IMPROVING THE TELE-CONSULTATION SERVICES - CAPABILITIES OF RETRO

Cheng-Hsiung Wang*, Chien-Cheng Lee**, Hewijin Christine Jiau*, Pau-Choo Chung*, Tsung-Lung Yang***, Kuo-Feng Ssu*, and Yu-Shian Kuo*

*Department of Electrical Engineering, National Cheng Kung University, Tainan, Taiwan ROC
**Department of Communications Engineering, Yuan-Ze University, Taoyuan, Taiwan ROC
***Department of Radiology, Kaohsiung Veterans General Hospital, Kaohsiung, Taiwan ROC

pcchung@ee.ncku.edu.tw

Abstract: Traditional medical tele-consultation systems focus only on providing interactive discussion functions for physicians and patients. As the tele-consultation system is used for healthcare, however, capabilities of fault-tolerance and reviewing performed consultations are equally important. In this paper, a tele-consultation system embedding the capabilities of retro will be presented. The system's capabilities of retro are addressed from two aspects: session-recovery and session-replay. The session-recovery functionality is responsible for tracking every connection and detecting any connection failures. Participants are allowed to reconnect immediately when failures occurred and will rejoin the consultation consistent with other participants'. The session-replay ability enables replaying the entire or specific interesting parts of performed consultations by multiple and intelligent replaying modes we proposed. Besides, we also adopted a new developed buffering control technology to smoothly replay the performed consultations. The goal of improving the tele-consultation system with above capabilities is to make the value of the tele-consultation services greatly better.

Introduction

Tele-consultation – a component of telemedicine - is a means for health related data assessments, opinions exchanges among two or more distantly located physicians, and providing patients in a remote location with consultations. Though traditional tele-consultation systems based on real-time videoconference and interactive medical images and information sharing may satisfy given requirements [1]-[6], they lacked for the capabilities of retro. Therefore, we proposed a web-based tele-consultation system augmented by capabilities of fault-tolerance and reviewing performed consultations.

The system's capabilities of retro are addressed from two aspects: session-recovery and session-replay. The session-recovery functionality is responsible for tracking every connection and detecting any connection failures. It also permits users to reconnect immediately when failures occurred and will recover the consultation process consistent with other participants'. The session-replay ability enables replaying the entire or specific interesting parts of performed consultations by multiple and intelligent replaying modes. The replaying modes we proposed include replaying the whole consultation process, replaying the consultation process started from any specific time, replaying all the time segments of any specific participant in charge of the consultation, and replaying all the time periods of any specific image. These replaying modes are particularly important for providing interns with the educational material and maintaining the argumentations possibilities aiding or enhancing the diagnostics performance. In addition, for the purpose of replaying the recorded consultation process smoothly, another issue has to be addressed in the system: buffering control.

The remaining of the paper is organized as follows. Section II describes the adopted methods. The results are presented in section III. Finally, this paper concludes with a summary in section IV.

Methods

We developed the medical tele-consultation system with a three-tiered web-based architecture [7]-[8]: user-services, application-services, and data-services tiers. We focus only on the application-services tier that implements the main features, including fault-tolerance and replay functionalities. Enhancement of a tele-consultation system with the capability of recording the consultation processes is an add-on advantageous feature for fault-tolerance and retrospective review. The usage of a tele-consultation system incorporating a mechanism to record down the consultation process, as

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well as, the discussed data (images, patient records), participants' voice signals, and image regions requiring special considerations, could be extended from opinions exchanges to special medical cases collection for studying, teaching and analysis. In our system, a consultation record is comprised of the following independent though related files: an audio record file recording the voice signals, an audio index file for indexing the audio record file, and a command file recording all actions taken during the consultation.

