Distributed Collaborative Visualization for Real Time Patient Health Monitoring

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I. Introduction

Real time patient health monitoring by medical experts during critical situations involves visualizing patient current status and retrieving Electronic Health Records (EHR) from stored databases to make efficient decisions. In this paper we introduce a distributed collaborative visualization of patient's health (COLPAT) by combining real time data from patient, stored data retrieved from electronic health records and create a visualization unit that can display these information to multiple experts who are geographically dispersed. EHR consist of textual information, lab data and real time data consists of images, video and text. Visual unit should be updated synchronously on multiple user systems who are geographically distributed with varying time delay. When multiple medical experts, working on particular patient information, send updates on the same visualized data, a time synchronized mechanism is required to update the visual unit on each expert system. To achieve synchronized updates we introduce a group synchronization technique which employs an adaptive time adjusting algorithm to modify the output time of the visualization unit. To evaluate our system, we have developed client-server architecture and proved the correctness of our algorithm for a number of variable delay visual updates.

II. Methodology

Collaborative Patient Health monitoring system (COLPAT) is shown in Figure 1. We envision an emergency situation, where patient health record is retrieved from the medical database, real time data are recorded from the patient and sent to the COLPAT server. The server generates the visual unit and sends the update to multiple medical experts who are connected via the Internet.

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Each expert can share, annotate, and update information on the visual unit in real time. COLPAT system architecture is shown in Figure 2. Data is collected from the patient in real time such as text, image and current status and corresponding electronic health record is retrieved from the server database consisting of demographics, medical history, laboratory test results.

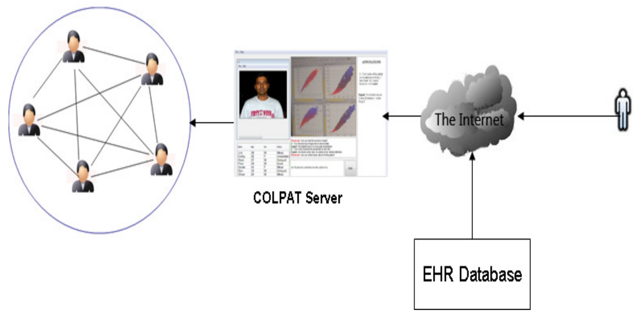

Figure 1. Collaborative Patient Health Monitoring System

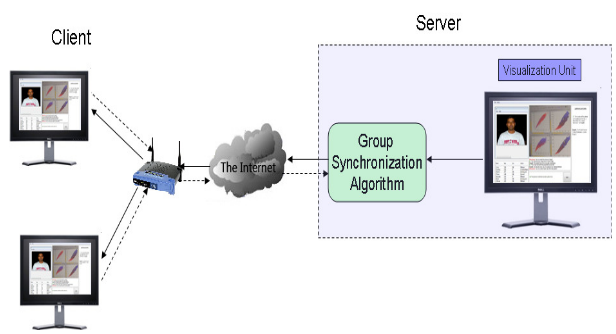

Figure 2. COLPAT System Architecture

The COLPAT server generates the visualize unit after retrieving the data from the database and sends the information to the clients. In order to share information among medical personnel and provide a collaborative and interactive environment with synchronized time delay, we developed a group synchronization algorithm which employs an adaptive time adjusting technique.

The update time of the applet on each client should be synchronized in time, so that any update made on the visual unit is shown on each user system for effective shared decision making on such life critical information. The group synchronization algorithm compensates for the randomness caused by varying network delays by following the subsequent steps: 1) choose an ideal target output time, 2) determine the method for reference output time, and 3) handle cases to select average additional delay (slide time) based on the client server network delay. The visual unit update time on each client is given by

$$H1 = T1 + \delta, \quad (1)$$

$$Hn = H1 + (Tn - T1)\ (n \geq 2), \quad (2)$$

Where δ denotes the delay between the COLPAT server and the client and *Tn* denotes the generation time of the visual unit at the COLPAT server. Each peer to peer network between the clients and the COLPAT server exhibits variable network time delay, which leads to varied update time of the visual unit on each system, hence we need to update the unit in synchronized manner. The synchronization of update is achieved by adding some slide time. Slide time is defined as the difference between the modified target output time t*n and the original target output time tn.

