System Theoretical Approach to Control and Synchronization of Teleeducation in Open Distributed Environment

Witold Jacak*, Gerhard Jahn*, Jerzy Rozenblit**

*Software Engineering Department
Polytechnic University of Upper Austria, Hagenberg - Linz, Austria
***Department of Electrical and Computer Engineering
University of Arizona, Tucson, USA

Abstract. The paper presents the system *Telesession Designer and Transmitter* for computer supported creation of interactive multimedia telepresentations of training session and the event based control system for telepresentation execution in an open and distributed environment. We propose a way of unifying these different objects into one standardized format, based on MHEG–Standard. Thus we call these objects *dynamic multimedia documents.* The presentation's objects will be stored in a distributed database, which elements (multimedia objects) can be stored somewhere in the open environment. An intelligent navigation system allows selection and preview of these objects from all over the world. The presentation is modelled in form of an event depending graph, representing the general flow of the education session. The final result - the telepresentation - will run in a both i.e. the peer to peer and the client/server environment.

1 Introduction

Multimedia incorporation proves not sufficient for training and education system implementation. Unlike the computer aided instruction and intelligent tutoring systems the contemporary education systems are to be developed as interactive learning environments. It is also important that students or training participants could not only conduct and record but also communicate their work.

From these reasons we develop the system *Telesession Designer and Transmitter* for computer supported creation of interactive multimedia telepresentations of training session and the event based control system for telepresentation execution in an open and distributed environment.

The production of large quantities of document-information, necessary for the expansion of services is a significant investment and it is important that this information remains available and is not lost because of incompabilities in the data structures supported by the applications [1].

Moreover such the information should be easy available for non professional software engineer (teacher, manager etc.), which additionally support systems

for easy creation of education sessions or workshop flow and its control. For the typical applications in teleeducation and telepresentation domain a number of requirements can be identified [7, 1]:
- portability in multi-vendor environment,
- media information to be able to group several monomedia entities into a single container
- structure of information, the real time interactivity, including easy acquisition of multimedia data can be ensured,
- easy, user friendly composition and synchronization in space and time,
- specification of links and use of non multimedia objects,
- generation of interaction with different user classes,
- ability to update and manipulate sets of data or object elements.

For the purpose of reusing different component multimedia object or scripts in different presentations, learning sessions or activations, a clear standardization specification is needed. Moreover, the design of distributed hypermedia applications needs presentation preparation tools, which allow easy creation of real-time performed learning sessions or final remote presentations. From above presented reasons we develop new methods and software for computer supported creation of interactive multimedia telepresentations of education session in an open and distributed environment.
We propose a way of unifying these different objects into one standardized format, based on MHEG–Standard *Multimedia and Hypermedia information coding Expert Group* [3, 2]. Thus we call these objects *dynamic multimedia documents.* The presentation's objects will be stored in a distributed database, which elements (multimedia objects) can be stored somewhere in the open environment. An intelligent navigation system allows selection and preview of these objects from all over the world. One such document becomes part of the presentation. The multimedia objects can be used as a part of different sessions or presentations. The presentation is modelled in form of an event depending graph, representing the general flow of the education session. The nodes in the presentation's graph represent the equivalence class of units with equivalent contents. The arcs of the graph are generated from the unit's precedence relation and conditions assign relation. Such the structure of the session is used to generate the event based control system for session execution automatically.
The final result - the telepresentation - will run in a both i.e. the peer to peer and the client/server environment.

The paper presents also the controller and synchronizer of execution of the telepresentations (consisting of most different multimedia objects like text, graphics, movies, videos and also nonhypermedia objects such as executable mathematical, simulation or design tools) in distributed electronic classrooms.

We assume that there exists a computer network which consists of peer to peer connected local area networks. The local network represent one virtual electronic class room. The server in the one of these networks plays the active role, as the presentation on-line sender. Another virtual class rooms are the active on-line receiver of the telepresentation. The goal of control system is to coordinate and synchronize the transmission of presentation units coming from different sources; i.e. from on-line camera, fixed prepared multimedia presentation, sound system etc..

