Vol. 39 No. 2 Transactions of Information Processing Society of Japan Feb. 1998

Regular Paper

Design of a Distributed Hypermedia System Based on Hypermedia-on-Demand Architecture

MICHIAKI KATSUMOTO† and SHUN-ICHI IISAKU†

We propose a distributed hypermedia system based on client-agent-server architecture, as well as presentation models for advanced information infrastructure. To achieve the advanced information infrastructure that will be the next-generation multimedia information system, the development of new technologies for system architecture, software for implementation, and presentation models is required. Therefore, we examine the need for a distributed hypermedia system for an advanced information infrastructure, software technology and human interface. The distributed hypermedia system which we propose is a platform providing flexible and sophisticated multimedia information navigation with high-quality video and audio such as HDTV or UDTV (Ultra Definition TV) and Hi-Fi audio or 3D audio. In this paper, we propose presentation models and system architecture for proposed hypermedia presentations from the standpoint of next-generation hypermedia system which will be needed software technology.

1. Introduction

In order to achieve advanced multimedia information systems, we here consider new presentation models for a next-generation hypermedia system with a more sophisticated media structure. Here, multimedia presentation and hypermedia presentation have to be clearly defined. In the studies of 1) and 2) , the hypertext presentation is organized by nodes and links, whereas a multimedia presentation is organized by a combination of continuous and discrete media. Furthermore, hypermedia presentation is organized by an extended hypertext presentation model in which each node has a multimedia presentation. However, the definition of multimedia presentation[1),2)] was inadequate, as it gave no clear definition of the temporal synchronization between continuous media, such as audio and video, and continuous media and discrete media, such as images, graphics and text, with the presentation scenario. Also not considered was transmission of media over a network depending on the presentation scenario, while maintaining the temporal relation between spacial relation. Accordingly, we now define a hypermedia presentation model consisting of several multimedia presentations and a proposed Hypermedia-on-Demand system (HOD). In addition, we consider several scenarios with temporal and spatial synchronization for this distributed hypermedia system.

On the other hand, there are cases in which quality cannot be guaranteed, due to the lack of capability of the user, agent, and server machines or load change in network capacities. For this reason much research into Quality of Services (QoS) guarantee functions has been done[3),4)]. That research, however, discusses systems that do not contain a scenario represented by a general Video-on-Demand System (VOD), and for this reason they did not deal with QoS guarantee functions for hypermedia systems. In addition, in a conventional hypermedia system, the links between the current reference point and the next reference point are fixed, and cannot be easily changed once the hypermedia system has been constructed. As a result, a hypermedia presentation with fixed links inhibits flexible or effective user navigation and the addition of expandable functions such as QoS guarantee mechanisms. To overcome these problems, we introduce new presentation models and a new system architecture for a distributed hypermedia system. The system is based on object-oriented modeling and takes into consideration agent concepts and different temporal synchronization methods that depend on intramedia or intermedia with QoS guarantee functions. Consequently, the QoS guarantee functions of the hypermedia system need to be considered. So far in this paper, we have discussed three different presentation models and corresponding system architectures: VOD, Multimedia-on-Demand system (MOD),

† Communications Research Laboratory, Ministry of Posts and Telecommunications

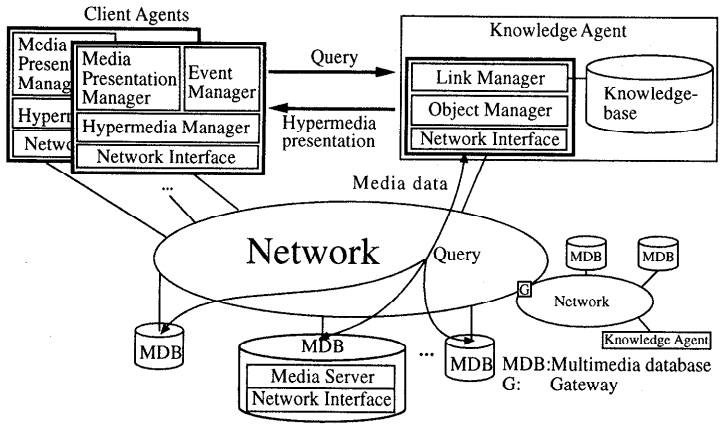

Fig. 1 Illustration of the system architecture of Dynamic Hypermedia System.

and Hypermedia-on-Demand system (HOD).

