Accepted for 3rd IEEE International Conference on Distributed Computing in Sensor Systems, June 18 - 20, 2007
Santa Fe, New Mexico, USA

Mobile Device-Centric Exercise Monitoring with an External Sensor Population

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Abstract

Current trends in the sensor networking research community indicate a shift in focus from the traditional research targeting enterprise, structural/industrial monitoring applications to more consumer focused applications. In this paper we discuss an ongoing project in our lab in the "people-centric" mobile device-based sensor networking area. We present an abstract archtecture of such a system and discuss a system that will be deployed at a gymnasium.

1 Introduction

Sensing and Wireless Sensor Networks have been active areas of research for the past several years now. Until recently, the major focus of research in this area has been towards use cases targeted at military, enterprise and environment/structural monitoring applications [1] [2]; not a lot of work has focused on individual consumers. However, we are now witnessing a new direction in research in this area, as is evidenced by projects like: MetroSense [3], Participatory Sensing [4], Satire [5]. These and several other projects are looking at various aspects of mobile device-based people-centric sensor networking and applications.

In this paper we briefly discuss a project we are currently working on in the mobile device-based people-centric sensor-networking space. Sensors with their ability to monitor ambient physical phenomena are a rich source of contextual information that can be utilized in consumer-oriented applications. Users' personal mobile devices (e.g. cell phones) have significant computing and networking capabilities. Hence these devices can be used to interact with sensors to support context-aware applications. We believe that an ecosystem rich in sensors and transient (in a spatiotemporal sense) user-owned, networked mobile devices will foster development of a new breed of applications and services that will enable intelligent device to device (and therefore people to people) interactions.

In the sections below we present an abstract architecture of such an ecosystem and discuss a work in progress that is a concrete implementation of this architecture in the form of a system that would be deployed in a gym.

2 Abstract Architecture

From a high-level architectural perspective, this would be a multi-tier system broadly comprising (i)a sensing tier, (ii) a mobile devices and (iii) an infrastructure backend. We briefly discuss these tiers and the interactions between them in this section.

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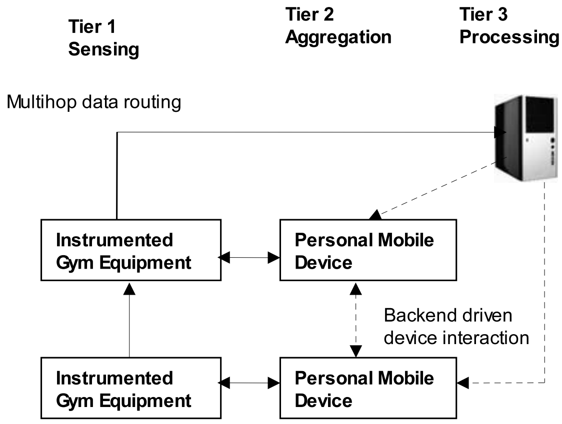

Figure 1. A Sensor Rich Gymnasium Architecture

Tier 1 - Sensing Tier: This would be the lowest layer in the system, comprising of relatively resource constrained (compared to the other tiers) sensors that measure some physical phenomena like acceleration, temperature, proximity etc. Compared to the sensor-mobile device relationship, the relationship between sensors in the network would be longer term.

Tier 2 - Mobile Device Tier: This tier would comprise of the users' personal, networked mobile devices. The devices will interact with the sensing tier and will act as a first level data sink of the sensed data. Mobile devices will have a transient relationship with the sensors in the sensing tier i.e. the interactions will occur when the mobile devices are in close proximity of the sensor(s). Depending on the applications being supported by the system, mobile devices in this layer could also interact with each other and/or the backend.

Tier 3 - Server Tier: The server tier will comprise of enterprise class machines that will support and drive the applications in the system. While a user's mobile device collects data on behalf of the user and thus has the user's view of the data, the server tier is the ultimate data sink of the system and has an aggregate view of the system. Depending on the system deployment and applications supported, sensed data would be routed to the server tier via dedicated gateways communicating with the sensing tier or via the mobile devices that interact with the sensing tier nodes. The server tier will be responsible to control/administer the system. Intelligent device to device interactions in the system will be driven by policies maintained in the server tier.

