The HOP sensor: Wireless Motion Sensor

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ABSTRACT
This paper describes the HOP system. It consists of a wireless module built up by multiple nodes and a base station. The nodes detect acceleration of e.g. human movement. At a rate of 100 Hertz the base station collects the acceleration samples. The data can be acquired in real-time software like *Pure Data* and *Max/MSP*. The data can be used to analyze and/or sonify movement.

Keywords
Digital Musical Instrument, Wireless Sensors, Inertial Sensing, Hop Sensor

1. INTRODUCTION
This paper presents wireless motion sensors. The application is a multipoint-to-one system. Three people can attach a sensor to their body; their acceleration will be measured in three dimensions and transmitted to a central base station at a data rate of 100 Hertz. The collected data can be used to analyze or sonify movement [1]. Distances up to 30 meters are allowed between transmitter and receiver. Goal of the project is to increase the number of users to over 10 people at the same data rate.

2. HARDWARE
The system consists of wireless nodes and a base station. The wireless nodes collect the acceleration data and send these samples to the base station at a rate of 100Hz.

2.1 Node
The node consists of an accelerometer, a transceiver chip with two antennas, three pushbuttons and a battery.
Earlier experiments with Xsens Technologies [2] pointed out that human movements can peak up to an acceleration of 6g. Information about the acceleration in all three dimensions is needed. This is why the LIS3LV02DQ [3] of STMicroelectronics, a three axes digital output linear accelerometer is used. This component provides an I²C [4] serial interface to communicate with the external world.

The radio chip used to establish the wireless link is the CYWM6935 of Cypress Semiconductor [5]. The chip runs the WirelessUSB protocol, a short-range, high-bandwidth wireless radio communication protocol that uses the 2.4 GHz band, so it is well suited for our application.

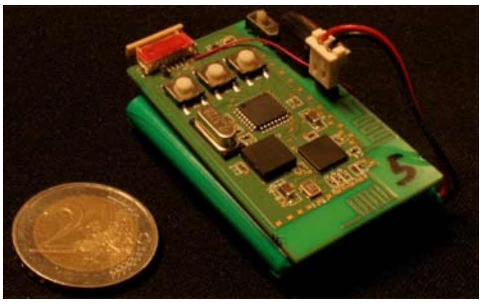

Figure 1. The node

The data of the accelerometer is acquired by the microcontroller, through the I²C interface. The microcontroller processes this information and sends the data to the transceiver chip through the SPI [6] interface. The chip transmits the data to the base station. For this project the ATmega168V of Atmel is being used [7]. The chip transmits the data to the base station.

Figure 2. Dataflow at the node

The node contains three pushbuttons, which the user can use to interact with software applications. To restrict the total number of bytes, sent by the node, the information of the buttons is encapsulated in the bytes with the acceleration data. Less data bytes means less time to finish the transmission protocol. The faster a node can send the data, the more nodes can be attached to one base station, while keeping the timeframe constant e.g. 10 ms.

Normally one acceleration byte for one dimension is represented by 12 bits in the accelerometer. The microcontroller ignores the 5 least significant bits and adds the information of one pushbutton, which is represented by one bit (e.g. 0 or 1). The 7 bits of the accelerometer and the bit of one pushbutton can be bundled into one byte. With the information of three dimensions and three push buttons it is clear that only 3 bytes are needed to be send to the base station.

Ignoring the 5 least significant bits of the accelerometer doesn't harm the accuracy, since acceleration noise can occur in the up to the 7th bit. The acceleration in the x direction of a node at rest is shown in Figure 3. These acceleration values are still affected by noise.