2. Dynamic Hypermedia System

The Dynamic Hypermedia System (DHS)[5] is a network-oriented platform for multimedia information networks to provide multimedia information space based on hypermedia presentation. The system architecture of the DHS has three components, as shown in **Fig. 1**. The client agents are located at user stations to provide the users with multimedia presentation capabilities. The knowledge agent manages links to information units by dynamic linking methods6) and generates multimedia objects. The multimedia databases (MDB) manage multiple media objects, such as text, image, and video and audio data. Further details of the DHS are explained in Refs. 5) and 6).

3. Presentation Models

We propose three presentation models[5] for an advanced information infrastructure: the Dynamic Hypertext, Multimedia and Dynamic Hypermedia models. These models constitute the next-generation hypermedia information system. They are more sophisticated than the Amsterdam Hypermedia Model[1),2)] because they include dynamically linking mechanisms and QoS guarantee functions to expand the flexibility of hypermedia information access.

- Dynamic Hypertext model: One fundamental difference between the dynamic hypertext model and conventional hypertext model is that this method supports a link to the dynamically next node at the time of user interaction. The next node is linked by dynamic link methods that search for media data to match the user's intellectual background or level of interest in the information. The Kansi link method[6] is a very suitable example. In addition to this, for continuous media data in video or audio, the linking relation is decided in real time.
- Multimedia model: This is the same as multimedia defined generally. Several media sources are integrated temporally and spatially to create presentations, as shown in **Fig. 2**
- Dynamic Hypermedia model: This model, shown in **Fig. 3**, integrates the dynamic hypertext model with the multimedia model. In other words, a node in the dynamic hypermedia model, is constituted by multimedia model.

New systems based on the above-mentioned presentation models are discussed in the following section.

4. Video-on-Demand System

The Video-on-Demand System (VOD) is one of the multimedia applications whose system architecture and QoS guarantee function implementation methods were previously discussed. The features of VOD are,

(1) Easy retrieval of desired video at any time,
(2) Interactive operation (play, pause, stop, etc.), with QoS guarantee.

To provide an advanced information infrastructure and hypermedia model, we add the following features to VOD.

(3) Ultra-high definition of video and image.
    - Spatial resolution: more than 4 million pixel (approximately four times

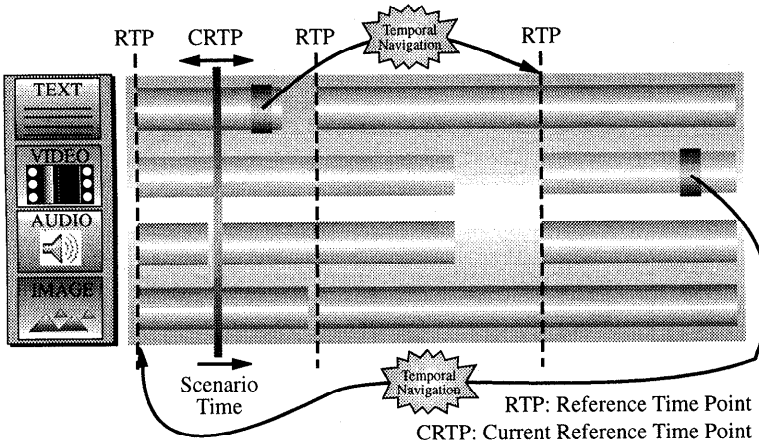

Fig. 2 Illustration of multimedia model.

