Wireless Inertial Sensor Package (WISP)

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ABSTRACT
The WISP is a novel wireless sensor that uses 3 axis magnetometers, accelerometers, and rate gyroscopes to provide a real-time measurement of its own orientation in space. Orientation data are transmitted via the Open Sound Control protocol (OSC) to a synthesis engine for interactive live dance performance.

Keywords
Music Controller, Human-Computer Interaction, Wireless Sensing, Inertial Sensing.

1. INTRODUCTION
The Wireless Inertial Sensor Package (WISP) is a miniature Inertial Measurement Unit (IMU) specifically designed for the task of capturing human body movements. It can equally well be used to measure the spatial orientation of any kind of object to which it may be attached. Thus the data from the WISP provides an intuitive way for a performer to control an audio and video synthesis engine. The performer is free to move within a radius of about 50m with no other restrictions imposed by the technology such as weight or wiring.

2. HARDWARE DESIGN
The WISP is a highly integrated IMU with on-board DSP and radio communication resources. It consists of a triaxial differential capacitance accelerometer, a triaxial magnetoresistive bridge magnetometer, a pair of biaxial vibrating mass coriolis-type rate gyros, and a NTC thermistor. This permits temperature-compensated measurements of linear acceleration, orientation, and angular velocity. The first generation prototype of WISP, shown in figure 1 next to a Canadian two-dollar coin, uses a 900 MHz transceiver with a 50Kb/s data rate. With a volume of less than $13cm^3$ and a mass of less than 23g, including battery, the unit is about the size of a largish wrist watch. The WISP can operate for over 17 hours on a single 3.6V rechargeable Lithium cell, which accounts for over 50% of the volume and over 75% of the mass of the unit.

The fundamental difference between the WISP and comparable commercial products is that the WISP is completely untethered (the unit is wireless and rechargeable) in addition to being far less expensive. All comparable commercial products cost thousands of dollars per node, require an external power supply, and are wired. A wireless communication option is available in most cases, but as a separate box which the sensor nodes plug into.

As can be seen in figure 1, the small size and flat form-factor make it ideal for unobtrusive, live and on-stage, real-time motion capture.

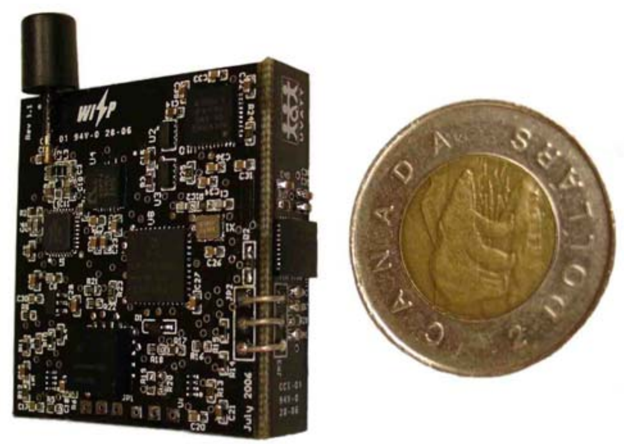

Figure 1 – WISP.

Figure 2 shows an end-to-end block diagram of the system. Although only one WISP is shown in the figure, the system uses time-division multiplexing to allow any number of WISPs to coexist on a single radio channel, subject only to aggregate data rate limitations. A channel can accommodate 4 WISPs, each sampling at a rate of 80Hz or 8 WISPs at 40Hz and so on.

