SMART USAGE OF CONTEXT INFORMATION FOR THE ANALYSIS, DESIGN, AND GENERATION OF POWER-AWARE POLICIES FOR MOBILE SENSING APPS

Doctoral Seminar I

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INTRODUCTION

INTRODUCTION

Mobile devices (MD) adoption by society

- → MD are used massively around the world [Qureshi, 2014] thanks to their Internet-enabled features, increasing storage and computing capabilities, and embedded sensors.
- → Sensors allow mobile devices to become *omni-sensors* of the environment.
- → By analyzing data from environment, smart devices become *context aware*.

INTRODUCTION

Contextual information from smartphones

- Context refers to the set of environmental states and settings that either determines an application's behavior or in which an application event occurs and is interesting to the user [Chen and Kotz, 2000].
  - Context aware mobile apps.
  - Location aware mobile apps, also known as Location Based Services.
- Considering their functional operation, these apps are known as **mobile sensing apps (MSA)** [Lane et al., 2010, Campbell and Choudhury, 2012].
- MSA core activities are:
  - Sensing data from environment.
  - Analyzing these data.
  - Generating high level information with a special meaning to the final user.

INTRODUCTION

Motivation

→ Advances in battery research are not at the same pace than those related to other components of MD [Kjærgaard, 2012].

→ The battery is a limited source of energy that is impacted by sensors and other embedded electronics usage.

→ It is mandatory for any mobile application development to consider the energy constraint and implement mechanisms to optimize battery duration.

Feature	**Average power (watts)**
Processor (1%)	0.06
Processor (100%)	0.41
Accelerometer	0.05
Bluetooth	0.28
Microphone	0.26
Screen	0.23
Wi-Fi scan	1.37
GPS	0.32
3G radio (idle)	0.47
3G radio (sending)	1.11

Table: Average energy consumption of a Nokia N95 Smartphone (in [Kjærgaard, 2012])

PROBLEM STATEMENT

PROBLEM DESCRIPTION

Current state of energy management

- → MSA access sensors in a continuous way over long periods of time.
- → Sensors usage impacts directly on battery.
- → Current smart devices' processors are designed to manage the heavy interaction with the user and the execution of mobile apps.
- → A continuous sensor reading is out of their current objectives [Priyantha et al., 2011].
- → API's[1] by manufacturers only accomplish generic tasks like turning on – off sensors

[1] API refers to Application Programming Interface.

PROBLEM DESCRIPTION

What do we need?

- → **High level information about user's context remains ignored**.
- → A special framework to generate smart policies for continuous sensor access.
- → This framework should consider:
  - → Mobile app requirements (e. g. the precision in the sensor data collection).
  - → Mobile device constraints (e. g. the current level of battery).
  - → Threshold values for performing a smart sensor usage (e. g. the lowest battery level for avoiding a permanent sensor usage).

PROBLEM DESCRIPTION

A possible solution is

- → A policy is a high level concept that defines the usage sensors should observe to keep low energy consumption and fulfill mobile app requirements.
- → The *smartness* of policies is achieved by leveraging information about the user's context obtained from sensors data.
  - → The user's context can be recognized by employing a pattern identifier mechanism that is fed by raw data collected by sensors.
  - → The pattern becomes the descriptor of user's context, and is the input for a policy generator mechanism that produces the policy to adapt the sensor usage, reduce the energy consumption and achieve mobile app objectives.

PROBLEM STATEMENT

Pattern identification

Given a set $V = \{v_1, v_2, \ldots, v_n\}$ of data values read from sensor S in the time interval $T = \{t_1, t_2, \ldots, t_n\}$, find the behavior pattern $Pattern_S$ that represents the activity of user.

$$PatternIdentifier(V) \longrightarrow Pattern_S \in Patterns \tag{1}$$

Where $Patterns$ is a set of patterns that represent an interesting state in the user activity.

PROBLEM STATEMENT

Policy generation

Given the pattern $Pattern_S$ detected in data from sensor S, parameters for assigning weight to energy eh and precision ph, and physical constraints status pc of a mobile device, find a policy to adapt the duty cycle of sensors.

$$PolicyGeneration(Pattern_S, eh, ph, pc) \longrightarrow DutyCycle_S \quad (2)$$

HYPOTHESIS AND OBJECTIVES

HYPOTHESIS

Hypothesis

→ Smart policies generated through contextual information can be employed to reduce the energy consumption in a mobile device when performing continuous sensor readings.

OBJECTIVES

Main objective

→ Reduce energy consumption when performing continuous sensor readings in mobile devices by making use of context information.

Particular objectives

→ Identify behavior patterns which can provide meaningful context information from raw data collected by sensors.