In course of the tele-consultation, only one participant can speak at one time through having the current control right (for simplification we use only "token"). The audio records are generated in the time interval starting from a participant gets the token to he/she frees the token. All the audio segments in a tele-consultation are saved in the audio record file according to the appearing sequence in the consultation and indexed by the associating audio index file. The audio index file records the speaker's ID and the time interval of each audio segment saved in the audio record file, as shown in Figure 1. It is worth to mention that all the 'time' in this file are relative to the starting of the tele-consultation and the time unit is one ms.

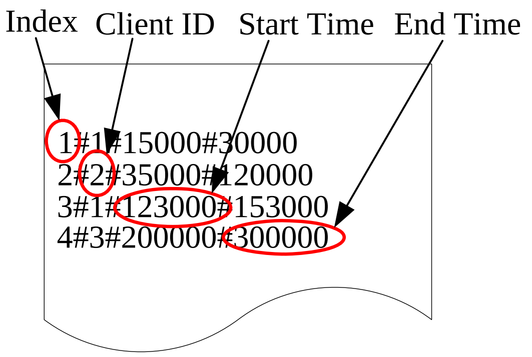

Figure 1: An example of the audio index file, where the "#" is a delimiter character of fields.

The command file records all commands invoked in a tele-consultation process. Each record consists of three fields: index number, presentation timestamp, and corresponding command. The index number is used for identifying each command, while the timestamp records the time the command arriving at the server and is also used as the playback time for this command. An example content of a command file is shown in Figure 2, indicating that the first command was issued at time equal to 0, that is, the starting of the consultation, and was a click window command; the second command was issued at time 3809 relative to the starting of the consultation and was a button slice command, etc.

In addition to these consultation records, for the purpose of accomplishing capabilities of retro, we designed the data structure of a consultation as an "IndexTree" for indexing the consultation process review/replay. Various types of data extracted from consultation records are indexed in the "IndexTree", including participants, images, audio, and commands. As shown in Figure 3, the "IndexTree" is devised to contain a sequence of Data Nodes and one root that stored the general information for quickly identifying the Data Nodes. Each Data Node, consisting of a User Node, a Command Node and a Picture Node, contains the information associated with the consultation events occurring within a token period. The User Node records the information about who is in control of this period, when the starting of this period is, and the index to the first command within this period in the command file. As to the Command Node, it records the index to some commands (by the name of status-affect commands) causing the change of the system status, such as the medical image content within this period. This design is particularly for efficiency considerations, because searching these status-affect commands from the command file during the replay recovery process is time-consuming. Therefore, when a specific time is selected as the starting point for replay, only those status-affect commands prior to that specified time in the Command Node, not all commands in the command file, will be executed to maintain consistent display. Associated with each status-affect command in the Command Node are the time when the command was performed and the index of this command in the command file. Besides, the Picture Node is designed for efficiently identifying the information about the medical images discussed within this period, when above images were selected for discussion, and the index of status-affect commands performed on these images in the Command Node.

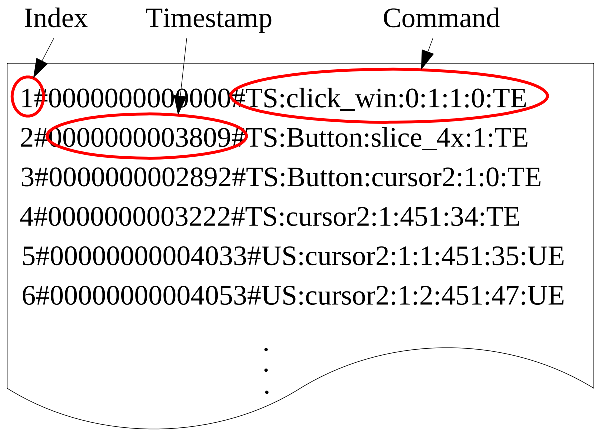

Figure 2: An example of the command file.