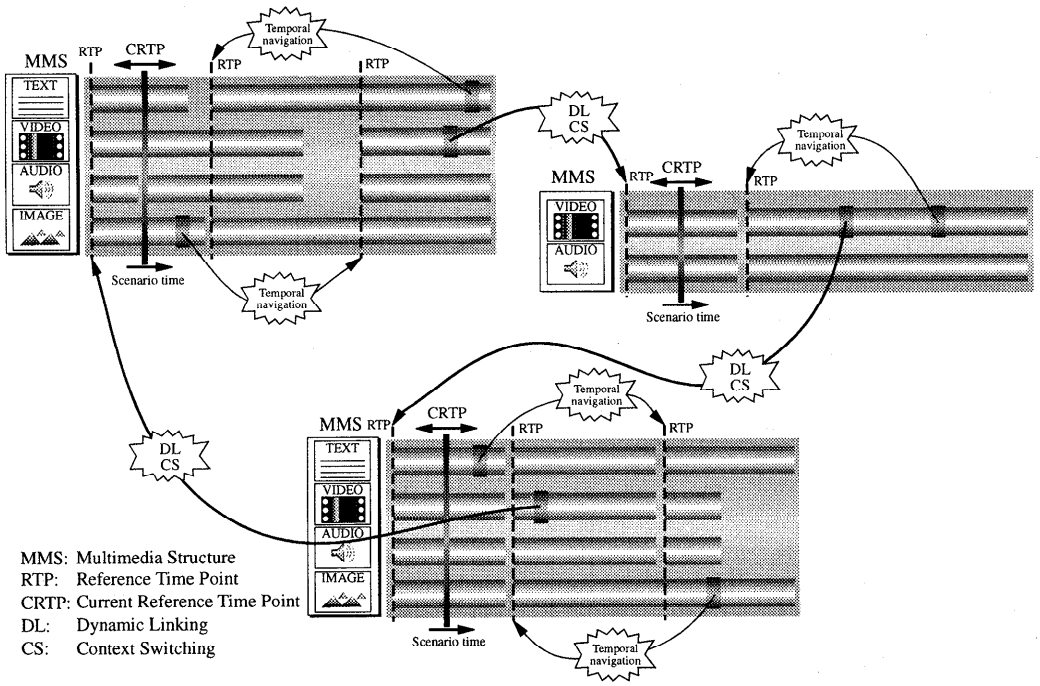

Fig. 3 Illustration of hypermedia model.

that of HDTV).

- Temporal resolution: 60 frame/sec.
- Depth: more than 24 bits/pixel.
- Display: large-sized plasma LCD screen, and UDTV monitor.

(4) Realistic audio or sound reproduction.

- 3D audio system.
- Multi-channel Hi-Fi audio system.

(5) Multi-angle viewer and control operations

- Easy operation with joy stick or mouse.
- Adaptation of dynamic hypertext model.

Figure 4 shows the VOD system architecture. For sample applications, digital cinema or medical care services using high-speed networks, such as CATV lines or digital satellite will be planned.

In VOD, the knowledge agent receives a query from each client agent and retrieves the multimedia data matching the query from multimedia databases (MDBs), and guarantees the media stream between each client agent and the

