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HugMe: A Haptic Videoconferencing System for Interpersonal Communication

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Abstract

Traditional teleconferencing multimedia systems are limited to audio and video information. Human touch, in the form of handshake, encouraging pat, comforting hug, among other physical contacts, is fundamental to physical and emotional development. This paper presents the motivation and design of a synchronous haptic teleconferencing system with touch interaction to convey affection and nurture. We present a preliminary prototype for haptic poking. Examples of potential applications for HugMe include the domains of physical and/or emotional therapy, understaffed hospitals, remote children caring and distant lovers' communication.

1. INTRODUCTION

With recent advances in interactive teleconferencing multimedia systems such as high-definition (HD) video and its 3D display, the limit with what can be done with audio-video contents has been reached. Fueled by several exciting discoveries, researchers nowadays have fostered their interest to incorporate the sense of touch in teleconferencing systems [1]. For instance, haptics is crucial for interpersonal communication as a means to express affection, intention or emotion; such as a handshake, a hug or physical contact [2]. Several studies have confirmed that infants deprived of skin contact lose weight, become ill and even die [3-4]. Furthermore, studies of human infants reveal that the absence of affectionate touch can cause social problems [4]. This need for haptic communication becomes more apparent for children with disabilities such as deaf-blinded ones.

The incorporation of force feedback in synchronous teleconferencing multimedia systems has been challenged by the high haptic servo loop (typically 1 kHz), consistency assurance, access control, transparency, and stability, among others [15]. On the other hand, asynchronous tactile playback does not provide real-time interaction. In this paper, we present a haptic audio-visual teleconferencing system to enhance the physical intimacy in the remote interaction between lovers. The HugMe system works with tolerable bandwsidth (30-60Hz) for haptic data yet provides synchronous interaction.

As an application scenario, assume a child is crying (lets say in daycare) while his parent is away. What would a child need to stop crying other than a hug and a kiss from his/her parent? As shown in Figure 1, the child is wearing a haptic suite (haptic jacket) that is capable of simulating nurture touching. The parent, on the other side of the network, uses a haptic device to communicate his feelings with his child. A 2.5D camera [5] is used to capture the image and depth information of the child and send it to the parent. The parent can touch the child captured with 2.5D camera, the touch information is calculated and sent to the child, and the child feels the touch via the haptic jacket. Whenever a collision is detected, a notification is sent from the parent host to the child host in order to activate the appropriate actuators embedded in the haptic jacket. Meanwhile, the force feedback of the child body is displayed to the parent using the haptic device.

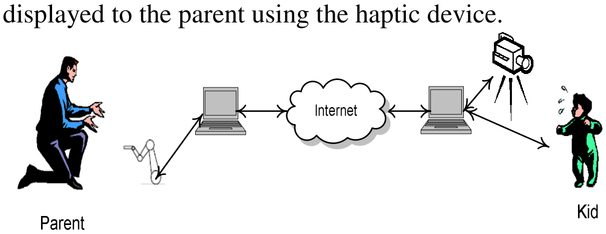

Figure 1. Synchronous haptic teleconferencing system

The remainder of the paper is organized as follows: section 2 describes related work and highlights the scope of this paper. In section 3, we present the architecture of the HugMe system and discuss design aspects related to haptic data representation and communication. Section 4 presents a preliminary implementation prototype for a haptic poke. Finally, in section 5 we summarize the paper contents and provide our immediate future work for this project.

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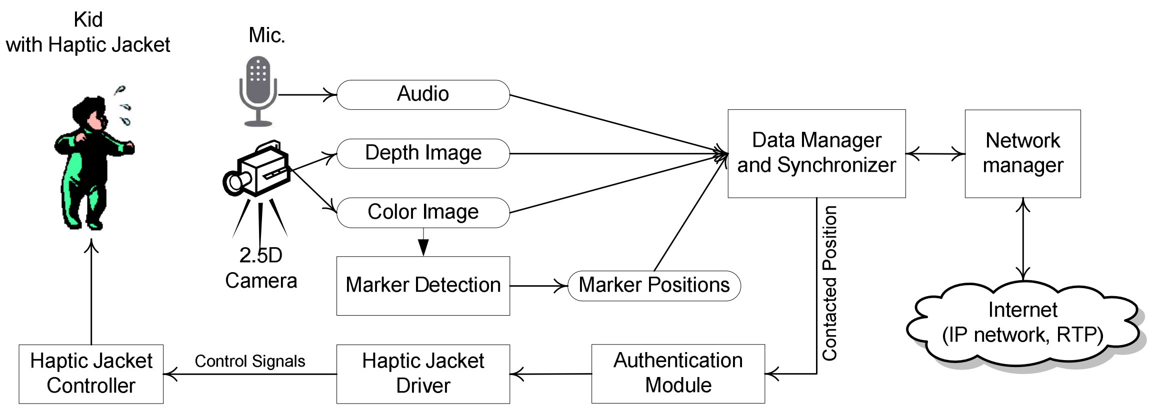