By properly recording and indexing these data extracted from consultation records, the "IndexTree" can provide efficient and accurate searching of the cut-in points, and quick identification of the necessary recovery steps for image status. For example, when a user specifies time T as the starting of replaying, the system will firstly use binary search in the IndexTree to find out which Data Node contains the specified time T. Then, from the Picture Node in that Data Node, the

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medical image discussed at time T is identified. As shown in Figure 4, the identified image is picA and the index of the command performed on picA in the Command Node is 1. According to this index value, the corresponding record in the Command Node will be found. Searching from that corresponding record, the accurate cut-in point in the Command Node for replaying can be recognized as the one closest to the Time T. Taking advantage of this mechanism, the system can correctly locate the cut-in point for each type of replaying modes. With these intelligent replaying modes, the medical tele-consultation system will provide users with the flexibility of reviewing interesting segments of consultation processes for experience learning and retrospective review.

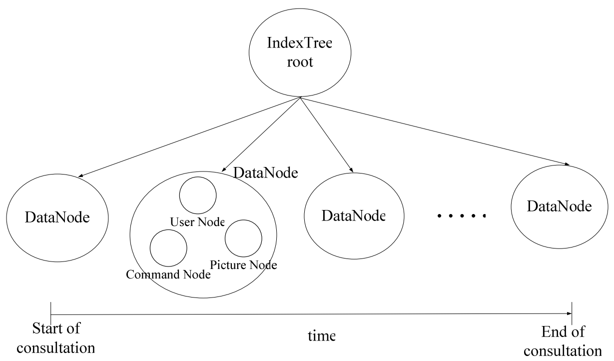

Figure 3: The architecture of IndexTree, which is composed of a root and a sequence of Data Nodes.

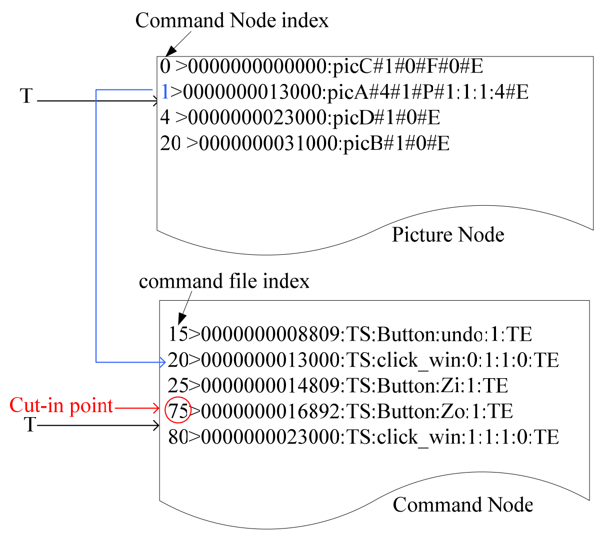

Figure 4: The procedure of identifying the cut-in point when a user specifies time T as the starting of replaying.

Results

Some design details worthy of further discussion are presented in the following. Systems with capability of fault tolerance will improve the acceptance of users. Using those records of each consultation in progress, we designed a mechanism responsible for detecting connection failures and providing reconnecting users with a consultation-consistent recovery when network failures occurred. For detecting connection failures, the server would determine an I/O exception if messages couldn't be delivered to some user through established TCP connection. Then the server would terminate other TCP and UDP connections related to that use and wait for his/her reconnection. The most crucial key of users' reconnection is to keep the consultation consistent with other participants', especially the status of discussed medical images. For efficiency considerations, the server would prioritize recovering the status of the image being discussed at the moment by re-executing those status-affect commands recorded in the command file, and then recover other images' status in the background.

