when new media streams V_1, A_1, and T_1 display. A multimedia input string is used as an input for this *transition network*, and

Figure 9: Augmented transition network for multimedia presentation as shown in Figure 8



the symbol "&"' between media streams indicates these two media streams are displayed concurrently. A multimedia input string consists of several input symbols and each of them represents the media streams to be displayed at a time interval.

When an ATN is used for language understanding, the input for the ATN is a sentence which consists of a sequence of words with linear order. In a multimedia presentation, when user interactions such as user selections and loops are allowed, we cannot use sentences as inputs for an ATN. In our design, each arc in a MATN is a string containing one or more media streams displayed at the same time. A media stream is represented by a letter subscripted by some digits. This single letter represents the media stream type and digits are used to denote various media streams of the same media stream type. For example, T_1 means a text media stream with identification number one. A multimedia input string consists of one or more media streams and is used as an input for a MATN. Multimedia input strings adopt the notations from regular expressions. Regular expressions (Kleene, 1956) are useful descriptors of patterns such as tokens used in a programming language. Regular expressions provide convenient ways of specifying a certain set of strings. In our framework, multimedia input strings are used to represent the presentation sequences of the temporal media streams. A multimedia input string goes from the left to right, which can represent the time sequence of a multimedia presentation as shown in [1].

Multimedia input string: $(V_1^*\&A_1^*\&T_1^*)(V_2^*\&A_2^*\&T_2^*)(V_3^*\&A_3^*\&T_3^*)$ (1)

In (1), the "&" between two media streams indicates these two media streams are displayed concurrently. The "*" symbol is used to indicate the media stream which can be dropped in the on-line presentation. For example, $V_1^*\&A_1^*\&T_1^*$ represents media streams V_1, A_1, and T_1 being displayed concurrently, but each of them can be dropped if Show_Outline and/or Show_Video buttons are not highlighted.

Table 1 shows a simple example of a condition/action table. A condition/action (transition) table in the MATN can be used to control the synchronization and quality-of-service (QoS). The first column in this table contains the input symbols. The second and third columns show the conditions and the actions, respectively. When the current input symbol $V_1^*\&A_1^*\&T_1^*$ is read, the condition is to check whether the pre-specified presentation duration to display V_1, A_1, and/or T_1 is reached. If it is not, the display continues. The start time (stime) is defined to be the time starting the display of V_1, A_1, and/or T_1, and the difference between the current time (ctime) and the start time is the total display time so far. The second condition is met when the total display time is equal to the pre-specified duration. In this case, a next input symbol $V_2^*\&A_2^*\&T_2^*$ is read. Conditions three to five are used to check whether Show_Outline and/or Show_Video buttons (as shown in Figure 5) are highlighted or not. The corresponding actions will be performed for each condition. Synchronization can be maintained by specifying the detailed control in the actions. For simplicity, details are skipped in this paper. Similarly, the process continues until the final state is reached.

PERFORMANCE EVALUATION

Table 2 shows the performance evaluation of streaming archived lectures in terms of the packet statistics of streams.

Table 1: Condition/action table: D(X_i) is the pre-specified presentation duration for X_i (i = 1, 2, 3). Display procedure is to display the media streams. Get_Symbol is a procedure to read the next input symbol of multimedia input string. Next_State is a procedure to advance to the next state in MATN.

Input Symbols	Condition	Action
X_1 (V_1^*&A_1^*&T_1^*)	If ctime-stime(X_1) < D(X_1)	Continue
	If ctime-stime(X_1) ≥ D(X_1)	Get_Symbol and Next_State
	If Show_Outline = true & Show_Video = false	Display T_1
	If Show_Outline = false & Show_Video = true	Display V_1 and A_1
	If Show_Outline = true & Show_Video = true	Display V_1, A_1, and T_1
X_2 (V_2^*&A_2^*&T_2^*)	If ctime-stime(X_2) < D(X_2)	Continue
	If ctime-stime(X_2) ≥ D(X_2)	Get_Symbol and Next_State
	If Show_Outline = true & Show_Video = false	Display T_2
	If Show_Outline = false & Show_Video = true	Display V_2 and A_2
	If Show_Outline = true & Show_Video = true	Display V_2, A_2, and T_2
X_3 (V_3^*&A_3^*&T_3^*)	If ctime-stime(X_3) < D(X_3)	Continue
	If ctime-stime(X_3) ≥ D(X_3)	Get_Symbol and Next_State
	If Show_Outline = true & Show_Video = false	Display T_3
	If Show_Outline = false & Show_Video = true	Display V_3 and A_3
	If Show_Outline = true & Show_Video = true	Display V_3, A_3, and T_3