→ Generate smart policies for sensor usage from context information, mobile app requirements and mobile device constraints.

STATE OF ART

MOBILE SENSING APPS (MSA)

Definition of MSA

The set of mobile apps that perform tasks related to data collection from sensors and information discovery from these data.

Reasons of the success of MSA

- → The increasing computing, storage, and communication capabilities existing in smart devices.
- → The multi-modality sensing capabilities included in smart devices.
- → The millions of smart devices already *deployed* around the world.
- → Smart devices can cover a wide and dynamic geographic area.

MSA: AN OVERVIEW

MSA: an overview

- Stages of MSA operation
  - **Sensor reading.**
  - Filtering (optional).
  - Feature extraction.
  - Classification.
  - Post-processing.
- Sensing scale of MSA
  - **Individual.**
  - Community.
- Sensing paradigms of MSA
  - **Opportunistic.**
  - Participatory.

ENERGY ISSUES IN MSA

Energy issue in MSA

- → General guidelines.
- → Focused on sensors' usage.

ENERGY ISSUES IN MSA: EFFORTS FOCUSED IN SENSORS' USAGE

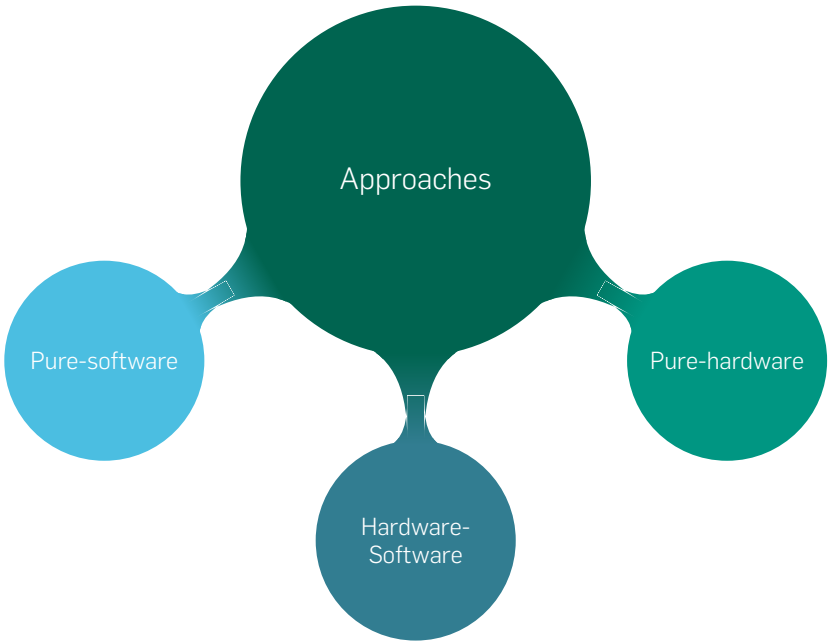

Figure: Approaches for solving the energy issue.

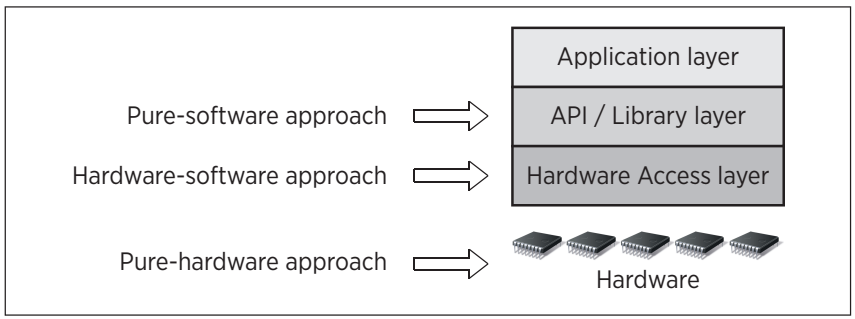

Figure: The relation between approaches for solving the energy issue and layers of a mobile platform.

ENERGY ISSUES IN MSA: EFFORTS FOCUSED IN SENSORS' USAGE

Advantages of pure-software approach

- → Modifying hardware and/or updating the mobile OS[2] of existing devices is almost impossible.
- → Implementations of pure-hardware and hardware-software approaches are application specific.
- → A pure-software approach can be implemented in a software unit and embedded in a mobile app as any other 3rd party library.
- → Cognitive processes can be conducted directly in a high software layer and re-configured and tunned.
- → A pure-software approach is not mutually exclusive with pure-hardware and hardware-software approaches.

[2] OS, Operating System.

SCOPE OF RESEARCH

Scope of research

The mechanisms to be produced:

- → will follow a *pure-software approach* for the creation of mobile sensing apps;
- → will collect data at an *individual sensing scale*, and
- → will access sensors in an *opportunistic paradigm* over long periods of time in a continuous way.