The *presentation sender*, controlled by the *moderator* is meant to be the central point for the presentation. It provides application programs (e.g. for exercises), the presentation's source and the control mechanism. Most of the control input comes from the moderator (by the moderator client) and it controls the receiver clients. The moderator client (also called teacher client) controls the presentation server and both directly and indirectly the receiver clients. The multi layer system for teleeducation is shown in Fig. 1. In the next sections, we present the necessary basic notions and system theoretical models for presentation session and session transmission system.

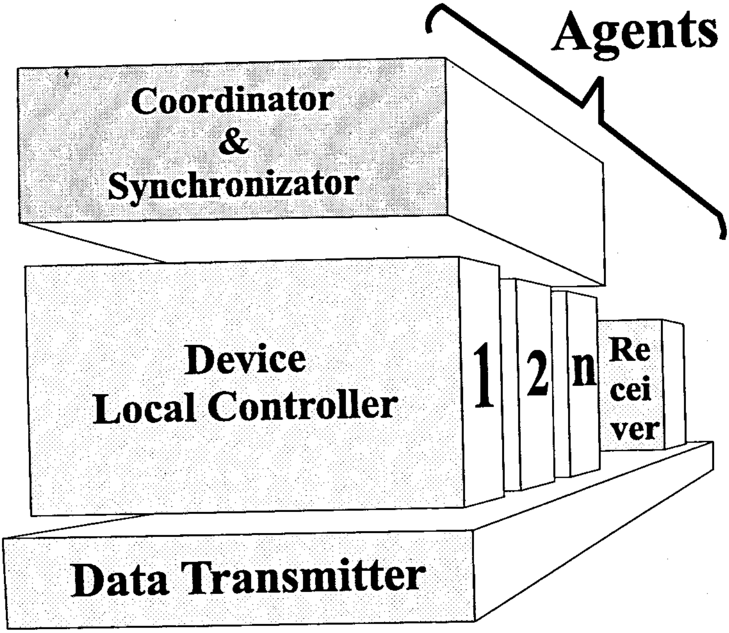

Fig. 1. Structure of multi agent transmission system

2 Education Session and Presentation Unit

An education session is a complete portion of the knowledge needed to present one learning or training item. The unit is characterized by the unchanged gross contents, which can be expressed with many different tools such as multimedia objects, on line transmitted experiments, on line control etc.

Presentation process is critically dependent on the education session representation [4,1]. Here, we use a general description of a education session, formally specified as follows:
Education session S_i is the weakly ordered set of presentation units and is represented by a three-tuple:

$$Ses_i = (U^i, \prec^i, \equiv^i) \tag{1}$$

where:
$U^i = \{u^i_k | k = 1, ..., L^i\}$ is the set of education units connected with i-th education session,
$\prec^i \subset U^i \times U^i$ is the unit precedence relation, and
$\equiv^i \subset 2^{U^i} \times 2^{U^i}$ is the unit equivalence relation.
The education session is shown in Fig. 2.

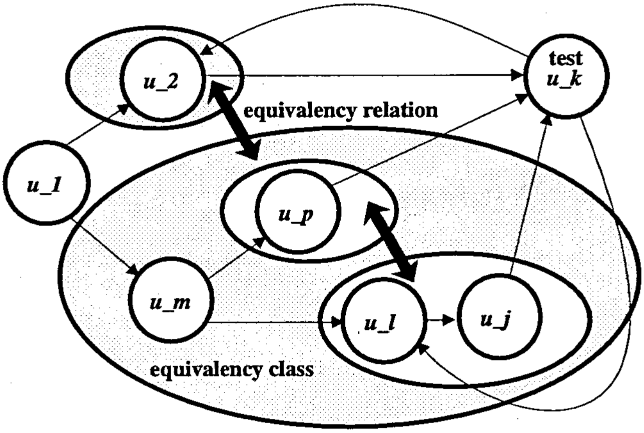

Fig. 2. Education session

3 Modelling and Control of Presentation Unit

The presentation unit is the multimedia based implementation of education unit contents. Composition of different multimedia documents, which present the contents of education unit create the complex multimedia object. This object forms the *presentation unit* equivalent to the *education unit* and will be formally used as education unit representation in education process [1,5,6].

