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Distributed Visual analytics for Collaborative Emergency Response Management

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Abstract--**In emergency response management, there is a large volume of incoming data and minimal time to process it before making critical decisions. Multiple experts, physicians, incident commander who are geographically distributed, collaboratively work on the collected data to make efficient and timely decisions. In this paper we introduce a distributed visualization environment that supports collaboration among geographically dispersed users. To achieve synchronized update among multiple users we introduce a group synchronization technique which employs an adaptive time adjusting algorithm to modify the output time of the visualization unit. In order to evaluate our system we have developed an interactive synchronous visualization unit, and tested our work by running it on varying network delay collaborative servers and achieve time synchronization among them.**

Index Terms— **Visual Analytics, Group Synchronization, Collaborative visualization, Emergency Response Management.**

I. Introduction

Emergency response management involves multiple medical experts, physicians, incident commanders working on the disaster site. Massive amount of heterogeneous real time data are collected from the disaster site [1]. The high demand of this application is to collect large amounts of data and display it to the incident commander for effective decision making [1]. If the information collected by COLVIZ server is not presented in an easily comprehensible manner, the value of this system will be severely marginalized. The goal of the proposed system is to present the input in a synchronized manner to a group of users and receive updates in a synchronized manner. As multiple users can update the same information, a relative output reference time is required for the data.

To improve the group or inter destination synchronization control various research approaches have been proposed particularly dealing with haptic media. [2] discusses a model for synchronized collaborative visualization using video. [3] discusses group synchronization of haptic media in a simulated environment.

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However these works do not propose a synchronous collaborative visualization with interactive techniques.

In this paper we propose an architecture that supports interactive collaborative visualization of a disaster site for emergency response management over a time delay constrained network. Our work involves development of an interactive visualization unit to be displayed in multiple servers. Each user can add, update, annotate the visual unit whose update has to be sent to all users with synchronized output time, else there is high chance that multiple users can edit the same information leading to disruption of life critical decisions. To ensure that each user receives synchronized updates from every other user, the proposed group synchronization algorithm works with reference time to update the collaborating servers.

The paper is organized as follows. In Section 2 we discuss our simulated emergency response application and in Section 3 we introduce the proposed synchronization technique. Section 4 describes our experimental setup and results and Section 5 concludes the paper and discusses our future work.

II. Emergency Response Management

The emergency response system is depicted in Figure 1. COLVIZ system consists of a three layer architecture as shown in Figure 2. Data is collected from the emergency sites (client), sent to the COLVIZ server and then broadcasted to the collaborative servers. As depicted in Figure 1, COLVIZ server collects real time data (e.g. patients' location, severity of injury, images) from the emergency site (client) [1]. The centralized COLVIZ server creates the visual unit after receiving real time data from the client side. Variable network delay exists between COLVIZ and the collaborative servers.

The delay variation is controlled using the group synchronization algorithm. Each collaborative server sends the arrival time of packets to the COLVIZ server; which decides the reference time and sends updates back to the collaborative servers after running the group synchronization algorithm. The reference time is used by the collaborative servers and the visual unit is updated with timing information. This ensures that the update time on each collaborative server is synchronized and avoids multiple users modifying the same data and sending it to the COLVIZ server.

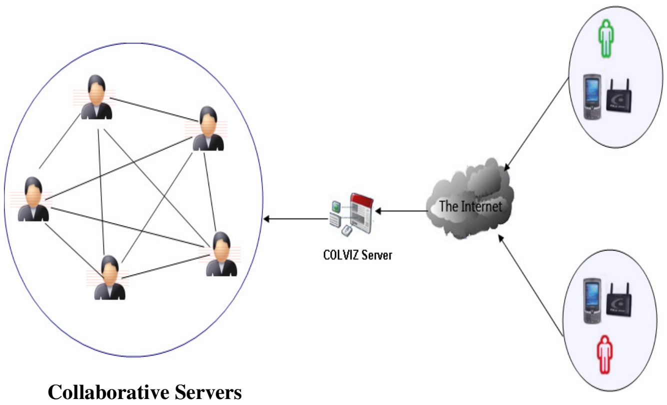

Figure 1. Emergency Response System

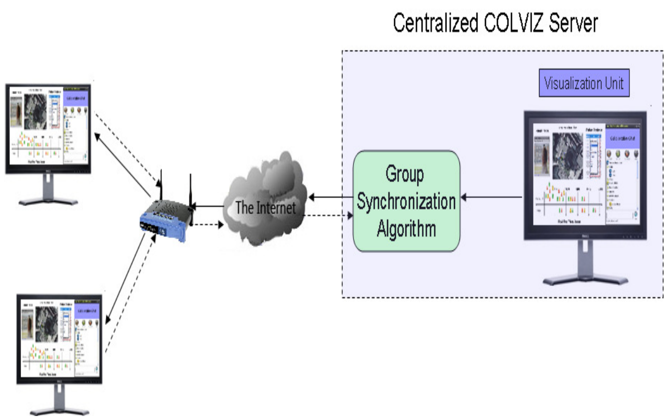

Figure 2. COLVIZ System Architecture

A. Client Architecture

Figure 3 represents the functional unit of the client. At the client side we collect heterogeneous multimedia from multiple users such as victims' location and triage information as provided by DIORAMA system [1] as well as patients' image and user profile information. The data is multiplexed and sent as packets using the data processing unit which adds a timestamp to each packet inorder to synchronize the visual unit update on multiple collaborative servers.