Figure 2. System block diagram on the child side

2. RELATED WORK

Existing researcher about interpersonal touch over a network can be categorized as synchronous and asynchronous communication systems. One of the early asynchronous systems was the Taptap prototype [6], which is a wearable haptic system that allows nurturing human touch to be recorded, broadcast and played back for emotional therapy. The tactile data is transmitted asynchronously.

Another commercially available hug shirt that enables people feel hugs over distance is proposed in [7]. The shirt embeds sensors/actuators to read/recreate the sensation of touch, skin warmth, and emotion of the hug (heartbeat rate), sent by a distant lover. The hugger sends hugs using a Java-enabled mobile phone application, in an as easy as an SMS is sent, through the mobile network to the loved one's mobile phone, which in turn delivers the hug message to the shirt via Bluetooth.

As per synchronous interaction paradigms, a tele-haptic body touching system that enables parent/child interaction is described in [8]. An Internet pajama is envisioned to promote physical closeness between remote parent and child. The pajama reproduces hugging sensation that the parent applies to a doll or teddy bear, to the child. A similar idea is presented in [9] where a human/poultry and poultry/human interaction is made possible using a doll, which resembles the remote pet, and a tactile suit that is put on the pet body.

Unlike most of the previous works, HugMe system enables touch interaction that is synchronized with audio/visual information. It is worth mentioning here that the HugMe system is not meant to replace human-human contact, but to enhance the physical intimacy in the remote interaction between lovers whenever they cannot physically meet for some reason. It has other interesting applications in the medical field especially with children and elderly [8].

Another distinguishing feature of the HugMe system is its ability to represent the haptic properties in an image-based format, and render the haptic interaction based on these images. More details about the image-based haptic rendering algorithm can be found in [11]. Notice that there is no need to transmit the haptic device position since the rendering will be performed locally at each machine. This will save a significant bandwidth of sending data every – theoretically – 1 millisecond.

Given that there will be two major data streams (haptic and visual) the transmission of media data is another research challenge. An abstract communication protocol for haptic audio visual environments needs to be designed and developed. This protocol should be designed to be highly customizable and flexible to satisfy the varying and sometimes conflicting requirements of the application. Finally, the synchronization between the instances of the applications at the two ends of the network is one of the major challenges in our system design.

3. HUGME SYSTEM DESIGN

This section describes a one-way version of the HugMe system, where, as shown in Figure 1, the parent is trying to touch the body of his/her child. The same system can be duplicated to enable the mutual touching between the two users. Figure 2 shows the system block diagram on the child side whereas Figure 3 shows the system diagram on the parent side. In the following, we briefly describe the comprising components of the proposed system.

3.1 Depth Video Camera

The depth video camera is capable of generating RGB and D (Depth) signals. The depth signal is a