3 A Sensor Rich Gymnasium Architecture

As a concrete implementation of the architecture we are building a sensornet system that will be deployed at a gymnasium. The following observations about the current trends in active lifestyles have motivated us to build such a system:

- Most Cardio equipment have sensing capabilities. However the sensors operate in silos making it difficult to share the sensed data with trusted third-parties (trainers, therapist, friends etc).
- Wearable sensors currently available in the market record data for individual users. However data sharing to enable community-based use cases is currently not possible.
- Strength training equipment do not have any sensing capabilities. Monitoring strength training workouts is an inconvenient, manual process.

We envision that the next-generation gymnasiums will have equipment instrumented with sensors that will form a co-operative, multi-hop sensor network to enable seamless workout and equipment monitoring applications. Users' personal mobile devices will be sensor-aware and will be transient members of the sensornet in the gym. While users workout in the gym, data from sensors will be aggregated on users' mobile devices, thus enabling a convenient mechanism to monitor workouts. Additionally, the sensed data will also be routed over the sensornet to a backend machine maintained by the gym personnel. This data will represent the usage information of all the equipment in the gym. This will be a rich data repository that can be mined to determine equipment usage patterns for maintenance purposes. The data could also be used for building some interesting social networking applications. For instance, the system could network users with similar workout routines or enable some friendly competitive games thus encouraging users to perform better in their workouts. Figure 1 is an architecture block diagram of the system and depicts the different tiers and interactions between them.

4 Implementation

We have built an accelerometer-based sensing platform that is used on weight training equipment to monitor strength training workouts. The current platform has the following components:

- Gumstix [6]: Marvell Xscale PXA255 based Embedded Linux motherboard with Bluetooth.
- ST Microelectronics 3-axis accelerometer [7] connected to the Gumstix over I2C.

In the current implementation, accelerometer readings are transmitted to the users' mobile device over Bluetooth. While a realtime inferencing engine hasn't yet been built on the phone, offline analysis of the collected data clearly indicates the weight lifting/releasing motion. This can be used to count the number of times the weight was lifted. Curve smoothing techniques result in data that will be easier to infer algorithmically. Figure 2 shows a sample acceleration graph of the weights being lifted for 12 times on a shoulder press machine.

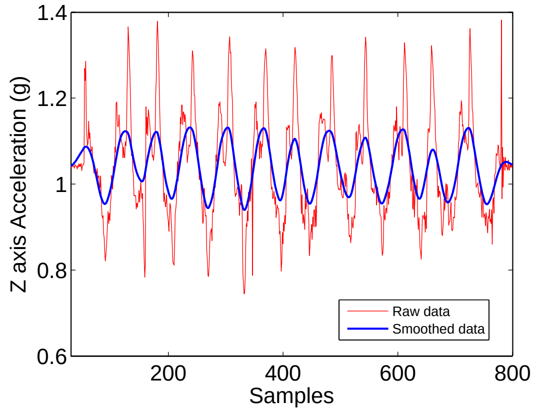

Figure 2. Accelerometer output from a gym machine (Sampled at 40Hz)

5 Conclusions and Future work

We have presented a work in progress in this paper. We described a general architecture of a mobile device-centric sensor network system and discussed a concrete architecture/implementation in the context of a gym. We envision a lot of opportunities for research and innovation in the mobile device-centric sensing space and this is a first step for us. A lot of work needs to be done on our part to realize the complete vision. Some of the milestones that we need to achieve in the near future are:

- Build a realtime inferencing engine for the mobile device to monitor weight lifting exercises.
- Integrate the sensing platform with an IEEE 802.15.4 [9] based sensing platform and build an adhoc multihop system.
- We have IEEE 802.15.4 radio capability integrated into some Motorola mobile devices [8]. This will be used to interface with the sensornet instead of using Bluetooth.
- Our current work focuses on strength training activities in the gym. We also plan to include cardio activities in the system.
- In the current implementation we do not yet have any mechanism to measure the weight being lifted. We plan to investigate pressure sensors and strain gages to enable this functionality.

6 References

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