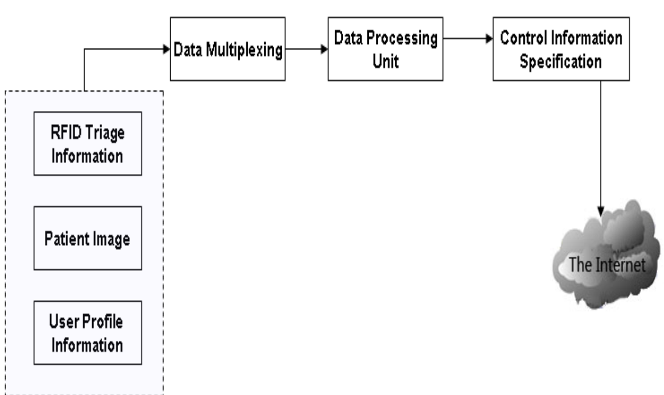

Figure 3. Client Functional Description

The control information specification updates real time data giving situational aware updates for efficient visualization at the server side.

B. Server Architecture

The server collects the information form the client side and stores the data in a database. After information transcoding for each media, a data to visual transformation is carried out to generate the visual unit. The server then packetizes the data and sends updates to the collaborative servers with control information for synchronization. Once the server gets updates on the arrival time of the packet from each collaborative server, it runs the group synchronization algorithm and updates the reference time to each server. The server with earlier arrival time increases the slide time to synchronize with other servers.

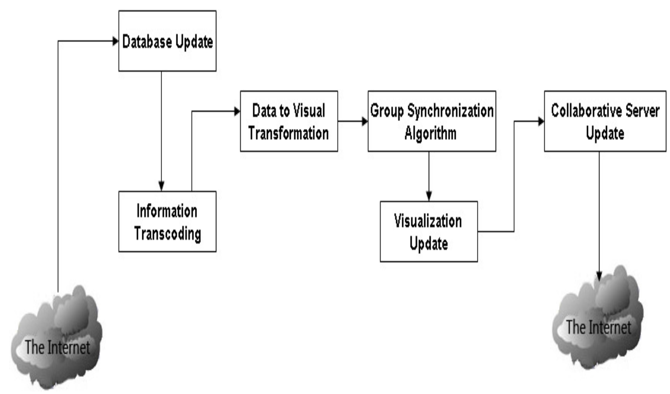

Figure 4. Server Functional Description

III. Group Synchronization Algorithm

Emergency response decision making capabilities are not restricted to a single incident commander. Various medical personnel and emergency responders can also participate in the decision making process. In order to share information among them and enable collaborative work on the inputs with synchronous updates on each collaborative server, we provide a group synchronization technique which employs an adaptive time adjusting algorithm to enhance the interactivity [5-6]

The group synchronization algorithm is robust to randomness caused by varying network delay. It adapts to varying delay constraints by following the subsequent steps: 1) choose an ideal target output time, 2) determine the method for the reference output time, and 3) handle cases to select average additional delay (slide time) based on the client server network delay. We have enhanced the synchronization maestro scheme [5] by considering the applet as a single entity and not considering inter stream synchronization within the data. Our scheme works similar to the synchronization maestro scheme, but for heterogeneous multimedia data, which was not supported in the original work. The ideal target output time at the collaborative servers is given as

$$H_1 = T_1 + \delta, \quad (1)$$

$$H_n = H_1 + (T_n - T_1)\ (n \geq 2), \quad (2)$$

Where δ denotes the target delay time and T_n denotes the generation time of packet at the COLVIZ server. Each peer to peer network between the collaborative servers and the COLVIZ server exhibits variable network delay, 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 t_n.

$$S_n = S_{n-1} + \Delta S_n \quad (3)$$

S_n is the total slide time for n packets

ΔS_n is the slide time for the nth packet

t_n and t^*_n are expressed by

$$t_1 = H_1, \quad (4)$$

$$t_n = H_n + S_n - 1\ (n \geq 2), \quad (5)$$

$$t^*_n = t_n + \Delta S_n \quad (n \geq 1). \quad (6)$$

Dn is the arrival time of the packet at server i
Rn is the reference time of the packet at server i

$$S_n = D_n - R_n \quad (7)$$

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

$$S_n = R_n - D_n \quad (8)$$

if the reference time is greater than the arrival time.

The recommended slide time (S_n) is calculated in order to adjust the output time of the packet for early arrived packets at server n.

Output time expansion: The client adjusts the total slide time (virtual time expansion) by adjusting it to the group synchronization control based on the reference time sent by the COLVIZ server. Here the arrival time is less than the reference time.