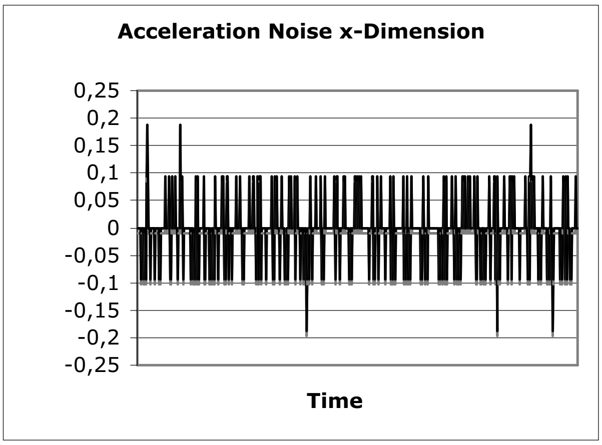

Figure 3. Acceleration in the x dimension of a node at rest

2.2 Base station

The base station consists out of a RF chip (the same chip as on the nodes), a microcontroller and a 'USB to UART' chip (CP2102) [8], which allows communication with a host computer by USB. The RF chip receives data from different nodes and sends them to the microcontroller through a SPI interface. The microcontroller on the base station knows according to the timing which node he has just received acceleration data from. It extracts the data (i.e. splits the acceleration and button information) and makes a new data packet.

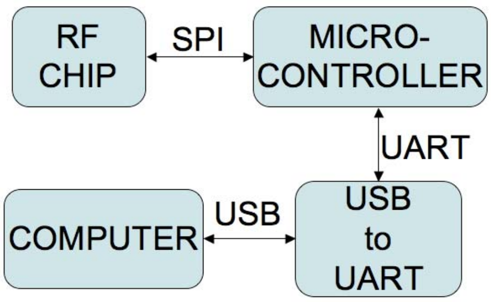

Figure 4. Dataflow at the base station

This packet contains the node address (one byte), a time stamp (two bytes), acceleration information (three bytes) and button information (three bytes). The microcontroller sends this packet to the 'USB to UART' chip, which sends the packet to a host computer by USB.

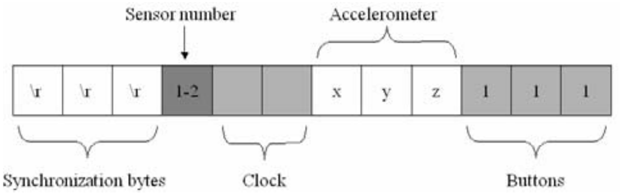

Figure 5. Data packet received by host computer

2.3 Transmission Protocol

The nodes communicate with the base station through the CYWM6935 RF chip with a 16 kB/s data rate. The protocol is a simple time division multiple access (TDMA) scheme. At the start of each timeframe the base station sends a start signal. The different nodes will send their data after each other to the base station when receiving this start signal. Hence the base station controls the data rate. By using TDMA it is not necessary to send address information from the node to the base station.

By using our Cypress radio chip with WirelessUSB, 78 different frequency channels are at our disposal. Every timeframe, the base station chooses another channel and includes the number in the start signal. Therefore the nodes know on which channel to respond. Different timeframes use different channels (different frequencies). This basic kind of 'frequency-hopping' can diminish bursts of packet loss due to other devices (e.g. Bluetooth, WLAN) considerably.

Two nodes can be connected to the same base station. It is possible to use different base stations with their own sensors at the same time. This is achieved by giving the different base stations (and thus also the nodes connected to this base station) their own frequency band.

2.4 Measurements

2.4.1 Properties

The different nodes each have a Lipo battery. The weight of such a node is 35g, including the battery. The dimensions are 8mm x 50mm x 30mm. The battery-life is approximately 18 hours. Distances up to 30 meters are allowed between transmitter and receiver.

2.4.2 Noise

In figure 3 a view is given of the noise of the accelerometer. The resolution of one acceleration sample here is 7 bit. The standard deviation of the noise is roughly 0,054g. If this value appears to be too large, there is a possibility to improve the noise by taking more acceleration samples but keeping the data rate constant. The microcontroller now reads the value of the accelerometer 4 times in one timeframe and takes the average of these samples before he transmits the acceleration data to the base station. By doing this, Figure 6 is obtained. The standard deviation is now decreased to approximately 0,024g.