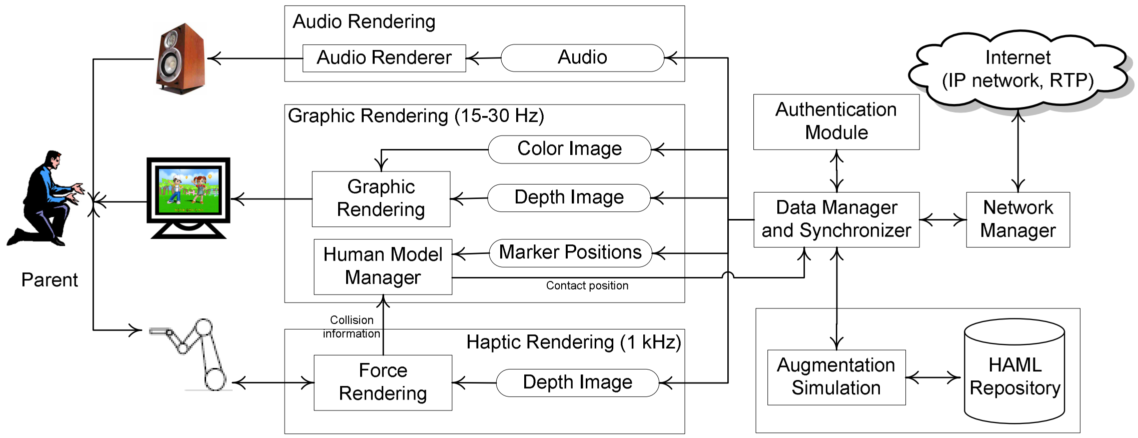

Figure 3. System on the parent side

grayscale bitmap image where each pixel value represents the distance between the camera and the corresponding pixel in the RGB image. The concept of operation is simple: A light beam is generated using a square laser pulse and transmitted along the Field Of View (FOV) of the camera. The reflected beam carries an imprint of the objects depth information. The depth information is extracted using a fast image shutter. A commercially available camera that serves this concept is the Z-Cam^{TM}, developed and marketed by 3DV Systems [10].

3.2 Graphic and Haptic Rendering

The graphic rendering module renders the 3D scene using OpenGL. All the pixels of the depth image will be transformed into 3-D space by using camera parameters and triangulated (with low resolution for fast rendering) and the color image will be mapped on it. Since the captured scene is transformed into 3D space, we can produce the stereoscopic view.

The haptic rendering module calculates 3D interaction force between the transformed depth image and the device position [11]. As a result, parent can touch the video capturing the child.

3.3 Marker Detector

In order to map the collision point in the haptic rendering and the touched point in real child, we need to track touchable part of the child. This component is responsible for tracking the movement of the remote user which can be used to construct a real-time representation (avatar). For instance, one possible tool that can be used is the Augmented Reality Tool Kit (ARToolKit) [12] that optically tracks markers, attached on touchable part of the child, in the images, and this information is mapped into the 3-D depth image space. By doing this, we can transform the collision information in the haptic rendering algorithm into the touched point on the child's body, namely the actuation point of the haptic jacket.

3.4 Human Model Manager

The human model manager keeps track of the user body position and calculates the touched point on the human model. This is accomplished by continuously sending the updated positions of the markers (at a rate of 30-60 Hz). The human model manager maintains a graphical representation of the remote user using a set of graphic primitives. The positions and/or orientations of these primitives are updated every time the remote user moves. The human model manager is consulted by the haptic rendering component to check for possible collision between the haptic device and the user model. Therefore, the haptic rendering is performed locally given the updated representation of the remote user.

3.5 Haptic Jacket

The haptic jacket is a suit that embeds vibrotactile actuators to simulate the sense of touch. One possible design is to use a network of tiny vibrating motors distributed over a flexible layer. In order to simulate the feeling of touch, the different actuators should be controlled in a manner that best matches the real touch or touch stroke to be initiated. For example, to simulate a poke, a concentric layout of motors may be used, where a center actuator simulates the poke touch while other circularly distributed motors form the surrounding concentric circles. In addition, we plan to use heaters to simulate the warmth of touch.

3.6 Data Manager and Synchronizer

This component is in charge of synchronizing the graphic and the haptic scenes and to manage the related information. One of the issues here is to maintain consistent between the two views using techniques such as local lag [13].

3.7 Network Manager

The network manager takes care of transmitting and receiving the graphic and haptic data from one end to the other. Furthermore, this component is responsible for communicating the markers positions across the network. This module relies on well known protocols for real time haptic communication such as ALPHAN protocol [14]. Notice that the marker and contact positions will be transmitted at the same rate as with audiovisual media (30-60 Hz).

4. Preliminary Implementation (Haptic Poke)

As a primary step towards the implementation of a complete haptic jacket, we implemented a Bluetooth-enabled prototype that facilitates thorough usability testing. The prototype comprises two components: a mobile device (phone) that sends – via Bluetooth – the haptic message (poke) and a gaiter-like wearable haptic device that applies the poke stimulus on the human neck using vibrotactile actuators (Figure 4). The mobile device runs a Java application that communicates with a Bluetooth ship embedded in the gaiter to apply a right, left, or back poke.

The gaiter has three pieces of hardware: a Bluetooth ship, a microcontroller, and vibrotactile actuators. The Bluetooth ship receives the haptic message and forward it to the microcontroller, which in turn instructs the appropriate actuators to run for a particular time interval and in a specific sequence to best simulate the feeling of a poke. We are currently experimenting with the poke prototype and will include our experimental results in the final version of our submission.