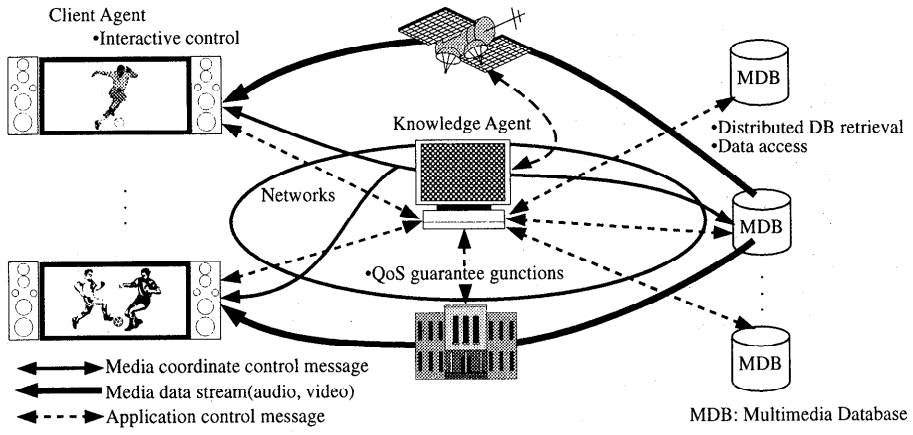

Fig. 4 Illustration of VOD architecture.

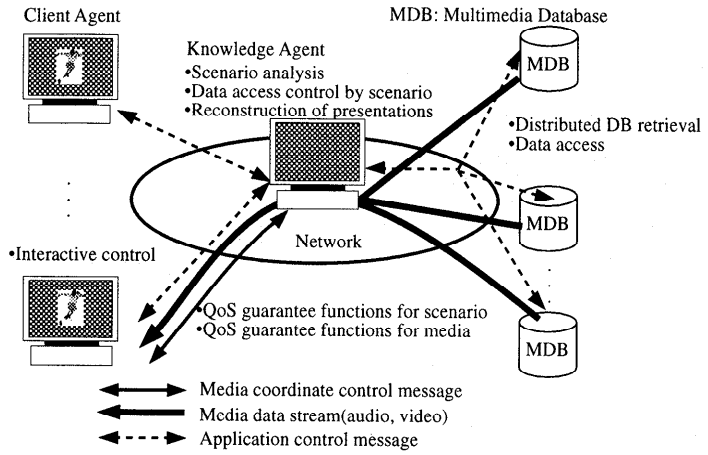

Fig. 5 Illustration of MOD architecture.

MDBs. As each QoS guarantee is fulfilled4), the knowledge agent manages the media stream of each client agent.

5. Multimedia-on-Demand System

The system architecture of the Multimedia-on-Demand system (MOD) is proposed, as shown in **Fig. 5**, based on the client-agent-server architecture of the DHS. MOD provides a multimedia model that consists of a multimedia presentation on the basis of a scenario. MOD is different from VOD, in that its presentation is based on a temporal and spatial scenario. In the MOD, information is organized by integrating several media, to provide a multimedia presentation. For example, one side, consisting of a title, the text, and a photograph (similar to newspapers), is provided through a network. The Metanode[5] is proposed as a data model for integrating multimedia presentations by integrating the data of several media, such as video, image text, etc. An example of an "Electronic Museum," Metanode is composed of image, video and audio as an MOD multimedia presentation model. To achieve multimedia presentations, the following is needed.

- Compression methods such as MPEG1 or MPEG2, JPEG.
- Material for a Hi-Fi stereo audio system.
- A workstation, high-performance personal computer, or mobile computer.

In MOD, the process of the knowledge agent after receiving a query from the client is,

(1) Retrieve the scenario that is most suitable for query.
(2) Retrieve several media data that are suitable for the scenario from MDBs.
(3) Integrate the media data as the Metan-

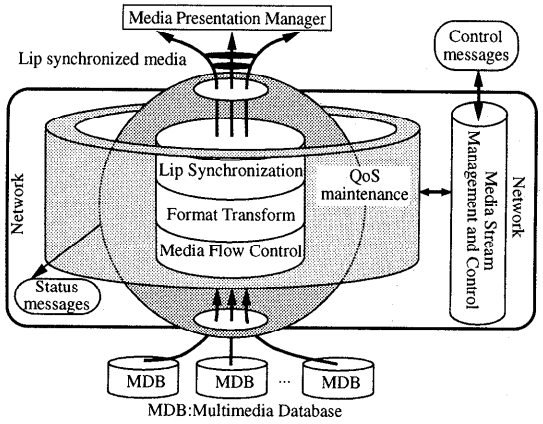

Fig. 6 Illustration of media object.