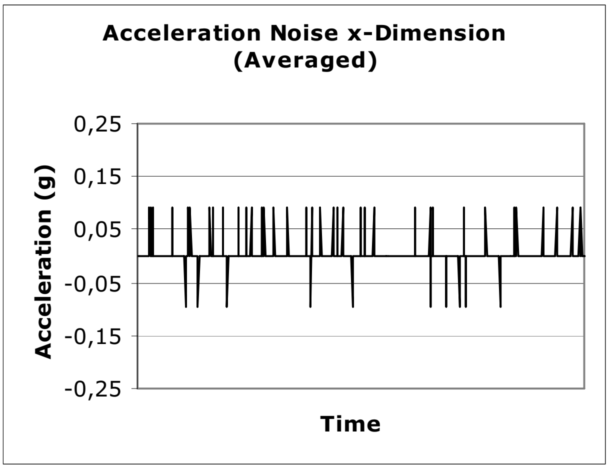

Figure 6. Data packet received by host computer

3. APPLICATIONS

The data can be obtained on the computer through a virtual COM-port. Applications are being developed by the Institute for Psychoacoustics and Electronic Music (IPEM) at Ghent University. Several applications in Pure Data and Max/MSP are already in use. These applications are being used for sonification of human movement and rhythm analysis [9].

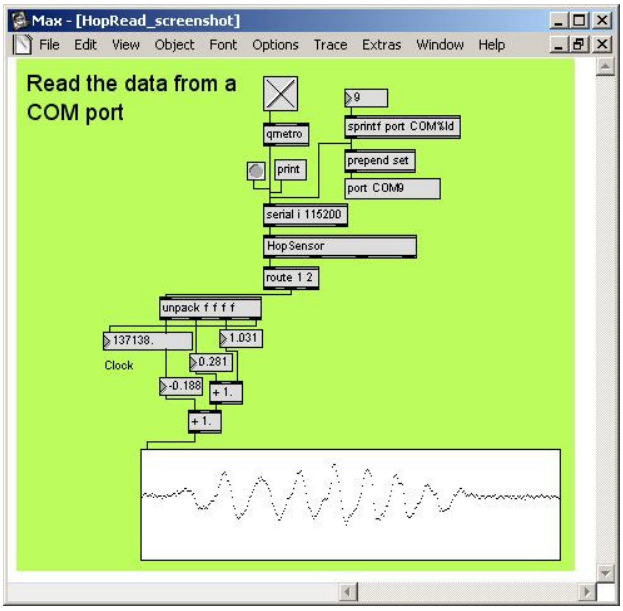

Figure 7. Visualizing the acceleration in Max/MSP

4. WEARABILITY

The nodes are mounted on a Velcro strip, what makes it very easy to attach a node around one's arm or leg. This way, the nodes do not interrupt the user's movement (figure 8).

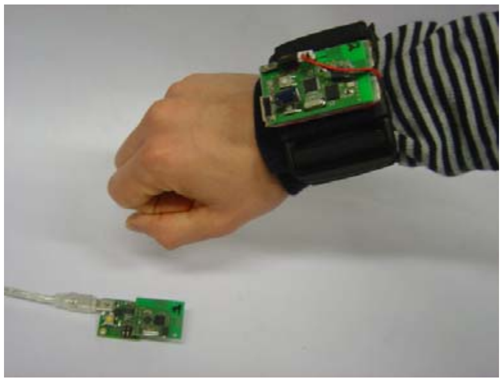

Figure 8. Node on Velcro strip

5. FUTURE DIRECTIONS

At this moment a new PCB-design is being tested. The CYRF6936 [10] of Cypress Semiconductor now replaces the radio chip. This chip has a maximum data rate of 1Mbps. By implementing this chip more nodes can be connected to one base station. A recharging circuit is added to the design in order to recharge the Lipo batteries by plugging an adapter to the node board. Later on, extra functionality can be added to the nodes by appending a gyroscope and magnetometer. By Kalman-filtering it is possible to trace the orientation of the node.

6. REFERENCES

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