WIRELESS SENSOR NETWORKS AND COMPUTER MUSIC, DANCE AND INSTALLATION IMPLEMENTATIONS

Mara Helmuth
(ccm)[2] College-Conserv. of Music
Center for Computer Music
University of Cincinnati

Jung Hyun Jun
School of Engineering
Computer Science
University of Cincinnati

Talmai Oliveira
School of Engineering
Computer Science
University of Cincinnati

Jennifer Bernard Merkowitz
Music Theory and Composition
Otterbein College

Kazuaki Shiota
(ccm)[2], CCM, Univ. Cincinnati
Shobi University
Tamagawa University

Amitabh Mishra
School of Engineering
Computer Science
University of Cincinnati

Ahmad Mostafa
School of Engineering
Computer Science
University of Cincinnati

Dharma Agrawal
School of Engineering
Computer Science
University of Cincinnati

ABSTRACT

Collaboration between the University of Cincinnati College-Conservatory of Music Center for Computer Music and the School of Engineering's Computer Science has resulted in the development of interactive performance systems for computer music. Several of the systems involved music generated by the movements of dance, culminating in a series of well-produced performances with 20 dancers and the music of two composers. Another system contributed interactive aspects to an installation environment based on a Tibetan monastery. Tmote sensors with light and received signal strength indication, and attached acceleration sensors provided data to the computer music system. Java instrument and client objects were created to bring this data into MaxMSP and Jitter to control selection of audio and visual material and digital signal processing. This paper is an overview of recent projects.

1. INTRODUCTION

Recently sensors have been used to build many new sound and music controllers, and connect performance with digital signal processing in new ways.[2] Sensors tracking human movement facilitate translation of gesture into sound. Tomie Hahn and Curtis Bahn's works [4] exploring wireless sensors with dance were one influence on Helmuth's exploration in this area. She used wired photocells with analog-to-MIDI converters (IRCAM's eobody and NOTAM's device) in the installation *Staircase of Light* (2003) for Beijing's SinoNordic Arts Space, and the related performance piece *China Prism* (2005); in both works a dancer's movements broke light beams to send data into MaxMSP patches for digital signal processing control. Wireless sensors, however, provide more flexibility in performance. The subtleties of human movement in dance can best be tracked without cumbersome cables or depending on particular light/sensor positioning. Network programming, in addition, allows a number of distributed sensors to exchange information to create more precise information on positioning within a space, and to describe movement types more accurately. A chance meeting in March, 2007 at the UC Graduate Poster Forum between CCM graduate student Jennifer Bernard Merkowitz who had done a piece using photocell sensors (*In the Key of Light*) and Jung Hyn Jun ("Peter"), a PhD student in computer science working on wireless sensor research with advisor Dharma Agrawal, initiated this collaboration.

The project so far has resulted in several performances of dancer-controlled computer music, and one installation. Programming of chips and Java objects was done by the computer science team, while the CCM team created the MaxMSP patches and sounds. The Tmote sky sensors can both receive and send data. The ones designated basestations usually received data, while other sensors distributed around the space most often sent data, sometimes also influenced by what data they had received.

2. DANCE SENSOR SYSTEMS I AND II

Two dancers were invited to wear sensors and move improvise with a computer music system triggering sound in response to their location, lighting levels they encountered, and proximity to each other. Twenty-three Tmote sky [12, 13] sensors were used, four of which had 3-axis accelerometer sensors (Breakout board for the 3 axis LIS3LV02DQ accelerometer [14]) attached. TinyOS-2.x [6] is a light operating system which was used to control and program the micro-chips (like communicational and computational processing unit) on Tmote sky sensors and to forward serial data from the sensors into MaxMSP MXJ(Java) objects (see Figure 1).

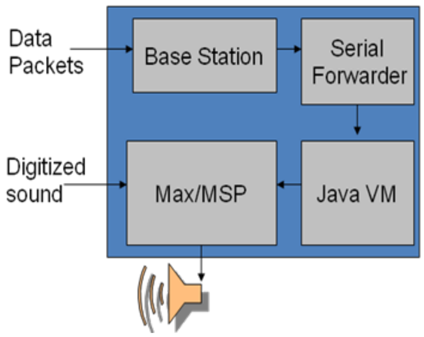

Figure 1. Flow of data into sound manipulation software.