Output time contraction: The client adjusts the total slide time (virtual time contraction) by adjusting it to the group synchronization control based on the reference time sent by the COLVIZ server. Here the target output time is greater than the reference time.

Here we modify our work by updating the earlier arrival time server to match the reference time. When each collaborative server receives the first packet from the COLVIZ server, the arrival time is sent back to determine the reference output time. The average later output time between the servers is chosen as the reference and the other servers have to modify their output time adding the slide time

IV. EXPERIMENTS

The visual analytic unit runs on the central COLVIZ server. The applet is generated from the database running on the same server. The generated applet is sent to the two servers acting as collaborative servers. The network delay between the COLVIZ and collaborative servers are recorded without and with the group synchronization algorithm to test our system. The testbed consists of Client, Server and Network emulation. The visual analytic unit is developed in Java Netbeans connected to Oracle database which sends real time updates to the applet and uploads images in real time. The applet is run on a Intel Core 2 Duo, T5870, 2Ghz processor laptop.

The WANem emulator [7] runs on a Ubuntu Linux machine with 2.6.27 kernel. The two collaborative servers are run on Dell, Win XP, 2Ghz and Dell Win XP 2.2Ghz system. The experimental results show that for each case, the servers are synchronized in time by adjusting the output time using the proposed group synchronization scheme. A comparative study for average packet delay is shown in Table 1.

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

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

Our method of reference selection involves selecting the server which has the later output time; hence in all cases we have virtual time expansion by increasing the slide time to match the reference time and synchronize the collaborative servers. Figure 5 shows the end to end network delay between collaborative server 1 and COLVIZ server (diamond line) and end to end network delay between collaborative server 2 with the COLVIZ server (square line); without the group synchronization algorithm. Ideally the delay difference should be zero, but on an average we delay difference of 24msec. Hence group synchronization is required.

The comparative study of network delay shown here is for one particular packet but in our experimental setup the algorithm adjusts based on the comparison of time delay and modifies the slide time for each packet. The delay requirement of the application is not milli-second time constrained, time delayed update is tolerable for collaborative servers. The delay simulation scenario emulates real time conditions but is not an ideal case. In our future work we plan to integrate bandwidth constraints, packet loss and the impact on the synchronized update which emulates more realistic scenarios.

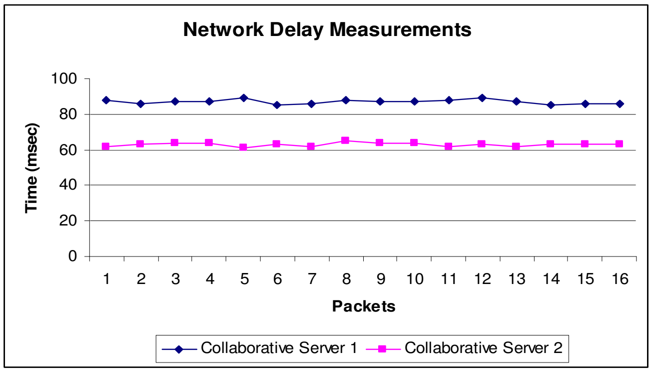

Figure 5. Network Delay without Group Synchronization Algorithm

Figure 6 shows a comparison of end to end network delay between collaborative servers 1 and COLVIZ server (diamond line), end to end delay between collaborative server 2 and COLVIZ server (square line) with group synchronization algorithm and (triangle line) without the group synchronization algorithm. We observe that by using the proposed synchronization scheme, the end to end network delays between COLVIZ and the collaborative servers are synchronized in time.

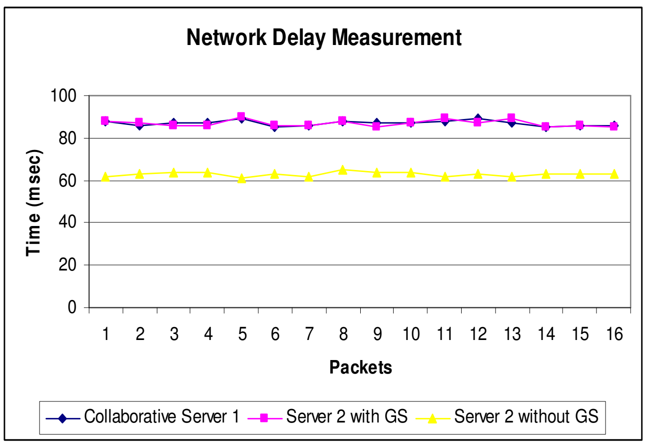

Figure 6. Network Delay with Group Synchronization Algorithm (note: the diamond and square lines overlap)

V. CONCLUSION AND FUTURE WORK

In this paper we introduced a distributed visual analytic system for collaborative decision making. In order to synchronize the updates from multiple users we implemented an enhanced group synchronization algorithm. The proposed system can significantly improve emergency response management where multiple experts participate in decision making. In our future work packet loss impact on the synchronization scheme will be considered which emulates real experiment data.

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