PadNET: Wearable Physical Activity Detection Network

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Abstract

This paper describes a low power, distributed platform that combines a wide range of different sensors in a wearable, hierarchical network. The architecture simplifies integration of the sensors into the user's outfit by structuring the hierarchy according to the anatomy of the human body. To date, acceleration and magnetic field sensors were used with the platform for a series of context recognition experiments. Other devices including gyroscopes and force resistive sensors are now being integrated. All designs are available over the internet under GPL licence.

1. Introduction

Context and situation awareness have often been described as key features of future electronic devices. They have the potential to make human computer interfaces (HCI) more user friendly. Furthermore, they allow automatic, intelligent data collection and autonomous 'just-in-time' information delivery [2].

To realize this vision, an electronic device such as a wearable computer relies on adequate information sources. One approach that has been followed up for some time now is the use of vision and audio sensors mimicking the human perception. This approach however, has the disadvantage that signal processing algorithms for extracting relevant information from the raw sensor signals are often very complex, thus requiring enormous computation power which, at the moment cannot be provided by current mobile or wearable computer systems. As an alternative, the use of many simple physical sensors such as accelerometers, magnetic field sensors, gyroscopes, and pressure sensors has recently generated much interest [7, 4, 3] where features (mean, variance, signal power, etc.) with low complexity are used for the recognition tasks. In this context, a number of sensor systems have been developed including Tea [5], Smart-Its [1] and SoapBox [6].

The PadNET Concept
PadNET has been developed mainly for user activity recognition. The main difference with respect to the platforms mentioned above is that it has been specifically designed as a wearable system pursuing two goals: easy distribution of the sensors over the user's body and seamless integration into the user's outfit. PadNET's architecture is motivated by the observation that most user activities can be characterized by certain motion and state patterns of distinct body parts. Thus, a person driving a car would be sitting, with his arms and legs slightly bent, periodically performing certain characteristic arm and leg motions (changing gears, turning the wheel and pressing pedals). The architecture of PadNET is shown in figure 1. As can be seen PadNET is a multistage sensor network with a hierarchy that reflects the anatomy of the human body. This architecture allows information from different, logically related sensors to be fused on their way to a central node reducing the amount of required cables and transmitted data. The use of a common main module for all sensor nodes simplifies integration of heterogeneous sensors into the network. Figure 1 illustrates the schematics of the main module that is used in the network.

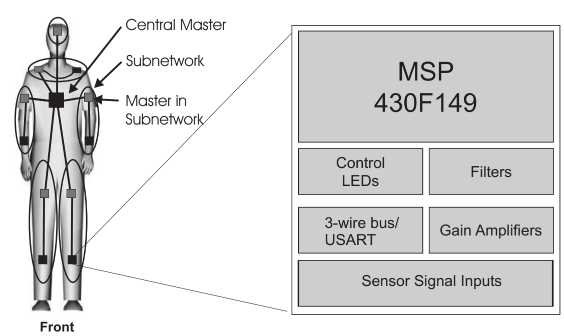

Figure 1. Left: Hierarchical Network Topology (subnetworks are encircled) Right: Schematics of main module

2. Architecture

PadNET is divided into subnetworks assigned to body parts that form a logical unit. Each subnetwork may consist of

Proceedings of the Seventh IEEE International Symposium on Wearable Computers (ISWC'03)
1530-0811/03 $ 17.00 © 2003 IEEE

multiple sensors that are connected to a local bus with a dedicated master. The communication within the subnetwork is based on a 3-wire bus. Two wires implement the communication between the nodes using I2C-bus similar protocols and the third is used to synchronize all sensors in a subnetwork. The wire-based data transmission within the subnetworks aims at using conductive textiles for interconnecting the sensor nodes. Figure 2 illustrates a bus implemented with conductive textile bands.

Figure 2. Usage of conductive textiles (white straps) to implement communication bus

The masters of all subnetworks form a higher level bus in which they are slaves to a central node. This two-layered hierarchical approach provides a logical separation of the sensor information with the objective to increase the amount of local processing, to minimize data transfer and to reduce the computational load on the central master.

All sensor nodes in the network are based on the main module depicted in figure 1. The module incorporates an MSP430F149 low power 16-Bit mixed signal microprocessor (MPU) from Texas Instruments running at 6 MHz maximum clock speed. The current module version processes three analog signals including amplification and analog low-pass filtering (2nd order Sallen-Key low pass filter). The bidirectional communication between the modules is handled through dedicated I/O pins. A 15-pin connector is used to power the node, to interconnect it to a subnetwork and to reprogram the MPU. Furthermore, it provides a serial connection using the USART interface. This main module is a host for different sensor types such as e.g. accelerometers, gyroscopes and magnetic field sensors. All these sensors provide motion based information relevant for activity recognition. Figure 3 shows the main module with a 3D-magnetic field sensor unit and with a 3D-accelerometer unit.

3. Applications

The sensor network has been developed to provide a research platform. The purpose of the platform is to simplify the distribution of multiple sensors on the human body and the acquisition of the sensor data.

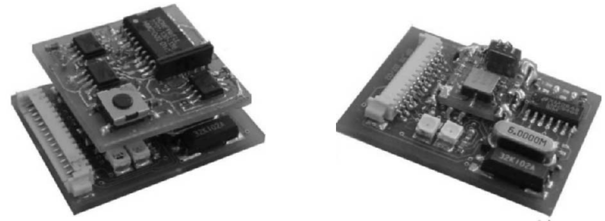

Figure 3. Sensor Node with two configurations, left: 3D magnetic field sensors, right: 3D accelerometers.

The platform allows evaluation of sensor configurations for activity recognition, as well as investigation of signal preprocessing routines. Apart from context sensing there are many other fields where this platform can be used, e.g. in gait analysis.

The sensor nodes can be operated alone, in a single subnetwork or with multiple subnetworks.

4. Follow ups

At the time of writing, a communication node is developed that will be used to interconnect the subnetworks through wireless links. The nodes are based on the RF-Transceiver module TR3001 from RFM. They are equipped with a microcontroller which handles the communication between the wireless nodes of the different subnetworks. Apart from magnetic field sensors and accelerometers, gyroscopes, force dependent resistors and pressure sensors will be integrated into the platform as well.

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