A Real-Time Control of Multiple Avatars using Wii Remotes and Avatar System

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***Abstract*—Virtual reality training and rehabilitation systems require an unobtrusive and inexpensive monitoring of users with minimum latency. Avatar system presents hybrid infrared and inertial solution for low cost deployment. In this paper we propose a synchronized extension of the Avatar system. The system allows monitoring of multiple users using time division multiplexing of infrared diodes on user's body and two Wii© Remotes as optical sensors. A network of inertial nodes on each user is controlled by a master node that serves as a gateway for communication with a capture device, synchronizes and drives infrared LEDs. The capture device communicates through Bluetooth with master nodes (iControl) and Wii remotes. We present system architecture, principles of operation, and performance analysis of the implemented system.**

***Index Terms*—Virtual Reality Systems, Avatar, Sensor Networks, Synchronization, Bluetooth.**

I. INTRODUCTION

Virtual training and rehabilitation applications require real-time unobtrusive monitoring with minimum latency. Existing monitoring systems are usually complex and expensive and based on infrared monitoring. A system of cameras in a dedicated room, such as Vicon [1], provide very good resolution and high speed, at a high price (typically 200-500,000$ per installation). In addition to the high price, obstacle to wider use is lack of portability, the system can not be easily transferred and deployed on another location. The system also requires use of infrared markers and manual system configuration. Another possibility is use of inertial sensors [2]. However, inertial based systems lack absolute positioning. Hybrid systems, such as ultra-sound based sensors [3], provide alternative for affordable position monitoring.

Wii gaming platform provides a low-cost solution for indoor location and activity monitoring. Standard Wii remotes feature infrared (IR) camera that can track position of up to 4 brightest sources. Due to the use of standard Bluetooth wireless interface, Wii remote can be used as component for system integration [4]. A single IR bar can be used to support multiple users using individual Wii remotes.

We integrated wearable inertial sensors with Wii remotes for absolute positioning in a real-time monitoring system we call Avatar [5]. Original Avatar system supports a single user.

In this paper, we propose original extension of the Avatar concept to support multiple users, using the same set of inertial sensors and Wii remotes. We implemented time synchronization and multiplexing of infrared sensors, controlled by the monitoring station.

We present system design and implementation, and performance analysis of the implemented system.

II. SYSTEM ARCHITECTURE

Avatar system integrates optical, wired and wireless sensors to achieve a cost-effective, unobtrusive, real-time body position monitoring system (Fig. 1) [5]. The system uses absolute positioning of a few reference points using infrared diodes on subject's body while the position and orientation of other body segments is determined using a network of inertial sensors embedded in the clothes and wired through serial interface. Gateway node *iControl* controls a network of inertial sensors and communicates wirelessly via Bluetooth with the capture device

Absolute positioning of the reference point is determined using two Wii© Remotes to determine absolute position of the shoulder reference points. We use two IR diodes to maintain visibility of at least one diode at all times. The remotes have known fixed position. Reference point position is determined by triangulation of two-dimensional point outputs from both sensors [6] and can be used for indoor location monitoring [7]. Wii© Remotes communicate with the capture device wirelessly using Bluetooth interface.

Individual inertial sensors (*iSense*) are designed as intelligent 5 degree of freedom (5DOF) sensors communicating with the gateway through the shared I2C bus.

System organization of the proposed multi-user system Avatar+ is presented in Fig. 2. The system still features two Wii remotes for absolute positioning, but activation of infrared LEDs of individual controllers is time synchronized. Individual LEDs are presented with red and blue color in Fig. 2. Symbolic representation of individual LEDs on Wii remotes is presented as red and blue dots.

Wii remote can track up to 4 moving objects and features infrared imaging sensor with resolution 128x96 pixels. A built-in image processing improves resolution by using 8x subpixel analysis to provide 1024x768 resolution for the tracked points.