Sound selection and processing was controlled by the sensor data. A sensor was attached to each arm of the two dancers, (see Figure 2), in the first performance on May 6, 2008. Analog data was converted to digital by ADC on the Tmote sky sensor, which was then packetized and sent to the basestation receiver, which was USB-connected to the computer. The basestation is same Tmote sky unit which is programmed to operate as packet receiver and to extract data from packets to forward to the computer.

The location of the dancers was estimated from Received Signal Strength Indicator (RSSI) data, a well-known localization technique. RSSI is basically a measure of signal strength (in voltage) of wirelessly transmitted signal at the receiver. Since the signal strength is inversely proportional to distance it travels, one can model the strength variation to estimate the approximated distance between transmitter and receiver pair. Also the Tmote sky uses close-to-omnidirectional antennae which propagate the signal in all directions. So using simple triangulation one can easily estimate the location of the receiver. The RSSI model strongly depends on the environment and wireless medium, so it worked best when the dancers were close to one another or to one of the sensors. Each sensor on the dancer's arm would detect the RSSI value of any sensor in its proximity, and forward that value to the basestation. The base station was programmed to recognize from the incoming data whether the dancer was close to one of the stationary perimeter sensors, or whether one of the dancers was close to the other. During the performance, if a dancer was close to one of the sensors planted around the stage or on the other dancer, a sound would be triggered. CCM composers Merkowitz, Kazuaki Shiota, Danny Clay and TR Beery contributed sound-triggering patches which reacted differently according to the light data and location of the dancers. Light was used primarily to control amplitudes of layers of sounds. Particularly effective were sounds that emerged in the dark, when most other sounds had quieted.

There were unexpected issues due to lighting problems, and the often lack of obvious connection between movement and sound, and the unreliability of the RSSI strategy for location tracking. Since the dancers could only trigger events in our simple patches, not make subsequent control gestures, it was only clear at the beginnings of sounds what effect the dancer had on the music. Some sensors were more sensitive than others, meaning that certain sounds were triggered with much greater frequency than others. On one hand, this undermined the diversity of the sound environment that the composers had constructed. On the other hand, the dominant sounds provided a musical foundation that structured the piece. However the improvisation of the dancers, the layering of the sounds of five composers, and light-controlled amplitudes did make an eerie and somewhat cohesive experience.

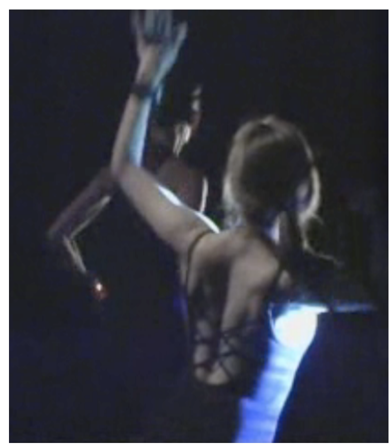

Figure 2. Dancers wearing blinking Tmotes on their wrists in a May, 2008 performance at CCM.

In the second performance Nov. 20, 2008, acceleration data from the intense solo dancer Karen Wissel's movements was used to control digital signal processing more explicitly, and in this case more successfully. Sound was by graduate students Paul Schuette, Shiota, and Wenhui Xie. Acceleration data of the movement on x, y and z axes allowed arm movements to control timbre and other parameters, and stimulated Wissel to do extended improvisations with particular sounds. Location of the dancer was more clearly linked to specific kinds of sounds. The movement of Wissel was detected by comparing the stream of acceleration information from the 3-axis accelerometer data from the sensor on her arm to a predetermined movement model from a training set, which was obtained before the performance. The method used was similar to the fuzzy logic algorithm.

In a related project, Xie also used a similar sensor configuration in a performance of her work for piano and computer. The accelerometer was suspended around one of her fingers, attached by a wire to a Tmote sensor attached to her wrist with a band. The sound of the piano was processed in MaxMSP, controlled by the accelerometer data. The avante-garde transformed piano sound was clearly related to the composer-pianist's hand movements.