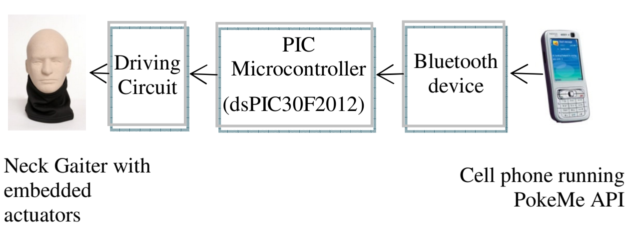

Figure 4. Overview of the poke prototype

The actuators require a current of around 70 mA to operate. This means that a driver circuit that can generate such current is needed since the microcontroller cannot provide the sufficient current necessary to drive the actuators (it provides a maximum of 1 mA at a digital output). Two JFET transistors were used in parallel to drive one actuator (each provides 50 mA). When the controller sends a high voltage to the transistor, the JFET channel will be closed, allowing current to flow from the source (Vcc) towards the actuator (as shown in Figure 4). Also, the commercially available Parani ESD200 Bluetooth Chip is used in the implementation.

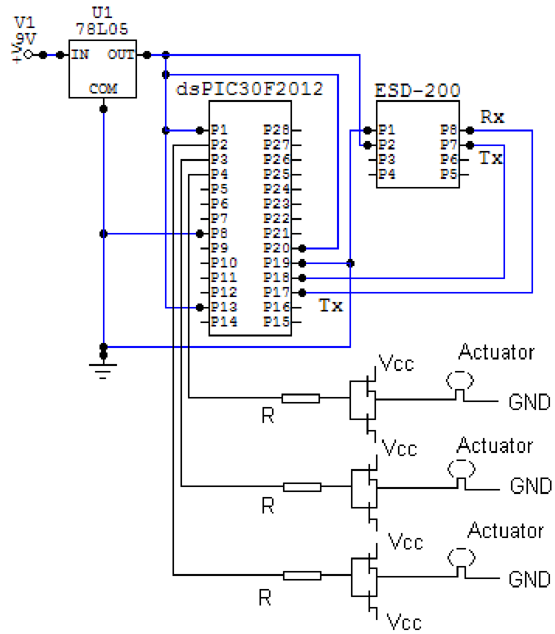

Figure 4. Control circuit of the poke prototype

Figure 5 shows a snapshot of the Poke actuators that are embedded in a gaiter-like wearable cloth. As per the network bandwidth requirements, ASCII codes are communicated from the mobile device to the microcontroller to distinguish the three messages (‘r’ for right poke, ‘l’ for left, and ‘b’ for back). Therefore, the bandwidth requirement is not significant in this case since no real-time haptic audio visual data is been transmitted.

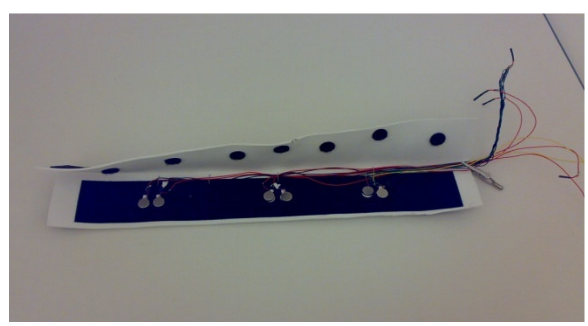

Figure 5. A snapshot of the poke prototype

5. Conclusion and Research Perspectives

HugMe system is a synchronous hapto-audio-visual teleconferencing system that enables people to exchange physical stimuli over a network. This system can be used in the domains of physical and/or emotional therapy, understaffed hospitals, and absent parents/children and lovers. Currently, we are investigating the following issues:

• *Haptic Jacket:* The development of a haptic jacket that can simulate a real touch is one of the major challenges for this project. First, the actuators need to be spread on a large area of the human body with an optimized distribution pattern using a mesh of actuators. Furthermore, the number of actuators to be used need also be optimized. On one hand, a high density of actuators implies higher interferences between adjacent actuators and thus an isolation mechanism will be needed. On the other hand, a small number of actuators make parts of the human body untouchable. Another planned feature is the generation of the touch warmth.

• *Access Control and Touch Authenticity:* The issue here is who can touch the child? How to make sure that the touching party is authenticated to touch the child? One possible solution is the use of biometric patterns to identify the touching party. While the parent is interacting with the child, the haptic identification features of the parent are computed and sent to the child host wherein they are tested against a set of authenticated users. The parent is granted touch if his pattern matches one of the stored.

• *Data Synchronization:* The wide variety of data communication, including audio, video, depth, haptic, and tracking information, makes it a real challenge to synchronize the various media when presented to the participants. The synchronization problem is divided into two categories: intra-modal and inter-modal synchronization. Intra-modal synchronization deals with data of the same media (such as haptic push/pull feelings) whereas inter-modal synchronization addresses the problem of synchronizing different media (such as synchronizing what you feel with what you see).

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