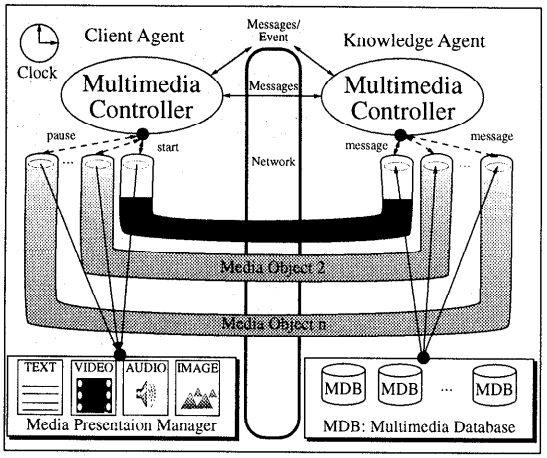

Fig. 7 Illustration of multimedia controller.

ode.

(4) Transmit the Metanode to the client agent, as closer to the scenario so long as possible.

5.1 QoS guarantee function at MOD

The multimedia model that we suggest composes several media data, which it is takes from a scenario with lip synchronizations using temporal connections and scene synchronizations. Therefore it is thought that, in MOD, the lip synchronization method and the scene synchronization method for each QoS guarantee function within a scenario is also necessary. For easily transmitting media data, a Media Object (MO), as shown in **Fig. 6**, encapsulates the lip synchronization, media handling, and media conversion method. To make multimedia presentation possible, Multimedia Controller (MMC) manages media objects. The MMC, as shown in **Fig. 7**, adds QoS guarantee function for the lip synchronization method. The QoS management function for the scene synchronization method is also controlled by the MMC. Furthermore, a QoS guarantee function corresponding to a change of the contents is necessary, because contents change with the progress of a scenario in MOD. In addition to this, it is consider that scheduling transmission provides a presentation as possible as near the scenario when QoS guarantee function. Load change in a system and the network conditions are always watched by the media stream management and control module. Furthermore, QoS negotiations based on the changes in the conditions such as network traffic, are reported by other control modules, and the QoS parameter of the entire scenario is changed by the media stream management and control module. The change is communicated to a MMC. When the MMC receives the notification of the QoS parameter, the MMC changes the agreement QoS priority for the scenario in each media object. The MMC provides a presentation while keeping QoS guarantee using the new QoS parameter provided by the QoS maintenance module in the individual media object. In the knowledge agent, the transmission schedule is changed as needed.

6. Hypermedia-on-Demand System

The Hypermedia-on-Demand System (HOD), as shown in **Fig. 8**, is provided to hypermedia presentation. In the HOD, the following conditions are assumed.

- Full screen (more than 1920×1080): video data provided at 60 frame/sec and non-interlaced.
- Multimedia presentation (960×540): video data provided at 30 frame/sec and interlaced.
- Multilingual audio or 3D audio.
- Screen size: more than 32 inches, proportions: 16:9.

For this, advanced hardware is required.

- High-performance workstation with multiple CPUs.
- Dedicated processor for controlling video and audio.

In HOD while several multimedia presentations are simultaneous or switching presented. Consequently, new QoS guarantee functions between individual multimedia presentation and multimedia presentations become necessary. As

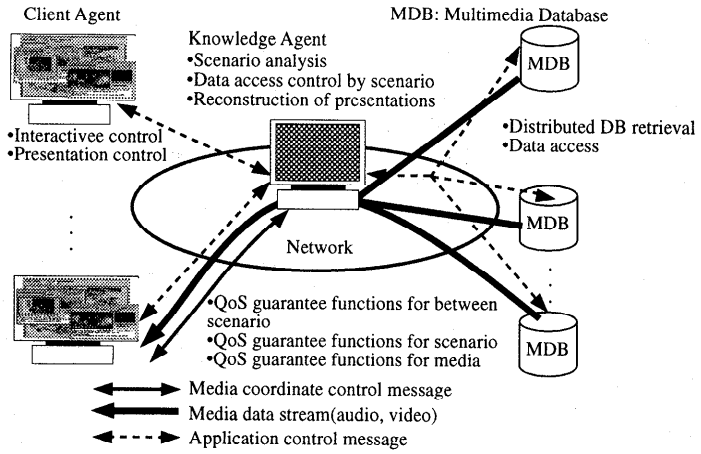

Fig. 8 Illustration of HOD architecture.