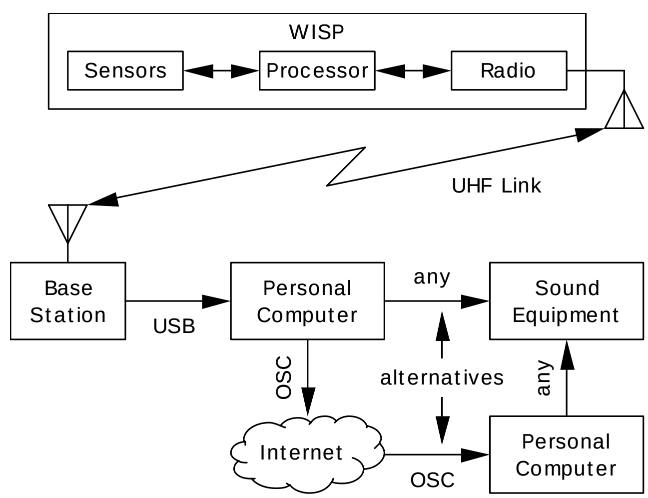

Figure 2 – End-to-end block diagram.

Application software running on a PC communicates with the network of WISPs via a USB connection to the base station. The PC application can display acquired data in a number of ways, and it can also format the data as Open Sound Control (OSC) messages and forward these over UDP in real time to any IP address in the world. In the present work, an audio synthesis engine running on the same computer as the WISP host application receives the OSC messages

3. PERFORMANCE

The data from the WISP are received by Max/MSP via the OSC protocol and converted into MIDI messages to communicate with a synthesis engine. The WISP is used to control audio and visual aspects of a live performance which, in turn, feedback to influence the emotional and physiological state of the performer allowing the performance to evolve in a natural self-organizing dynamic.

3.1 The Data

The windows-based WISP application sends out the roll (rotation about x), pitch (rotation about y) and yaw (rotation about z) angles from the sensing unit over OSC. These angles are commonly used in aerospace literature to describe, for example, the orientation of an aircraft [1].

The data is read into Max/MSP using the standard OSC reading objects. By subtracting successive samples of each orientation angle, measures of angular velocity are obtained in addition to the raw orientation angles. With 3 angles and 3 angular velocities we have a total of 6 control parameters for each WISP. The data are then conditioned and transformed into MIDI control change messages which are sent to an audio synthesis engine.

3.2 Firespinner with Single WISP

The WISP is mounted onto a firespinning staff and used to control audio synthesis and effects parameters. The art of firespinning involves a performer who spins a stick around in various planes of motion at various speeds. The WISP is particularly suitable for capturing such gestures because it can measure the orientation of the stick as well as its first derivative. This results in a highly intuitive interface for control of synthesis and effects parameters by the performer.

A variety of mappings to the virtual space were experimented with. Some of these include mapping angular velocities to low frequency oscillator rates, signal amplitudes, and low pass filter cutoff frequency as well as mapping orientation angles to sample playback positions, and playback speed, effectively giving the performer audio ‘scratching’ control.

3.3 Multiple WISPs

Currently we are experimenting with mapping the data from multiple WISPs in a performance environment into the virtual synthesis space. Initial work includes an animated human body model instrumented by 17 WISPs attached to a dancer’s body at key skeletal articulations. Since each WISP is small and wireless. this sort of whole-body gesture analysis is easy to implement and non-invasive for the performer. The challenge is in mapping such a large amount of data in an artistically meaningful manner.

4. RELATED WORK

Previous works on wearable or playable motion sensors for NIME applications have mostly involved the use of accelerometers to obtain performer acceleration and tilt data. A survey of these designs can be found in the 2nd author’s previous work [3]. Works [4] and [5], not mentioned in [3] have also attempted accelerometer-based designs. Benbasat et al. [6], implemented the Sensor Stack, incorporating inertial, tactile, and sonar distance sensing into a small modular unit. Young and Fujinaga [7] used gyroscopes with accelerometers to acquire Japanese drumming gestures.

5. FUTURE WORK

Future work will focus on improved sourceless tracking of the full-body human model using 17 WISP’s. The Extended Kalman Filter will be incorporated onboard each WISP to achieve improved gesture tracking through exploitation of a priori knowledge of anthropometric and kinesiological constraints. Dimensionality reduction techniques, allowing the effective mapping of many low-level control parameters to a few high-level features, used to drive audio synthesis and control audio effects, will also be investigated.

6. ACKNOWLEDGMENTS

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