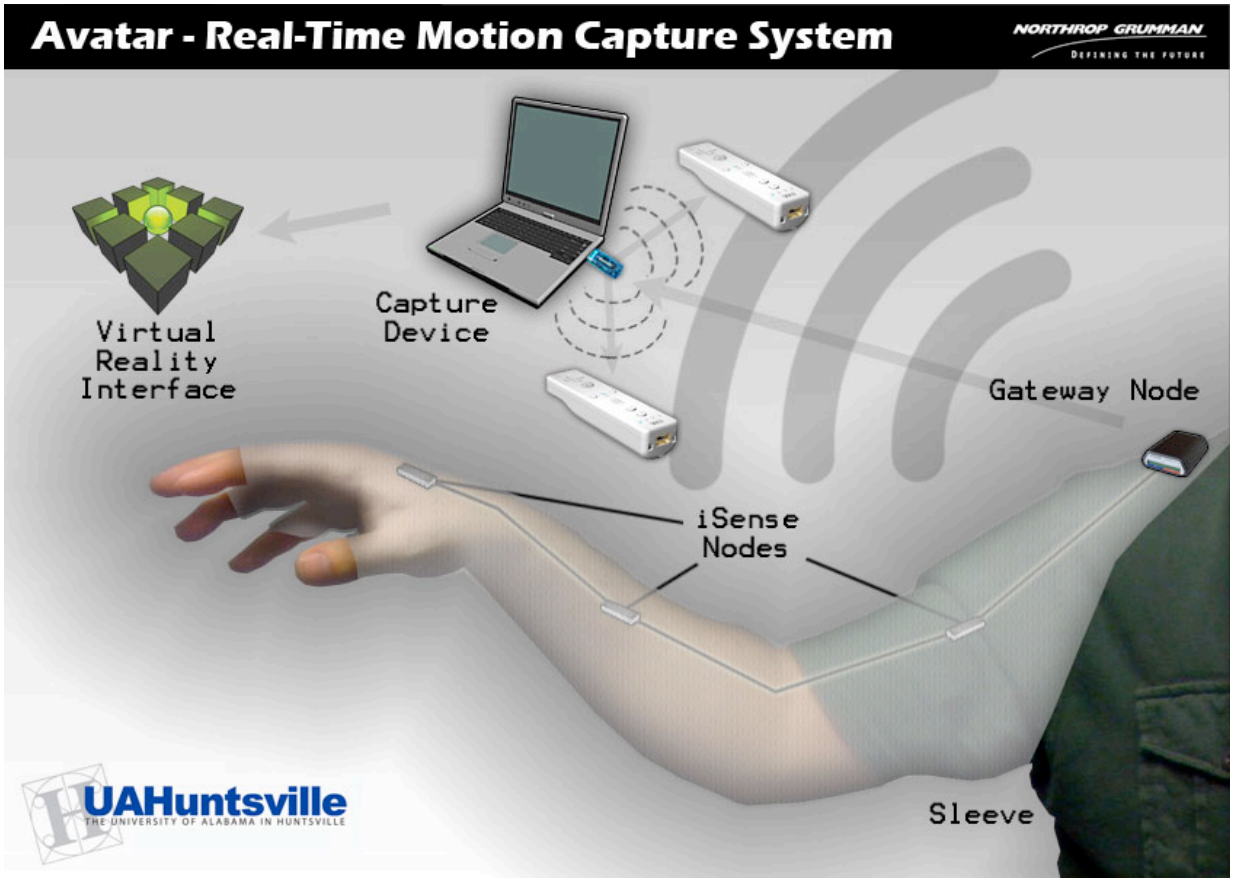

Fig. 1. System organization of a single user Avatar system (from [5] with permission).

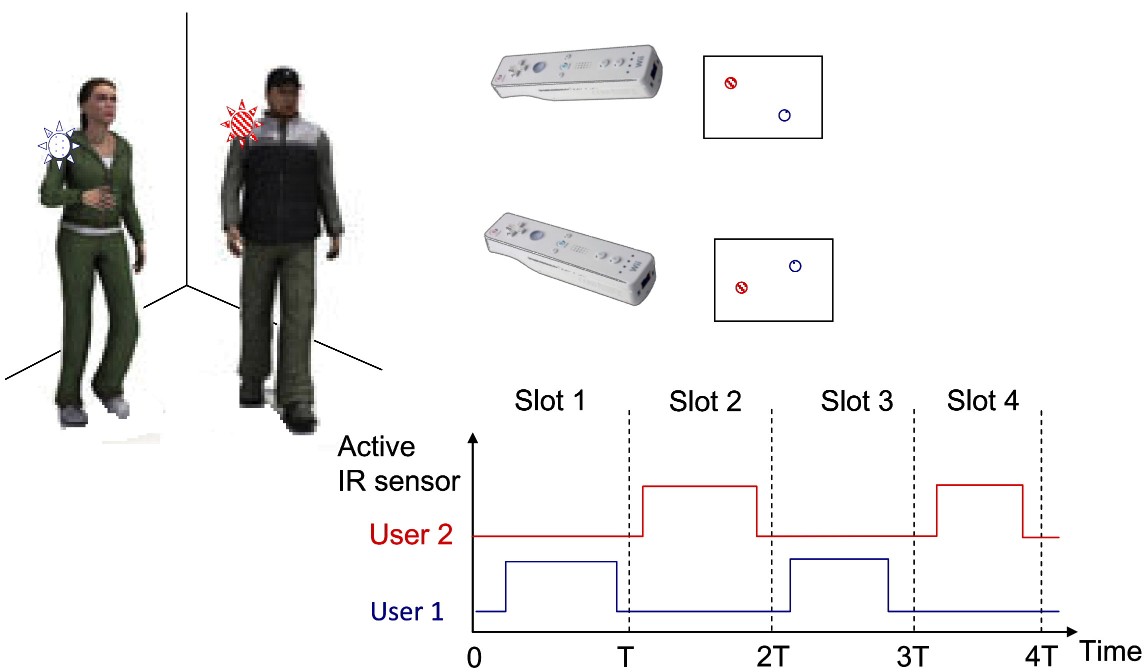

Fig. 2. System organization of the multi user system Avatar+. Time division multiplexing of synchronized controllers.