3. INSTALLATION SYSTEM

The first version of the *Hidden Mountain* installation by Mara Helmuth had been done with audio alone, in Beijing with wired photocell sensors, and sounds recorded travelling in Tibetan areas of Qinghai province of China in 2007, including monastery sounds and folk songs. The second version premiered Feb. 10, 2009 at CCM in the Cohen Family Studio Theater. In addition to the audio material heard earlier, it included video, and a new wireless sensor system. The system for dance was expanded to track participants' movements in the space better, and to assimilate gestural information from sensors mounted on percussion beaters and a revolving prayer wheel. The acceration changes in the wheel and beaters were tracked by these sensors. In addition, microphones brought the live sounds of the bowl gongs, bells and other Tibetan temple instruments played by participants into the signal processing patch. The movements of the participants were traced using both RSSI and laser pointers with light sensors. In an effort to get more precise and reliable location information for the installation, a system was developed to send light data from clients to sensors worn by participants. These sensors send information about the current and previous locations in relation to the sensors, plus a timestamp. From this information one can track the path and speed of the participant around the installation. The wireless sensor devices along with laser pointers were used for more precise localization of a mobile user who is also wearing a wireless sensor device embedded in a Tibetan scarf. This idea combines the localization using RSSI and disconnection of laser beam with known location. When the laser beam is broken by a user, the wireless sensor monitoring the laser beam intensity detects this change. At this instant the sensor collects the RSSI from every sensor nearby the user. This information is used to calculate the closest user from the interrupted laser beam, and report the user's location and time of the event. The sensor on each mobile user maintains its previous and current location that laser beam was crossed and the time spent between two locations. With this information, the user can easily determine the location and the average travelling time. Each scarf with embedded sensor has a unique identification number so that the speed of the participants are estimated by measuring the time taken for a participant to move from one point to another.

The installation consisted of seven stations of interactivity in a small theater with a balcony on 3 sides. All of the stations on the first floor were facilitated by a Mac Pro running TinyOS and MaxMSP/Jitter, and fed 5 speakers and one video screen. The stations contains various Tibetan instruments including bowl gongs, bells, cymbals, a horn, most of which were playable by the "audience". Tmote sensors picked up acceleration of the beaters of the bowl gongs (see Figure 3).

Figure 3. Station 2 with Tibetan cymbals (left), two bowl gongs and one beater with a sensor attached (right).

The stations included 1) a hallway greeting area where each participant is shown how to strike a bowl gong and given a scarf with embedded sensor to wear so that their location is tracked, 2) a table with a bowl gong, beater with inlaid sensor, microphone and Tibetan cymbals, where the participant can strike or roll the gong, and this acceleration data is sent back to the computer 3) a sensor-inlaid prayer wheel to be revolved by the participant, which affected the video mixing, 4) a video station and risers for people to sit, where sensors tracked their location 5) a table with Tibetan temple bell, horn and microphone, 6) a listening area with Tibetan rug, where a recording of a remote mountain monastery's service is heard, and which starts playing when one enters, 7), cowbells mounted on a spiral staircase which are heard processed when one walks up or down the stairway, and 8) a table on the balcony with more bowl gongs, cymbals, scriptures and a separate computer and audio system performing synthesis based on transformed sounds of the instruments. The actions and movements of the participants influence the sound and video. Some compenents of the installation were purely visual and were not electronically connected, including the Tibetan drum, and the prayer flags hung around the balconies.

The installation received mostly positive comments. Further work is needed to clarify the use of the accelerometer data, and other aspects.

4. DANCE SYSTEM III

The most recent dance system was a collaboration with CCM dance faculty Shellie Cash and twenty of her students. The spring dance show is performed multiple times over one of the last weekends of the year, with costumes, lighting and high production standards. For the Spring 2008 show, we decided to use pressure sensors to get more accurate triggering of events, and events which could be sustained or cut off by the dancers. The battery life of laser pointers had become a factor in the previous situations. The stage setup included 10 pressure strips around the edges of the stage, so that a number of dancers could start and stop sounds throughout the piece. We also wanted some very obvious tracking of dancers movements with acceleration, in a way that would be visible and not constraining on the dancers. The accelerometer was put into a large foam ball (see Figure 5) with a USB battery.