The multiple and intelligent replaying modes we proposed provide users with reviewing the specific interesting parts of performed consultations instead of the entire one. However, in order to replay the recorded activities smoothly, another crucial issue has to be addressed in the system: buffering control. Usually start latency and network jitters are two main causes to the unsmooth of a stream playback. For resolving the problem, buffering has often been employed. In contrast to the traditional approach where the buffer size reflects data capacity, our system employs the time-lasting based buffering control that the buffer size reflects the play time of the streaming data. However, for the command stream in a medical tele-consultation system, different commands have different play time. Some operations might invoke a large amount of commands within a very short time period. The resulting burst high rate of commands consumption from the buffer may result in buffer empty if the buffer size could not accommodate the consumption rate. Therefore a new approach of the buffering control, particularly the buffer size adjustment, is devised in the system. A start threshold, a maximum threshold, and a buffer size adjustment are used in the dynamic buffering control in our system. The start threshold reflects the number of commands that should be received before the replay starts. The maximum threshold regards the point when the incoming data are approaching the buffer capacity, that is, this system is regarded as buffer full. The maximum threshold is always set at a fixed ratio of the buffer size, while buffer size is set to accommodate the network jitters and the variable command consumption rates.

Thus, there are two situations which should be considered during the process of replaying. The first one is the buffer depletion resulted from that the buffering could not properly handle network delay or that the sending rate from the server does not match with the consumption rate in the client. As we know, the number of commands stored in the buffer would decrease when the rate of retrieving commands is higher than the rate of incoming commands. This situation happens when

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the on-processed commands are invoked from some specific operations, such as mouse movement, mouse drag, tele-pointer, or drawing line, causing the system to consume a large amount of commands in a very short time interval. When this situation occurs, a signal is issued from the client to notify the server of the increase of the sending rate, while at the same time the start threshold is increased.

The second situation is buffer filled up when the incoming commands reach to the maximum threshold. This situation indicates that the retrieving rate is much smaller than the incoming rate, and that the buffer size is not enough to serve for the buffering and therefore should be increased. Thus when this situation occurs, the buffer size is increased. Furthermore, the expected execution time and operation types of the latest incoming commands are examined. If the expected execution time is relatively far away and the operation types do not belong to those which could result in high command rate, the server is signaled of the decrease of the sending rate. Figure 5 depicts the main concept of the dynamic buffering control.

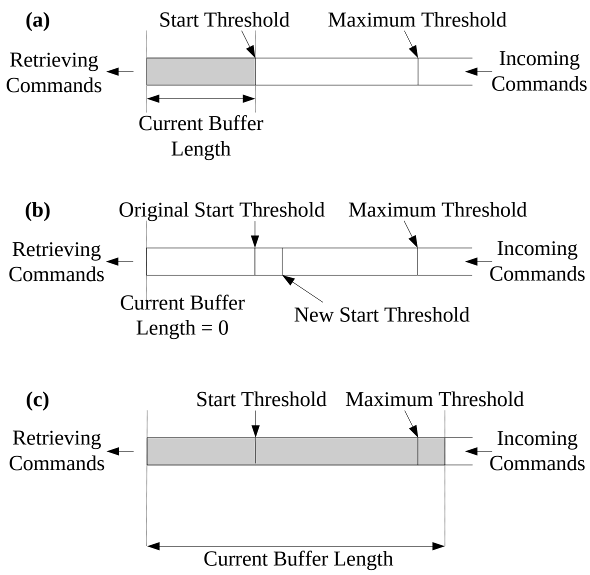

Figure 5: The adaptive buffering control: (a) playback start, (b) buffer depletion, (c) buffer filled up.

Conclusions

Taking advantage of recording the necessary information of consultations in progress can enhance the capabilities of the tele-consultation system, including session-recovery and session-replay. With the capability of session-recovery, the system can detect connection failures and recover the consultation process consistent with other participants'. Meanwhile, multiple and intelligent replaying modes are designed in our system, users can review the specific interesting parts of performed consultations instead of the entire one. These functionalities in the tele-consultation systems are not only timesaving for reviewing the performed consultations but also useful in training, studying, preventing the possibility of arguments, and enhancing the diagnostic performance. Furthermore, the smoothness of replaying the performed consultations can get significant improvement by adopting new developed buffering control technology.

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