Table 2. Performance evaluation of streaming archived lectures

	Codec	Clip bandwidth (bps)	Average bandwidth (bps)	Protocol	Total packets	Lost packets
Audio	5 (Kbps)	5,000	5,039	TCP	510	0
Video	15 (Frame per second)	51,000	51,026	TCP	40,685	0

In this sample, the codec value of audio packets is 5 Kbps whereas the value of video packets achieves 15 frames per second. Both demonstrate an acceptable quality for the learners. Each archived lecture is encoded by RealEncoder at the clip bandwidth of 56kbps, of which audio and video account for 5,000bps and 51,000bps, respectively, as shown in the table. The average bandwidth for rendering the streaming lectures at the client side is 5,039bps for audio and 51,026bps for video; both are higher than the clip bandwidth of encoding. This guarantees the rendering quality smoothly for the streaming lectures. The total packets consumed in the sample lecture in Figure 6 for audio and video clips are 510 and 40,685, respectively, and there are no packets lost attributed to TCP that is used as the underlying transport protocol for the solution of RealPlayer for Java. This further ensures the quality of presentation, although the efficiency drops slightly. With the smoothly rendering performance, the supplementary lecture notes in HTML, and architecture-neutral learning platform by Java, the learners can benefit from the flexibility, efficiency, and timeliness supported by JIADL.

CONCLUSIONS

In this paper, we presented the JIADL system which is based on the multimedia augmented transition network (MATN) model for supporting asynchronous distance learning. The inputs for the MATN model are modeled by the multimedia input strings. The multimedia input strings have the capabilities to capture the temporal relationships of the media streams, and to model the concurrent and optional displaying of the media streams in a distance learning multimedia presentation. In addition, the synchronization and quality-of-service (QoS) of each distance learning multimedia presentation are maintained by a condition/action table in a MATN.

As far as the references surveyed, our work presented is the pioneering study in the literature towards integrating RealPlay G2 and Java JMF in the distance learning application. The experimental results demonstrate that the paradigm proposed is efficient and cost effective. In addition to supporting asynchronous distance learning, the paradigm has a variety of potential value-added applications in cultural heritage multimedia applications, marketing for electronic commerce, multimedia digital libraries, and lifelong learning. For example, The National Palace Museum of R.O.C. had published a series of video tapes, with a preview function being simply provided the JIADL paradigm.

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REFERENCES

IEEELibrary. *The IEEE/IEE Electronic Library Online, http://www.ieee.org/ielonline.*

JavaJMF. *Java JMF AFI, http://www.javasoft.com/products/java-media/jmf/index.html.*

RealPlayerJava. *RealPlayer for Java, http://www.real.com/.*

Abdel-Wahad, H., & Jeffay, K. (1994). Issues, Problems, and Solutions in Sharing x Client on Displays. *Journal of Internet-Working Research and Experience*, 5(1), 1-15.

Arcelli, F., Santo, M. D., & Chianese, A. (1998). Client-Server Architecture for Distributed Learning Environments: A Proposal. *In Proc. of the 31st Hawaii International Conference on System Sciences*, 395-403.

Maly, K. et al. (1997). Interactive distance Learning over Internets. *IEEE Internet Computing*, 1(1), 60-71.

Egan, M. et al. (1993). Learner's Perceptions of Instructional Delivery Systems: Conventional and Television. The American Journal Distance Education, 2(4), 47-55.

Kleene, S. (1956). *Representation of Events in Nerve Nets and Finite Automata, Automata Studies.* Princeton University Press.

Min, D., Choi, E., Han. Y.-T., Hwang, D., & Jung, J.-H. (1998). Distributed Multimedia Conferencing System for Distance Learning. *In Proceedings of Multimedia Software Engineering*, 88-95.

Patterson, E. K., Wu, D., & Gowdy, J. N. (1998). Multi-Platform CBI Tools Using Linux and Java-Based Solutions for Distance Learning. *In Proceedings of IEEE International Conference on Acoustics, Speech and Signal Processing*, 1909-1912.

Reed, J. A., & Afjeh, A. A. (1998). Developing Interactive Educational Engineering Software for the World Wide Web with Java. *Computers Education*, 30(3/4), 183-194.

Saini-Eidukat, B., Schwert, D. P., & Slator, B. M. (1999). Designing, Building, and Assessing a Virtual World for Science Education. *In Proceedings of Int'l Conf. Computers and Their Applications*, 59-65.

Stefano, A. D., Fazzino, F., Bello, L. L., and Mirabella, O. (1997). Virtual Lab: a Java Application for Distance Learning. *In 6th International Conference on Emerging Technologies and Factory Automation Proceedings*, 93-98.

Syed, M. R. (2001). Diminishing the Distance in Distance Education. *IEEE Multimedia*, 8(3), 18-20.

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