Let MM be a set of different multimedia objects such as text documents, figures, images, movies etc. To create the presentation unit $p\_u_k^i$ for given education unit u_k^i from education session Ses_i the composition function should be given. The composition function

$$C^i : U^i \rightarrow 2^{MM} \tag{2}$$

assign the sets of simple multimedia objects $m \in MM$ to every education unit $u \in U^i$

$$C^i(u_k^i) = \{m_j | j \in J_k^i\} = M_k^i \subset MM \tag{3}$$

The structured set of multimedia objects and documents M_k^i is called *a presentation unit* (p_Unit) of education unit u_k^i from Ses_i.
Then, the presentation unit is composed of different simple objects belonging to different multimedia object classes. Each of such the object is described by two basic forms:
– the first one described a static property of the multimedia object using the SGML [2,3] formalism,
– the second one presents the object's controller needed to its properly presentation during the execution and transmission of the session.
The properly presentation of the unit's components needs a time and space coordination and synchronization. It causes a multilevel control system for p_Unit execution. This control system is realized on two levels:
– execution level, which performs the presentation of each simple object - component of presentation unit,
– coordination and synchronization level, which scheduling the presentation of unit's components according to the presentation scenario.

The presentation of the given object m from the set MM is controlled by the following event based system [9]:

$$Contr\_m = (S_m, X_m, Y_m, \delta_m^{ex}, \delta_m^{in}, \lambda_m, \tau_m) \tag{4}$$

where:
• $S_m = Space\_Pose \times Logic\_State$ is the state set of object m where $Space\_Pose$ describes the location of object in the screen and $Logic\_State$ presents current status of object during its presentation on the screen.
• X_m is the external (control signal) event set,
• Y_m is the output (message) event set,
• T is own time base,
• $\delta_m^e : (S_m \times T) \times X_m \rightarrow S_m$ is the external state transition function,
• $\delta_m^i : S_m \rightarrow S_m$ is the internal state transition function,
• $\lambda_m : S_m \rightarrow Y_m$ is the output function,
• $\tau_m : S_m \rightarrow \Re$ is the time_activity function.
The controller is in the form of discrete event based dynamical system DEVS, developed by Zeigler [9]. For every active state the its life time should be given and for passive state its life time is equal to infinity.

3.1 State transition - the control of simple presentation

The possible transitions of the states are presented in Fig. 3. The life cycle shows that the control signals are accepted only in states not later than the one indicated. Once an object arrives at state "Terminated", it cannot by presented anymore, as long as if is not reset, either implicitly or explicitly by receiving a "reset" signal, which is accepted in any state other than "Idle". In addition , an object's states contains one further component "Pause", which is controlled by the signal pair "pause/continue". These signals are accepted at any time, but take effect only in the "Running" state. The states "Preparing, Starting, Terminating, Resetting" allow for adjustment of hard/software caused delays. This model presents only a standard states, signals and messages. Besides those signals shown in Fig. 3, the controller may accept further signals and emit additional messages. It can be easy extended on an application defined states and signals.

