An Interactive Cooperative Teleworking Environment - $T\eta\lambda\varepsilon\mu\alpha\theta\varepsilon\iota\alpha$ *

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Abstract

In this paper we present the design and the implementation of an interactive environment for cooperative teleworking. Telemathea offers tools that support the communication and the teleworking between tutor and trainee, who may reside in remote geographical regions. This environment offers audio communication over the network as well as support for joint editing of text documents and still images. It supports different audio coding techniques so as to adjust to the available bandwidth, and makes use of the RTP protocol in order to facilitate the exchange of audio and, in the future, video packets.

1 Introduction

Multimedia telematics applications for communication and cooperative teleworking give the opportunity for creative joint-work independently of geographical locations. Applications of this kind provide tutors and trainees with the ability of continual, close and efficient cooperation without any need for transportation and personal meetings. Furthermore, the environments for Computer Supported Cooperative Work (CSCW) may give the opportunity for virtual meetings, conferences and presentations without the limitation of physical presence ([2]).

Initially a few applications for Remote Expert Consultation were developed that attempted to provide experts with the ability of limited cooperation. An approach to Remote Expert Consultation was RECPhone ([3]) which was implemented as a part of the European project TELEMED/RACE. The aim of RECPhone was to fulfill the remote doctors' needs for communication and cooperative telediagnosis. RECPhone provides its users with capabilities of transferring files and medical images and interchanging text messages and cursor coordinates in order to attend virtual medical meetings for telediagnosis.

*$T\eta\lambda\varepsilon\mu\alpha\theta\varepsilon\iota\alpha$ (telemathea) is the Greek word which best describes cooperative teletraining.

Applications for Remote Expert Consultation have been enhanced with facilities for joint-editing of text files and document conferencing so as to develop environments for cooperative teleworking.

Based on the major principles of RECPhone, Telemathea was developed in order to offer an environment for cooperative teleworking and colaborative learning. Telemathea is a telematics application that aims to answer the needs, of remotely located, tutors and trainees for an open line of communication, interactive conferencing and cooperation. It offers end-to-end communication over networks by using multimedia information handling and interchange ([5,6,7]).

Telemathea offers a number of advantages which can be summarized as follows:

- Interactive one-to-one communication, enhanced by audio over the network.
- Modular design and open architecture. This permits the adaptation of Telemathea, with relatively small effort, so as to use the more advanced facilities of the broadband networks, when they will be widely realized.
- Provision of a shared text and image editor that can offer the ability of document conferencing.
- Ease of use. Telemathea has a user friendly interface that hides from the user most of the network layer details.

As it can be understood, Telemathea is an environment that can be put into immediate use over the existing networks, and can greatly aid the implementation and realization of cooperative teleworking and colaborative learning services. This use can offer a number of advantages to the tutors and trainees among which are the following:

- Interactive communication by means of interchanging text and audio messages according to the principles of What I See Is What You See (WISIWYS).
- Capability of real time communication and work with a remotely situated tutor.
- Both tutors and trainees do not suffer from loss of creative time by avoiding useless transportation.
- The use of cooperative teleworking and colaborative learning solves the problem of the limited number of experts and reduces the cost of cooperation among remotely situated individuals.

A general description of the functional model, the major principles of design and implementation and the possible future enhancements will be presented in the following paragraphs.

2 Description

Telemathea has been developed under the Unix operating system ([8]) and its user interface has been based on the X Window system with the use of the facilities offered by the OSF/Motif [9,10], Xtoolkit and Xlib. It has been installed and successfully tested on a variety of workstations with 486DX processor, and SCO Unix/SCO Open Server operating system.

2.1 Communication layer

The implementation of the mechanism that manages the network connections needed for the realization of the services offered by Telemathea, is based on the TCP/IP protocol suite ([11]) and makes use of the client server model. The workstations communicate with each other with the use of the socket mechanism in connection-oriented or connectionless mode of operation and well-known ports.

In order to take advantage of the multitasking capability of the Unix operating system, all the services have been implemented as separate processes. Furthermore, there is a unique process (communication control process) that manages the network connections of the communicating workstations. This solution has been chosen because of the nature of Telemathea, which demands concurrent communication (transmission/reception of different kinds of data and control packets) and management of the graphical user interface. There are two types of packets that are exchanged between the communicating workstations, the control packets and the data packets.

The control packets are exchanged between the communication control processes through a bidirectional network connection. The management of the interaction between the communicating workstations and the joint-editing of text files and still images are performed through these control packets.