The sensor provides location information with 100Hz update rate, and features 33 degree horizontal and 23 degrees vertical field of view. It is impossible to track multiple users and multiple reference points with only 4 tracked points, particularly with always present reflections and other IR sources. Moreover, with multiple imaging sensors it would be necessary to manually associate points with users. Therefore, we activate LEDs only on one user at the time. Since the control program determines active user in every time slot, we can decode signals from the imaging sensors and associate triangulated position to a particular user.

To allow efficient "decoupling" of tracking points from user to user we introduce idle time slot between activation of individual LEDs, as represented in Fig. 2. Since the update interval of Wii remote is 10 ms, we introduce "inactive" time slot of 10 ms between individual activations of sensors.

Personal controllers are synchronized through wireless (Bluetooth) connection on iControl module that controls other inertial sensors embedded in clothes of each user. The control application running on PC was developed in C# in .NET framework. We implemented control application with multiple threads careful synchronized to improve real-time performance and reduce time-jitter.

Our primary concern was real-time performance of standard PC computing platforms. A fine precision synchronization of in the order of tens of microseconds is possible on embedded platforms [8]. However, it is very well known that modern operating systems feature significant overhead associated with multiple layers of software isolating applications from actual hardware. Therefore, we designed testing setup to determine real-time performance and time jitter during execution of our application.

III. EXPRERIMENTATION AND RESULTS

We measured typical latency and jitter of time synchronization between two nodes controlled by a monitoring station. Our primary objective was portable system that can be easily deployed. Therefore, for our testing environment we used Toshiba laptop of 3GB RAM, Intel U4100 processor running at 1.3GHz, Windows 7 Home Premium edition, with USB CSR Bluetooth interface.

A snapshoot from of time synchronization of controllers running at maximum switching frequency of 50Hz is presented in Fig. 3. Variation of active periods in both controllers can be clearly seen.

We evaluated the performance of the system at switching frequency of 5, 10 and 20 Hz. The results of performance analysis are presented in Table 1. All performance measurements are collected during 5 minute successive tests.

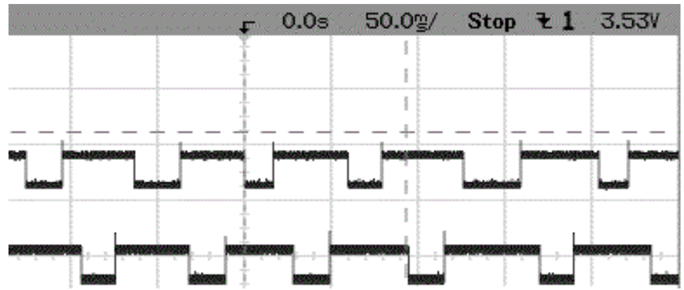

Fig. 3. Time division multiplexing for two users at maximum frequency (50Hz); IR LED is active when the signal is low.

For all three switching frequency nominal idle time is set to 10ms (update time of the Wii remote). Therefore, expected active time at switching frequency of 5Hz is 200ms – 10ms = 190ms.

The average idle time is relative stable and independent from sampling frequency (17 – 19ms). The most critical parameter is overlap between active times of LEDs on controllers. This overlap is possible because of unpredictable delay through multiple layers of software and wireless communication. The maximum overlap between active periods caused by time jitter is 3-5 ms that is significantly smaller than the update rate of Wii remote.

Table 1. Real-time synchronization performance.

Frequency [Hz]	Average idle time [ms]	Maximum overlap [ms]	Expected active time [ms]	Measured active time [ms]
5	19.2	4.8	190	110 – 195
10	18.5	4.4	90	45 – 95
20	17.4	3.2	40	20 - 55

IV. CONCLUSION

This paper describes an implementation of a real-time monitoring system Avatar+ as an extension of the original Avatar system for multiple users. The proposed hybrid solution combines off-the-shelf optical sensors (Wii remote) and custom made inertial sensors *iControl* and *iSense*. The proposed solution presents an affordable alternative for field experiments, virtual rehabilitation and virtual training applications.

A low cost multi user solution is made possible by employing time division multiplexing. However, the price is decreased temporal resolution of user localization. We demonstrated that the system can perform reliably with update rate in the order of 20-30 Hz.

In the future, we will evaluate system performance of the proposed approach for more than 2 users and application specific dynamics (e.g. military training vs. computer assisted physical rehabilitation).

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