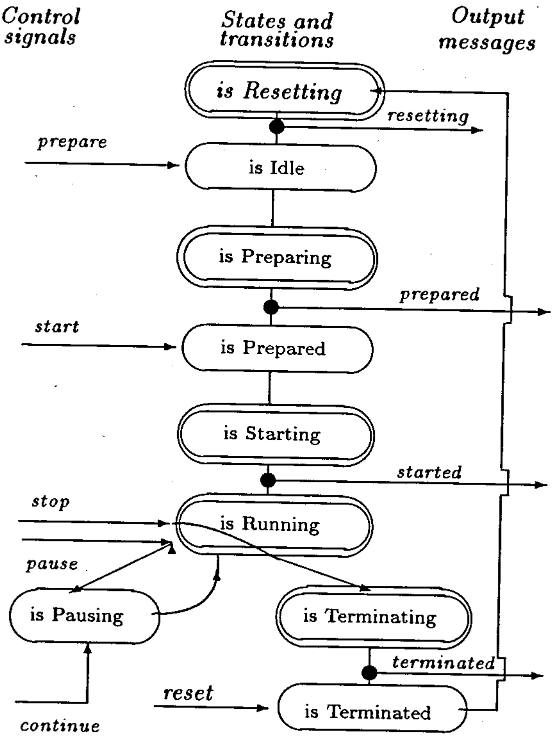

Fig. 3. Life cycle of state transition for presentation unit

3.2 Coordination of p_Unit presentation

As we have previously mentioned, the presentation unit is a composition of the simple objects. In the special case, the p_Unit can contains only one object.
The presentations of each unit's component have to be coordinated and synchronized in time and space. In order to synchronization of the component's execution, the higher level of control is introduced. This level will be called the coordination and synchronization level.
To present a contents of multimedia objects, a coordinator of p_Unit realization must exist. That implies that a component object not coordinated by any p_Unit will not be presented. Generally, p_Unit should performed the coordination and synchronization of different objects presentation.
Let $C_i(u_k^i) = M_k^i$ be the set of multimedia objects assign to this p_Unit. Formally, a coordinator and synchronizator of the p_Unit for the given education unit u_k^i is represented by the following structure:

$$\text{Syn p\_Unit}_k^i = (SU_k, IQ_k, AX_k, RB_k, Akt_k, Gen_k) \tag{5}$$

The components of the synchronizator p_Unit have the following meaning:

- $SU_k = X\{S_m | m \in M_k\}$ is the global state set of presentation. The vector $(s_1, s_2, ...s_M)$ describes the current status of presented unit's components,
- $IQ_k = \bigcup\{Y_m | m \in M_k\}$ is the messages queue, generated by controllers of unit components in execution level,
- AX_k is the authoring external events. The external event $x \in AX_k$ is used to initialize, activation or deactivation of particular unit's flow parts,
- RB_k is the rule base; logical synchronization of p_Unit performance,
- $Akt_k : IQ_k \rightarrow SU_k$ is the actualization function which up dates the global state register based on coming messages from the unit's components,
- $Gen_k = \{g_m(RB) : SU_k \times AX_k \rightarrow X_m | m \in M\}$, is the set of generation functions of control signal (external event) for each object's controller

To present the objects from the p_Unit it is necessary to produce a presentation scenario for this unit. The scenario describes the composition and scheduling of object during the presentation flow. Generally, scenario can be represented by a graph, which determine the running of a given object depending on current global status of the unit. The system for design and execution of presentation has three main level:the multimedia object specification layer, the education session design layer and the application layer. This multilevel structure of telepresentation system is shown in Fig. 4.

