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Open source hardware based sensor platform suitable for human gait identification

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Most initiatives about embedded sensing capabilities in computational systems lead to devise an *ad hoc* sensor platform, usually poorly reusable, as a first stage to prepare a data corpus or production prototype. In this paper, an open source hardware platform for sensing is described. This platform was intended to be used in data acquisition for gait identification, and is designed in a way general enough so many other projects could reuse the design to accelerate prototyping. The platform is based on popular open source hardware and software like Arduino and Raspberry Pi using well known languages and libraries. Some experimental results about the throughput of the overall system are reported showing the feasibility of acquiring data from up to 6 sensors with a sampling frequency no less than 118 Hz.

1. Introduction and objectives

The design and development of a sensor platform are usually the starting point in almost every project related to biomedical research and pervasive computing. This kind of infrastructure, known as *sensor network* [1], is in the focus of the research community for several years, resulting in an assortment of proposals for each field of application, like in the case of e-Health, activity recognition or gait identification.

To start modeling human gait, as considered by our research workgroup, a suitable dataset with properly qualified data on human motion is required. There exist several datasets that vary in the domain of application and size, as stated in a recent review by Moore et al. [2]. Our group intends to contribute in the same terms with a dataset consisting of samples of acceleration and angular velocity measured on the main joints of the human locomotor system oriented to activity recognition.

These types of research initiatives take shape usually in two stages: a first one of experimental nature, intended to obtain data and prepare the corresponding algorithms to solve the task, and a following second one in what a system is deployed in a real scenario ready to be used. Ho et al. [3] named these stages *Learning* and *Developing* phases, respectively. In the learning phase the work is focused on exploring the capability of sensors and in the ways they may be integrated. In order to do this, different options regarding embedded platforms and sensors available in the market are assessed for the project requirements and the resource availability. In the developing phase the requirements of the sensor network are re-stated from the lessons learned in the first stage (in this case, the authors reported that new HF and UHF RFID components were added) to be applied in the case of study.

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Following this methodology, the first stage of the research involves the acquisition of data needed to explore options and confirm hypotheses. Their requirements are related mainly to the flexibility and affordability of the proposal, given that the subject of study usually compels some modifications regarding the type of sensing and characteristics of the data to be acquired. For example, Ohgi reported in [4] that two prototypes were built to incorporate different kinds of sensors to the data logger.

In a second stage, the development phase, an *ad hoc* sensor platform must be designed and produced with specific requirements related with the regular use, like *wearability*, power consumption and wireless connectivity. In relation to this issue, Benbasat and Paradiso hold in [5] how they tend to discard the electronic boards used in the prototype and the redesign the circuitry depending on the particular physical constraints of the system. Another example is the development shown in [6] that was designed under physical constraints of weight, waterproof and hydrodynamics given that it would be attached to a swimmer using a waist belt, while it was based in a previously developed system intended to identify the type of stroke [7] using a different experimental data acquisition platform.

Every sensor platform is an investment where all requirements are not usually known in advance, so many times it must be re-engineered during the experimental phase. In [3] due the cost of hardware, an RFID simulator reader was developed and used instead of a physical RFID reader. In some cases, the projects are devised using only one sensor platform, due to the cost and complexity of its design and manufacturing, restraining, therefore, the capabilities of the experimental phase because of the requirements of the deployment phase.

This paper details our findings on the architecture of a sensor platform based on open source hardware and software. This kind of foundation allows us fast prototyping, especially in the research phase, with flexible, inexpensive, general purpose hardware and software components. Nowadays, open-source interest makes possible the creation of open-source scientific devices made of free open-source software on top of open-source microcontrollers [8]. This, combined with 3D printing facilities, allows us to dispose of highly sophisticated scientific equipment while driving down the cost of research tools.

The main contribution of this paper is the design and implementation of an open source sensor based platform suitable to be used in data acquisition oriented to the human gait analysis. Our proposal is general enough to be employed in a similar situation where a portable, low cost, open source and remotely operated platform would be required. Bandwidth and power consumption measures are provided based on tests with an actual prototype which can be used to assess the suitability of our proposal in some other applications.

The remainder of the paper is organized as follows: Section 2 summarizes some findings about this area, and digs in the requirements of other similar initiatives. Section 3 describes the architecture and the design proposed by our team. Section 4 exposes the implementation of our system and the main performance details of it. Section 5 discusses our main findings and prospects some suggestions for the future designs.

2. State of the art

Along the last years of developing of sensor networks and sensor platforms, independently of its field of application, there seems to be some agreement on the main issues and constraints of these systems. In [9] the authors list the challenges established in the development of the pervasive healthcare systems, being a main fact that several issues concern to the development of the sensor platform. Among the topics highlighted by the authors are the need of interoperability and the intention of simplifying the deployment and enhance the scalability. These goals are completely aligned with the conclusions of Akyildiz et al. [1], that stated that flexibility, affordability and flowing deployment are some the desired goals related to the success of sensor networks. Moreover, the authors identify the main constraints and requirements in the development of these systems, such as fault tolerance, scalability, cost, hardware, topology change, environment and power consumption.

Lo and Yang, in [10] state that most hardware platforms for pervasive healthcare applications are proprietary designs. They hold that this lack of interoperability and standards tampers the development of pervasive sensing applications. Two directions have been followed to resolve this: propose a compact modular platform, and develop an open source based platform. One example of the design of a modular platform is reported in [5] where the modularity is the basis to overcome the problems of developing systems of sensors from scratch, sharing portions of their hardware and software infrastructure. The design of a modular sensor platform will allow us to (a) encapsulate the knowledge, (b) to reduce the repetition of circuit design, and (c) to simplify prototyping. In this particular case, the author of [5] developed a set of hardware modules or panes which could be combined to obtain the desired sensor system. They extended the modularity also to the software, where each of those panes should be associated with blocks of code (or a library) that could be included in the main code when the sensor pane was attached to the processor pane.

This topic of software modularity is at the foundation of a main result in the field of networked sensors: the operating system TinyOS.[1] In [11] the authors point to the lack of system software support as the main problem to cope with when gathering off-the-shelf components to build a prototype. The main contribution of [11] to this matter is the development of the tiny micro threaded operating system TinyOS. TinyOS design addresses two important restrictions: intensive concurrency and efficient modularity. The hardware chosen for the first version was the very limited ATMEL 90LS8535 4 MHz processor with 8 kB of flash memory as the program memory and 512 bytes of SRAM as data memory. The

[1] http://tinyos.net.

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