UNIVERSITY OF ST ANDREWS
SCHOOL OF COMPUTER SCIENCE

Energy-efficient sensing with Android smartphones.

Author:
Martin Maciej Kukla
mailto:mk74@st-andrews.ac.uk

Supervisor:
Dr Tristan Henderson
mailto:tnhh@st-andrews.ac.uk

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I declare that the material submitted for assessment is my own work except where credit is explicitly given to others by citation or acknowledgement. This work was performed during the current academic year except where otherwise stated.

The main text of this project report is NN,NNN* words long, including project specification and plan.

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Martin Maciej Kukla

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1 Introduction

Smartphones are widely used devices. They provide advanced services by exploiting user's context e.g., a client is indoor. The context is inferred in mobile sensing process. Although useful, mobile sensing may lead to fast battery depletion, which is of key importance for mobile phones.

Mobile phones sensing is a complex process. It compromises acquiring raw sensor data and extracting a relevant information out of them. For example, accelerometer data may indicate that the user is not moving. Modern mobile phones are rich in sensors. Google Nexus 7 is not only equipped with standard sensors such as microphone, camera, IEEE 802.11, GPS, Bluetooth or accelerometer, but also magnetic field, gyroscope or ambient light. All of those sensors may be sampled and provide raw sensor data from which meaningful information could be obtained. This process usually involves feature extraction and classification. Different features may be useful depending on a sensor and a type of information we want to obtain e.g., number of peaks in accelerometer data may be a good predictor to answer whether an user is walking or running. The classification is an inference, which assigns a high-level class to feature vector e.g., 2 peaks in one second is interpreted as a client is walking.

Energy consumption is a crucial issue in phone sensing. Both phases of phone sensing incur additional energy costs. Simple physical sensor are energy-efficient themselves, but their careless sampling may result in high energy consumption. For example, while accelerometer is being sampled, high-power components including CPU are active which may significantly drain the battery life [3]. For other sensors like camera or GPS, the sampling itself is an expensive operation [XXX example/reference]. Also, the data extraction process is computationally intensive, which means high energy demand. [XXX example/reference].

In mobile phone sensing, there is a specific energy-accuracy tradeoff. Energy efficiency of mobile sensing may be improved while decreasing the accuracy of the context information. For example, we could sense GPS less often. Although this results in energy savings, the location coordinates may be inaccurate during the periods when GPS not being sensed.

This project investigates an energy-accuracy tradeoff in phone sensing. It reviews the current state of the art and identifies possible enhacements. Also, the unique method of energy measurement is proposed and used to determine energy profiles of different sensors available across different devices. As a proof of concept, the energy efficient sensing library was built, which embodies part of the ideas presented in this dissertation.

2 Objectives

This project aims to investigate the energy-accuracy tradeoff in phone sensing. It tries to critically review the current state of the art methods for energy-efficient sensing and identify possible enhancements. The outcome of this research is a smart sensing library for Android smartphones, Sensy, which embodies the ideas presented in this dissertation.

3 Context survey

3.1 Energy measurement

To improve energy-efficiency of sensing, an accurate method of measuring power consumption needs to be established. This task is relatievely easy for Nokia phones. There is a Nokia Energy profilier [XXX references], an application delievered by Nokia, which accurately measures power consumption and is widely used by research community [XXX references]. Google does not provide such an application for Android smartphones making this task more difficult.

The Power Monitor is a hardware power measurement solution delivered by Moon-Sooon PowerSolutions [2]. It is designed for analyzing power of single lithium (Li) batteries (all Android phones). Although the tool provides accurate measurements, it can only be used in lab environment e.g., it can't measure energy consumption of GPS sampling while a client is moving outdoor. It is also expensive, and thus, it can't be directly used by mobile phone clients. Android platform solves this problem by enforcing on mobile phone vendors to make relevant measurements and save them available on mobile phones before selling them [XXX reference]. This information may be further utilized by software power profiles.

Software power profiles on Android smartphones use a power model to determine current energy consumption. They continuously query states of hardware components such as CPU, wireless card or screen. For example, wireless card may be switched off, listen or send information. Each state of each of the components has assigned a value indicating its energy consumption (this should be provided by a mobile phone vendor as descrbied in the previous paragraph). Software power profilers aggregate all of those corresponding power consumption values to estimate current energy consumption of a device. Example applications using this method includes PowerTutor [4] and Battery Monitor Widget [1]. Although this method provides online energy measurement and is practical for clients, those measurements are only rough estimation. The energy demands of hardware components provided by the vendor can change across time as battery characteristics change. Also, the energy consumption values of physical sensors are often missing, which makes it impractical for phone sensing applications.

3.2 Phone sensing

3.3 Energy-accuracy tradeoff in phone sensing

4 Requirements specification

The project and the library should satisfy a following set of requirements:

(a) Primary requirements

- All software components of the project will work on the Android mobile operating system.
- Energy efficiency and accuracy of the library should be tested against a baseline implementation.
- The project should empirically determine energy costs of different sensors.
- The library will be integrated with Tristan's experience sampling method (ESM) mobile application.
- As part of the project, a study with real users should be conducted.

(b) Secondary requirements

- The library will calculate energy costs of different sensors in real time.
- Software components should work on a variety of Android devices.
- The energy saving algorithm should be adaptive according to current battery life.
- The library intends to manage mobile applications' contention for sensor usage.

(c) Tertiary requirements

- The energy saving algorithm should improve its performance by learning from user behaviour.

5 Software engineering processes

6 Ethics

7 Design

8 Implementation

9 Evaluation and critical appraisal

10 Conclusions

References

[1] Battery monitor widget - android apps on google play.

[2] Monsoon solutions.

[3] Bodhi Priyantha, Dimitrios Lymberopoulos, and Jie Liu. Enabling Energy Efficient Continuous Sensing on Mobile Phones with LittleRock. In *Proceedings of the 9th ACM/IEEE International Conference on Information Processing in Sensor Networks*, IPSN '10, pages 420–421, New York, NY, USA, 2010. ACM.

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