Also, a distinct network connection is established for each kind of data packets that have to be exchanged between the communicating workstations. These connections are handled by the process that is responsible for the realization of the corresponding service. Such a connection is active as long as the two workstations communicate by interchanging this kind of information. By using different processes to transmit different kinds of data packets there is a more effective way of exploiting the available bandwidth and the synchronization of the communicating processes becomes easier.

2.2 Communication modes

There are three different modes of communication between the two counterparts:

Interactive mode. It is the most important mode of communication and it is used when a user desires to have a direct communication with another user. For this mode, a client-server model has been implemented, where the requestor of the communication is the client and the respondent of the request is the server.

Batch mode. This mode of communication is used when there is no need for immediate response by the receiver of the message. The communicating process in this case is the following: The sender selects the information to be sent (some data files, or images followed by explanatory textual information and topics for discussion) and after specifying the peer's address he[1] transmits them. The receiver will be notified for the new message as soon as possible and will reply at his own will.

Mixed mode. This mode of communication is the combination of the two previously described modes. In this mode the initiator starts a batch mode communication and the receiver is informed immediately for the message. The batch session is followed by an interactive session, provided that the receiver is able to reply immediately.

[1] "He" should be considered as "he/she" throughout this paper.

2.3 Architecture

Telemathea can be divided in two major parts, the local data processing part and the communication part. There is also a minor third part that consists of the modules that interact with the sound drivers for recording and playing back audio messages. The firt part deals with the local processing and representation of the data handled by the application (eg. plain or formatted text, still images and audio), the selection and encoding/decoding of the data that are to be transferred or received, and the storing/retrieving of data files. The second part is responsible for the communication process (session establishment, data transfer over the network, error checking, synchronization, etc.). More specifically, Telemathea can be divided in several modules that offer a number of facilities, which can be summarized in the following:

User friendly graphical interface. Telemathea offers a friendly and easy to learn graphical user interface that provides fast access to the mostly used functions, and releases the user from taking unnecessary actions or making improper use of some functions. Also, an on-line help option is provided.

Local data processing. This module provides joint-editing of textual information/still images during the conference and the selection of the data to be sent to the other peer of communication.

Communication. The processes that are responsible for transmitting/receiving different kinds of data (text, image, audio) are parts of this module. The communication control process is included in this module too. The protocol that describes the principles of the communication between two nodes is implemented here. There is also a trailing procedure that keeps track of the cooperation for the proceedings of the interactive session. This procedure registers the initiating time of each session, the address of the communicating counterpart, the subject, the mode of communication and the main topics of the cooperation.

Data handling. This module takes over the storing and retrieval of data used by Telemathea. During the retrieval or the storage of some data files the application takes into account the type of this information (plain/formatted text, still image, audio message) so as to code/decode it properly. This module also keeps track of the session establishments and the data transfers between the two end users, during the conference.

2.4 Functional overview of the services offered by Telemathea

The basic aim of Telemathea is to support the interactive cooperation and communication between its users by using multiple media. Communication can take place by means of interchanging textual messages, still images, audio and data files. Also, cooperation can take place by means of joint-editing of text files and still images (document conferencing). The services provided by Telemathea can be summarized in the following topics:

1. Transfer of text files and still images.
2. Interchange of text messages.
3. Audio communication.
4. Joint-editing of text files and still images.

All these services are accessible through a graphical user interface. The communication control process is responsible for the synchronization of Telemathea's operation. Each of the services mentioned above is implemented by one or more separate processes.

2.4.1 Transferring of text and still image files

This service is offered in both interactive and batch mode. When two Telemathea applications communicate in interactive mode, any user can select a set of text and/or still image files and send them to the remote peer. Telemathea supports ordinary ASCII files and GIF and X11-bitmaps for still images. Provided that enough bandwidth is available, the file transfers take place within short time limits. File selection takes place through appropriate windows of the user interface. While a file transfer occurs, the recipient is informed about its progress. The names of the files that have been transferred are shown in a list. Then the recipient can see the contents of any file appearing in this list, at his own will.

The scenario for file transfers in batch mode is the same except that there is not an interactive session in progress during the transfer process. Nevertheless, the remote user will be informed after the completion of the overall procedure.

The Telemathea application uses a file transfer client process that initiates the communication procedure and sends the files, and a file transfer server process that receives the files. These processes implement a variation of the trivial file transfer protocol (tftp, [12]).