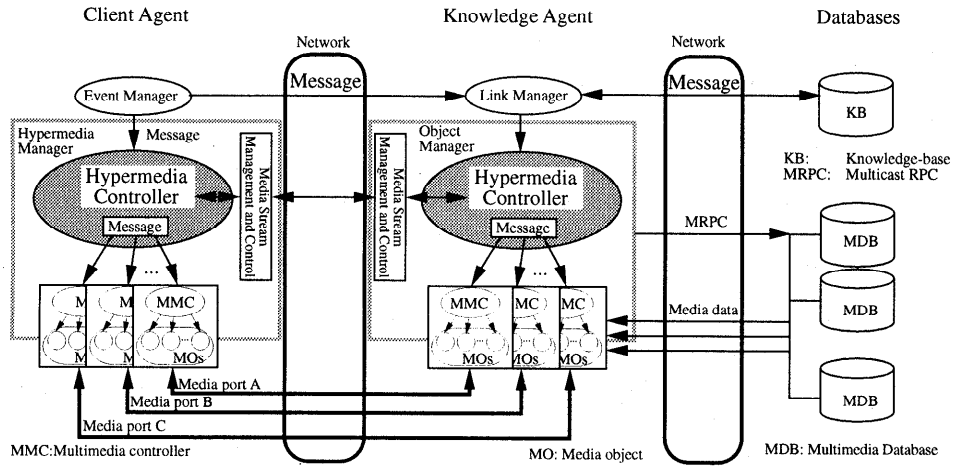

Fig. 9 Illustration of hypermedia controller.

for the functions of the knowledge agent, in addition to the functions needed with MOD, a function to manage individual multimedia presentation becomes necessary. And, in the client agent, the presentation control functions change to audio device becomes necessary, in addition to the demand control that is interactive from a user. A hypermedia presentation consisting of several multimedia presentations requires two elements. The first is the QoS change and guarantee function by context switching at multimedia presentation interval. The other is the QoS change and guarantee function that is necessary in addition to the QoS guarantee function for a multimedia presentation at MOD.

6.1 QoS Guarantee Functions at HOD

In the dynamic hypermedia model, we defined three types of hypermedia context switching[5], "pause," "continue," and "stop," as context switching in navigation between multimedia presentations, and QoS mechanism must be able to correspond. In the case of "continue," when several presentations are executed simultaneously, several presentations are provided in one display. In this case, the order of QoS for an individual presentation must be set in advance. When an indication that the media is continuous is contained in hypermedia presentation, QoS change should be considered from the viewpoint of characteristics of the presentation. Consequently, a new QoS change function becomes necessary. For example, a presentation of overlapping lower part needn't guarantee that is always high QoS, and QoS guarantee of the presentation does not equally guarantee about with active presentation's QoS parameters. However, when the presentation is in-

Table 1 Comparison of characteristics of VOD, MOD, and HOD.

	VOD	MOD	HOD
Spatial resolution	2000 × 2000	720 × 480 (960 × 480)	1920 × 1080
Temporal resolution	60 frame/sec	30 frame/sec	60 frame/sec
Audio (Hi-Fi)	Multi-channel	Stereo	Multi-lingual
Transmissions	Satellite, CATV	ATM (wide area)	ATM, CATV
User stations	Custom	WS, PC	WS
Display	Large (plasma, LCD screen)	More than 17in. (general monitor)	HDTV or UDTV monitor (more than 32in.)
Applications	Medical services Digital cinema	Electronic news General database	Electronic museum Technical database
Synchronization and QoS	Media	Between media Integrated Media	Between Media Integrated media Between integrated media

dicative of active, synchronization between presentations needs to occur, prior establishment of the order of presentations is important, and a mechanism that seems to guarantee several QoS is necessary. Fundamentally, one presentation is presented at one audio device, when one presentation is indication of active, the audio device is changed the QoS guarantee of the presentation. Therefore, quickly QoS change function between presentations are necessary.