$$Sn = Sn-1 + \Delta Sn \quad (3)$$

Sn is the total slide time for n packets

ΔSn is the slide time for the nth packet

*tn and t*n* are expressed by

$$t1 = H1, \quad (4)$$

$$tn = Hn + Sn-1\ (n \geq 2), \quad (5)$$

$$t^{*}n = tn + \Delta Sn\ (n \geq 1). \quad (6)$$

Dn is the arrival time of the visual unit at client i

Rn is the reference time of the packet at client i

$$Sn = Dn - Rn \quad (7)$$

if the reference time chosen by the COLPAT server is less than the arrival time or,

$$Sn = Rn - Dn \quad (8)$$

if the reference time is greater than the arrival time of the visual unit. The recommended slide time (Sn) is calculated in order to adjust the output time of the packet for early arrived cleint.

III. Results

The testbed consists of Client, Server and Network emulation. The server platform is an Intel Core 2 Duo, T5870, 2Ghz processor laptop. The visual analytic unit which resides in the server, is developed in Netbeans connected to Oracle database which sends updates to the applet and uploads images in real time. Collaborative chat enables sharing of data, adding annotations and decision making by multiple users. The WANem emulator runs on a Ubuntu Linux machine with 2.6.27 kernel. The two clients run on Dell, Win XP, 2Ghz and Dell Win XP 2.2Ghz system.

Group synchronization achieves the synchronized update time of visual unit on the clients. To test our system we updated the visual unit on each client without the algorithm and measured the time delay between the client and the server. We then tested our algorithm and updated the visual unit with the algorithm on each client and recorded the time delay between the clients. A comparative study for visual unit update time delay is shown in Table 1. Ideally the time difference between the clients and the server should be zero. Consider Study 1, the first client is updated at 63msec the other client should also be updated at the same time, but has more delay, so client 1 is adjusted to update at 87msec. For study 1 we see that the time difference is 24 msec. and we reduced the time difference to 0msec for different cases using the group synchronization algorithm.

Cases	Without Scheme Client 1	With Scheme Client 1	Without Scheme Client 2	With Scheme Client 2
Study 1	63 ms	87 ms	87 ms	87 ms
Study 2	84 ms	84 ms	78 ms	84 ms

Table 1 Comparative Study of Network delay with and without Group Synchronization

Figure 3 shows a comparative analysis for with and without the group synchronization algorithm.

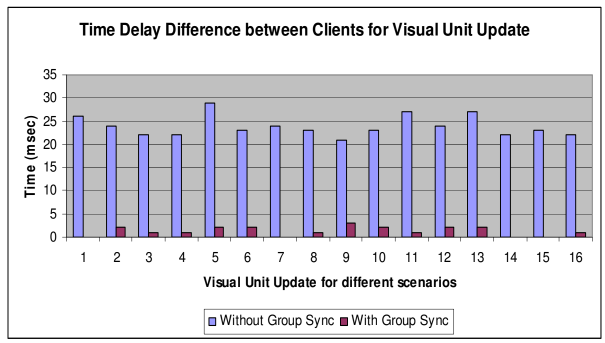

Figure 3. Time Delay between clients for Visual Unit Update

IV. Conclusion

In this paper we introduced a distributed collaborative visualization system for real time patient health monitoring. In order to synchronize the visualization at multiple users we implemented an enhanced group synchronization algorithm. The proposed system can significantly improve the real time monitoring of patient status and support visualization of the information where multiple experts participate in decision making in real time.

References

[1] Gloria Mark, Keri Carpenter, Alfred Kobsa, A Model of Synchronous Collaborative Information Visualization, Proceedings of the Seventh International Conference on Information Visualization (IV'03)

[2] BN Tatsuya Hashimoto and Yutaka Ishibashi, Group Synchronization Control over Haptic Media in a Networked Real-Time Game with Collaborative Work, The 5th Workshop on Network & System Support for Games 2006 — NETGAMES 2006

[3] Jeffrey Heer, Fernanda B. Viégas, Martin Wattenberg, Voyagers and Voyeurs: Supporting Asynchronous Collaborative Information Visualization, *CHI 2007,* April 28–May 3, 2007, San Jose, California, USA

[4] Yoshio Suzuki and Nobuko Matsumoto, Development of Remote Visualization and Collaborative Visualization System in ITBL Grid Environment, A. Veidenbaum et al. (Eds.): ISHPC 2003, pp. 269–277, 2003

[5] WANem The Wide Area Network Emulator, http://wanem.sourceforge.net.