4 Transmission Coordination of Teleeducation Session

We assume that there exists a computer network which consists of peer to peer connected local area networks. The local network represent one virtual electronic class room. The server in the one of these networks plays the active role, as the presentation on-line sender. Another virtual class rooms are the active on-line

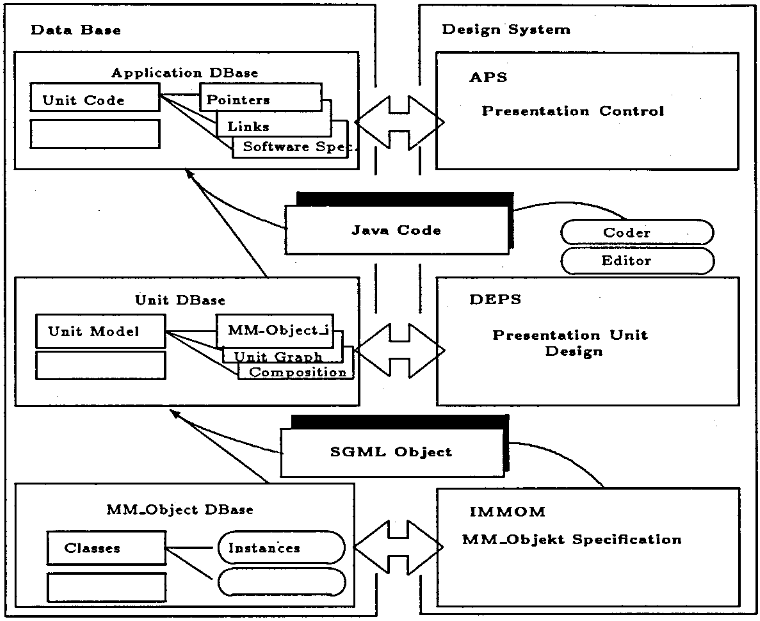

Fig. 4. Multilevel structure of p_Unit design system

receiver of the telepresentation. The goal of control system is to coordinate and synchronize the transmission of presentation units coming from different sources; i.e. from on-line camera, fixed prepared multimedia presentation, sound system etc..

4.1 The controller and synchronizer of the telepresentation session transmission

The controller and synchronizer of execution of the telepresentation session (consisting of most different multimedia objects like text, graphics, movies, videos, on-line TV transmission, and also nonhypermedia objects such as executable mathematical, simulation or design tools) in distributed electronic classrooms has the hierarchical structure: - supervisor level of session sender and session receiver (moderator, coordinator and synchronization),
- local controllers and transmitter level and,
- session execution level.

4.2 Modelling of transmission controller and synchronizer

The control system of transmission is modelled as a multi-agent hierarchical real time object oriented system . A simple component - an agent is an object from agent class. The architecture of an agent consists of two components.

A simple agent architecture Each agent of transmission coordination system is defined as a pair:

$$Agent_i = (Structure_i, Behavior_i)$$

Structure of a simple agent The structure component of an agent is defined the following tuple:

$$Structure = (Interface, Contracts)$$

The interface is the set of *end ports.* The ports are directly accessible to the behavior component and are defined by the set of port references.

$$end - port = \{port_a, port_b, ..\}$$

Some of these port references in the $end - port$ set also can appear in the *peer-interface* set. These are the so-called *external end ports.*

Agent Interface - Peer Interface The $Peer\_Interface$ is a class of input/output port references representing the ports that appear on the outside of the agent

$$Peer\_Interface = \{port_1, port_2, ..., port_n\}$$

$$port_k = (port\_name_k, protocol\_class_k)$$

where:

- the port *name* is the name of port reference k and it must be unique with respect to other port references in the peer interface.
- the protocol class is the basic class of the protocol of messages associated with the port reference.

The port reference from peer interface which does not belong to the external ports are called the $relay - ports$.

Agent Contracts The contracts are defined by the set of binding contracts.

$$Contracts = \{contract_1, contract_2, ..., contract_m\}$$

Binding contracts are defined by the set of m contracts. The m-th contract is a pair

$$b_m^{contract} = (end\_point_1^m, end\_point_2^m)$$

Each of these end point defines the connection port on another agent

$$end\_point_{1/2}^m = (port\_name_l^k, agent_k)$$

where:
$port_l \in Peer\_Interface$ of an agent $Agent_k$.
The agent structure is shown in Fig. 5.