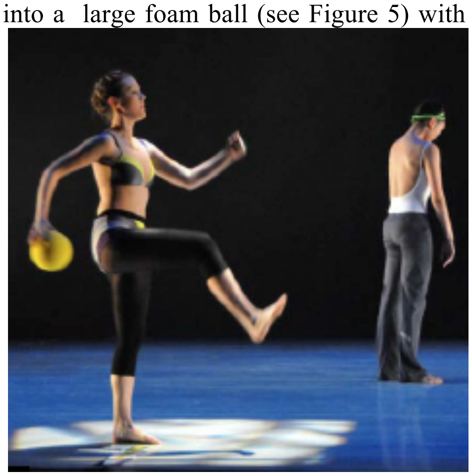

Figure 5. Dancer with accelerometer in ball.

The dancers could roll or throw the ball without damaging the sensor. The music was created by Helmuth and Shiota. Wissel assisted training the students. The system worked well most of the time in performance. Infrequently the sensors were unreliable. The contrast of Helmuth's natural sounds with Shiota's shimmering textures, the dance performance, and in particular the technology which allowed dancers to contribute to the composition of the work, and the complex and more reliable sensor system made this one of the more successful collaborations.

5. CONCLUSIONS AND FUTURE WORK

These systems created through interdisciplinary collaboration allowed for successful performance wth dancer-controlled computer music, and innovation in installation interactivity. Future projects include (1), integrating the use of infrared sensors into the systems, (2), making the systems more robust, (3), expansion of the *Hidden Mountain* installation, (4), continue working with a technique that was explored but not used in performance yet: having the sensor network recognize specific gestures by dancers and (5), creating interactive performances with other musical instruments.

6. REFERENCES

[1] Agrawal, D.P. and Q.-A. Zeng, *Introduction to Wireless and Mobile Systems,* Brooks/Cole, August 2002.

[2] Cook, P. "Principles for Designing Computer Music Controllers." *Proceedings of the Conference on New Interfaces for Musical Expression, 2001.*

[3] Eren, H. *Wireless Sensors and Instruments*. CRC Press, Inc. 2005.

[4] Hahn, T. and C. Bahn, "Pikapika – the collaborative composition of an interactive sonic character", *Organised Sound,* Cambridge University Press, New York, USA, 2002.

[5] Helmuth, M. Merkowitz, J., McKinney, B., Shiota, K., Stark, C. "Center for Computer Music in Cincinnati in 2007: (ccm)^2", Proceedings of the International Computer Music Association, 2007.

[6] Ijji, "TinyOS Article abstract originated by Priva," Dec 18, 2007, http://www.shvoong.com/exact-sciences/engineering/17260360-ti ny-os/.

[7] Kapur, A., M. Yang, E.L., Tindale A.Ar, and P.F. Driessen. "Wearable Sensors for Real-Time Musical Signal Processing" in *The Proceedings fo the IEEE Pacific Rim Conference (PACRIM), Victoria, Canada: 2005.*

[8] Krishnamachari, B. Networking Wireless Sensors. Cambridge University Press, 2005.

[9] Li, Y., Thai, M. T., and Wu W. 2007 *Wireless Sensor Networks and Applications* (Signals and Communications Technology). Springer-VerlagNew York, Inc.

[10] Mostafa, A., Jun, H.Y., Agrawal, D.P., Helmuth, M. "Dancing with the Motes," Fifth IEEE International Conference on Mobile Ad-hoc and Sensor Systems, (IEEE MASS 2008), pp. 538-540. September 29-October 2, 2008, Atlanta, GA.

[11] Tindale, A.R., A. Kapur, G. Tsanetakis A., A. Schloss. "A Compoarison of Sensor Strategies for Capturing Percusssive Gestures." *Proceedings of the Conference on New Interfaces for Musical Expression*, 2005.

[12] Weinberg, D., J. Zhang, "Sensor Wireless Network Final Report," from University of Massachusettes Lowell. htpp://faculty.uml.edu/yluo/Teaching/AdvCompArch/reports/WeinbergZhangFinalReport.pdf.

[13] www.capsil.org/capsilwiki/index.php'TELOSB/TMote_SKY_last_visited_Dec_28,_2009.

[14] LIS3LV02DP Data Sheet. http://www.sparkfun.com/datasheets/IC/LIS3LV02DQ.pdf