To offer guaranteed QoS in HOD hypermedia presentations, we propose the Hypermedia Controller (HMC) as shown in **Fig. 9**. The HMC provides hypermedia presentation like an architecture that contains the above-mentioned functions and thus fulfills the QoS guarantee. When the HMC receives context switching or a change of state of presentation from the event manager of the client agent, it contorol the QoS condition of individual multimedia presentation with considertion of the previous states, and comunicats to the media stream management and control module. The media stream management and control module that receives this messages and negotiations as needed, and the QoS parameter is established. The QoS can be changed by communicating the QoS parameter established in each MMC.

7. Summary

Presentation models and system architecture for a distributed hypermedia system in an advanced information infrastructure have been proposed. A mechanism necessary to fulfill QoS guarantee functions in an HOD system described in this paper was considered, and VOD, and the QoS functions of MOD were defined. The characteristics of each system are summarized in **Table 1**. In the QoS function in an HOD system, quick setting and adjustment of the QoS is important. The design and implementation of actual parameters and primitives is a subject for further study. In the implementation stage, the QoS mechanism for the dynamic hypermedia model will be realized with a hypermedia controller. In addition to this, the QoS mechanism for the multimedia model using the multimedia controller will be developed in the hypermedia manager.

References

1) Hardman, L., Bulterman, D.C.A. and Rossum, G.: Links in Hypermedia: The Requirement for Context, *ACM Hypertext '93*, pp.183–191 (1993).
2) Hardman, L., Bulterman, D.C.A. and Rossum, G.: The AMSTERDAM Hypermedia Model: Adding Time and Context to the Dexter Model, *Comm. ACM*, Vol.37, No.2, pp.50–62 (1994).
3) Little, T.D.C., Ahanger, G., Folz, R.J., Gibbon, J.F., Reeve, F.W., Schelleng, D.H. and Venkatesh, D.: A Digital On-Demand Video Service Supporting Content-Based Queries, *Proc. of ACM Multimedia 93*, pp.427–436 (1993).
4) Hashimoto, K., Watanabe, M., Katsumoto, M. and Shibata, Y.: End-to-End QoS Architecture for Continuous Media Services, *Proc. ICOIN-10*, pp.578–583 (1995).
5) Katsumoto, M., Seta, N. and Shibata, Y.: A Unified Media Synchronization Method for Dynamic Hypermedia System, *Journal of IPSJ*, Vol.37, No.5, pp.711–720 (1996).
6) Katsumoto, M., Fukuda, M. and Shibata, Y.: Kansei Link Method Based on User Model, *Proc. ICOIN-10*, pp.382–389 (1995).

(Received May 12, 1997)
(Accepted September 10, 1997)

Michiaki Katsumoto received the B.S., M.S. and Ph.D. degrees from Toyo University in 1991, 1993 and 1996 respectively. He is working now Communications Research Laboratory of Ministry of Posts and Telecommunications. His research intetests include hypemdia system and multimeida database. He is a member of IPSJ, IEICE, IEEE Comupter Society and ACM.

Shun-ichi Iisaku received the PH.D. degree from Hokkaido University in 1982. He joined Kokusai Denshin Denwa Co., Ltd., where he worked in the R&D Labs and his interests were network architecture and communication protocols. In 1995, he joined the Communications Research Laboratory of the Ministry of Posts and Telecommunications. His research interests are intelligent multimedia retrieval and image processing.