2.4.2 Interchanging text messages

A trivial way for interactive communication between two Telemathea's users is by interchanging text messages. This service is offered only in interactive communication mode when the available bandwidth cannot support audio communication. Provided that both users agree to communicate by text messages, two windows are activated in both user screens. The left window is used for editing and sending messages to the remote user and the right window is used for the representation of the received messages. The communication by interchanging text messages is fully bidirectional and is performed by two separate processes in each workstation. Both the client process (that sends messages) and the server process (that always waits for the remote user's messages) are running simultaneously during the interactive communication session.

2.4.3 Interchanging audio messages

This service is the standard way for the communication of the trainee and the tutor during the interactive mode. The audio stream to be transmitted is coded in a suitable form. Available codings are the current stage are the following:

- Pulse Code Modulation (PCM).
- Adaptive Delta PCM (ADPCM).
- Variable ADPCM (VADPCM).

The audio packets are transmitted with the use of the Real Time Protocol (RTP, [1]). This protocol has the advantage that it offers information which can be used in order to estimate the Quality of Service. In this way it is possible to automatically select the encoding that fits best for the available bandwidth ([13], [14]).

The network mechanism consists of two sound servers that reside in each of the communicating workstations. Between the servers a UDP connection is established. The audio stream from each workstation is encoded, broken in RTP packets and delivered to the server, which transmits them as UDP packets to its peer.

The major reasons for the choice of the previously described mechanism are the following:

- UDP is chosen instead of TCP because the error checking and the retransmission mechanisms of TCP introduce unacceptable delays.
- The complementary information provided by RTP enables us to estimate the Quality of Service and accordingly act.

In the case that the available bandwidth is not enough for audio communication of acceptable quality, Telemathea reverts its users to the communication by means of interchanging of text messages.

The audio messages of each interactive session are saved by the trailing procedure and can be replayed at any time by both the communicating counterparts.

2.4.4 Joint-editing of text files and still images

This facility is offered in the interactive mode of communication. It allows the concurrent document processing by adding or making changes on textual information and still images. This service is referred as Joint Editing and Document Conferencing and is a major part of a CSCW tool.

The model used for the communication in this service is the master-slave model, where the roles of the master and the slave are interchanged between the two communicating peers. When one of the two counterparts wants to make some changes in the document, he requires permission to be the master of the conversation. As soon as the other user has completed his changes, the request is satisfied and the roles of master and slave are interchanged. Only the master peer has the right to alter the document, while the slave peer watches the changes on his own screen. The master peer translates the changes into specially formed message packets that describe the modifications on the common document, and sends them to the slave peer. On the other side, the slave peer is responsible for decoding these packets, for presentanting the corresponding changes and for updating the local copy of the common document.

Concerning the service of joint-editing of text files, the master peer has the authority to take the following actions:

- Insert text at a point indicated by the cursor.
- Mark a region of text.
- Cut a marked region of text.
- Paste a previously cut region of text in a point indicated by the cursor.
- Scroll the text window.
- Move the cursor.

All the changes that the above actions cause to the common document are immediately reflected to the remote peer.

Concerning the service of joint-editing of still images the following actions can be taken by the master peer:

- Insertion of a comment that starts at a selected point of the common image specified by a mouse click.
- Drawing of free shapes and single spots by means of a paint brush.
- Drawing of rectangles by specifying the upper left and the lower right corners.
- Drawing of circles.
- Redrawing of the whole image.

All the previously described actions become visible to both peers almost immediately. During the joint-editing of still images the cursor shape indicates the performed action.

3 Conclusions - Future Work

The design and the implementation of Telemathea, an environment for interactive cooperative teleworking and colaborative learning, has been presented. Telemathea can be used over conventional networks as well as high speed networks and depending on the available bandwidth it can support audio communication over the network.

In the future the joint-editing facility should be augmented so as to support image and text formats of well known word/still images processing applications (eg. Microsoft Word, Xpaint, Xfig, etc.). Also the communication process can be enhanced by video communication, provided that the network infrastructure will be able to support such a facility. Moreover, the communication protocols should be enhanced in order to exploit the characteristics of the broadband networks and especially of mechanisms that are offered by them and provide real-time control of the QoS.

Another future improvement is the integration of Telemathea with other multimedia applications in a unified multimedia applications library and the interaction with distributed Multimedia DBMS's for the easier access to public, raw, multimedia material.

Finally, the cooperation of more than two persons is a very important point for future work, thus Telemathea must be augmented so as to support multi-personal audio/video conferences and joint-editting.

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