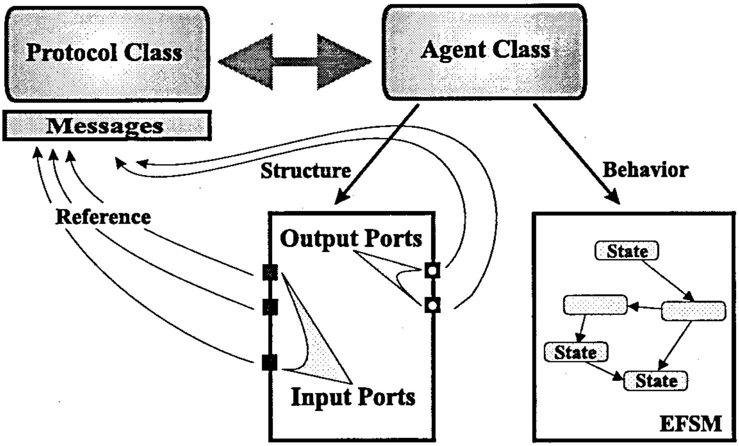

Fig. 5. Agent structure

4.3 Agent behavior

The behavior will be specified as extended state machine model.

$$Behavior = State\_Machine$$

$$State\_Machine = (M, S, A, t, g, entry, exit)$$

where:

- $M = IM + OM$, the set IM defines the input messages, and the set OM defines the output messages.

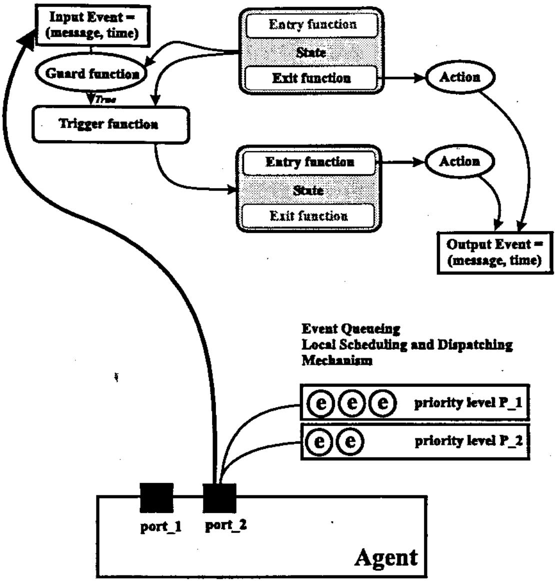

Fig. 6. Agent behavior

- S is the agent state set
- A is the agent action set
- g is the guard function.

$$g : E \times S \times Peer\_Interface \rightarrow \{T, F\}$$

The guard function must evaluate to true or false. This function defines an evaluation that must be performed when a message is received, to decide whether a transition will be taken.

$$E \subset Time \times IM$$

is the set of input events

$$e_{in} = (time, i\_message)$$

- t is the trigger function (transition function)

$$t : E \times S \times \{T, F\} \rightarrow S$$

where and $\{T, F\}$ are the values of guard function g.
$t(e, s, B) = t(e, s, g(e, s, port)) = s_{new}$ iff $g(e, s, port) = T$,
and
$t(e, s, B) = t(e, s, g(e, s, port)) = s$ iff $g(e, s, port) = F$

- the function

  $$entry : S \to A$$

  is the entry function, which decides on the entry action of the agent. An entry action is performed when a state is entered by way of any transition. The entry function can generate the output event

  $$e_{out} = (time, o\_message)$$

- the function

  $$exit : S \to A$$

  is the exit function, which generates the exit action. The exit action is taken when a state is vacated by way of any transition.

The agent behavior is presented in Fig.6. All components of presentation transmission and moderation system have these same mathematical structure. Each agent-controller communicate with other agents with help adequate messages. The work of whole system is coordinated by central moderator agent.

Above presented system enable to design the teleeducation session and to transmission it in open distributed environment.

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