The analysis, design, and generation of policies will be implemented focusing in the usage of the GPS receiver and mobility data.

METHODOLOGY

METHODOLOGY

Steps

I **Research on the characteristics of data delivered by sensors, in this case the GPS receiver.**

Identify special characteristics of GPS data that may trigger the study of techniques like outliers elimination, noise reduction, filtering, windowing, and framing to launch pre-processing of data delivered by sensors.

II **Definition and selection of mobility patterns to be identified.**

This step is needed to identify the target mobility patterns that will be employed later in the pattern identifier element.

The set of target mobility patterns defined here will be part of the input for the pattern identifier element.

METHODOLOGY

Steps

III **Research and adaptation of algorithms to detect mobility patterns of user based on data delivered by GPS.**

The pattern is helpful to get information about user's context and therefore in the generation of policies.

The selected algorithms should consider the constraints present in mobile devices.

IV **Creation of the pattern identifier element (PIE).**

This element must identify the pattern from data collected by sensors by employing the algorithm(s) selected in the Step 3.

The pattern identified must be included in the set of mobility patterns defined in the Step 2.

METHODOLOGY

Steps

V **Creation of the policy generator element (PGE).**

It includes the definition of a formal representation of policies.

This policy generator element will obtain the duty cycle that the GPS receiver must implement to perform the next GPS reading.

VI **Development of a software element (SE) that integrates both PIE and PGE.**

This software element will be implemented in the Android platform.

VII **Experimentation.**

Key aspects are precision and energy saving.

This step involves the definition of experiments and the development of mobile applications that employs the constructed software element.

METHODOLOGY

Basic idea of proposed method

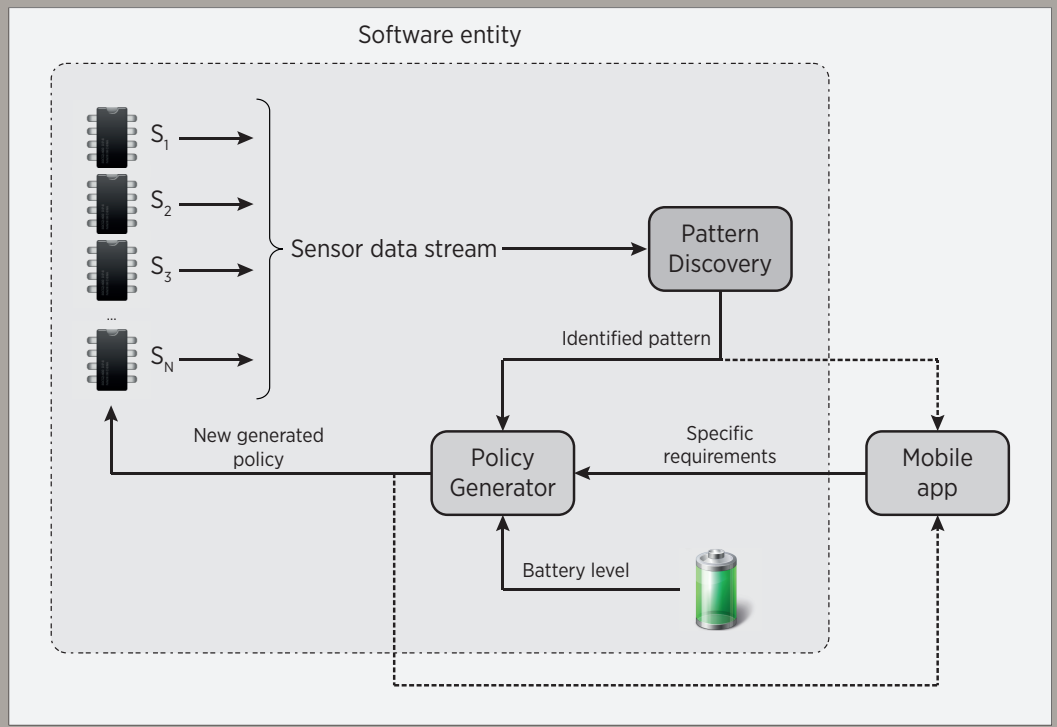

Figure: Workflow described by the proposed methodology

CONTRIBUTIONS

CONTRIBUTIONS

Contributions

- → A mechanism for detecting patterns (contextual information) from the data read by sensors of MD (specifically the GPS receiver).
- → A mechanism for generating policies for accessing sensors that considers mobile app requirements and information about user's context.
- → A software element able to read data from sensors using the policies generated by the described mechanisms and transmit these data to an external server.

SCHEDULE

SCHEDULE

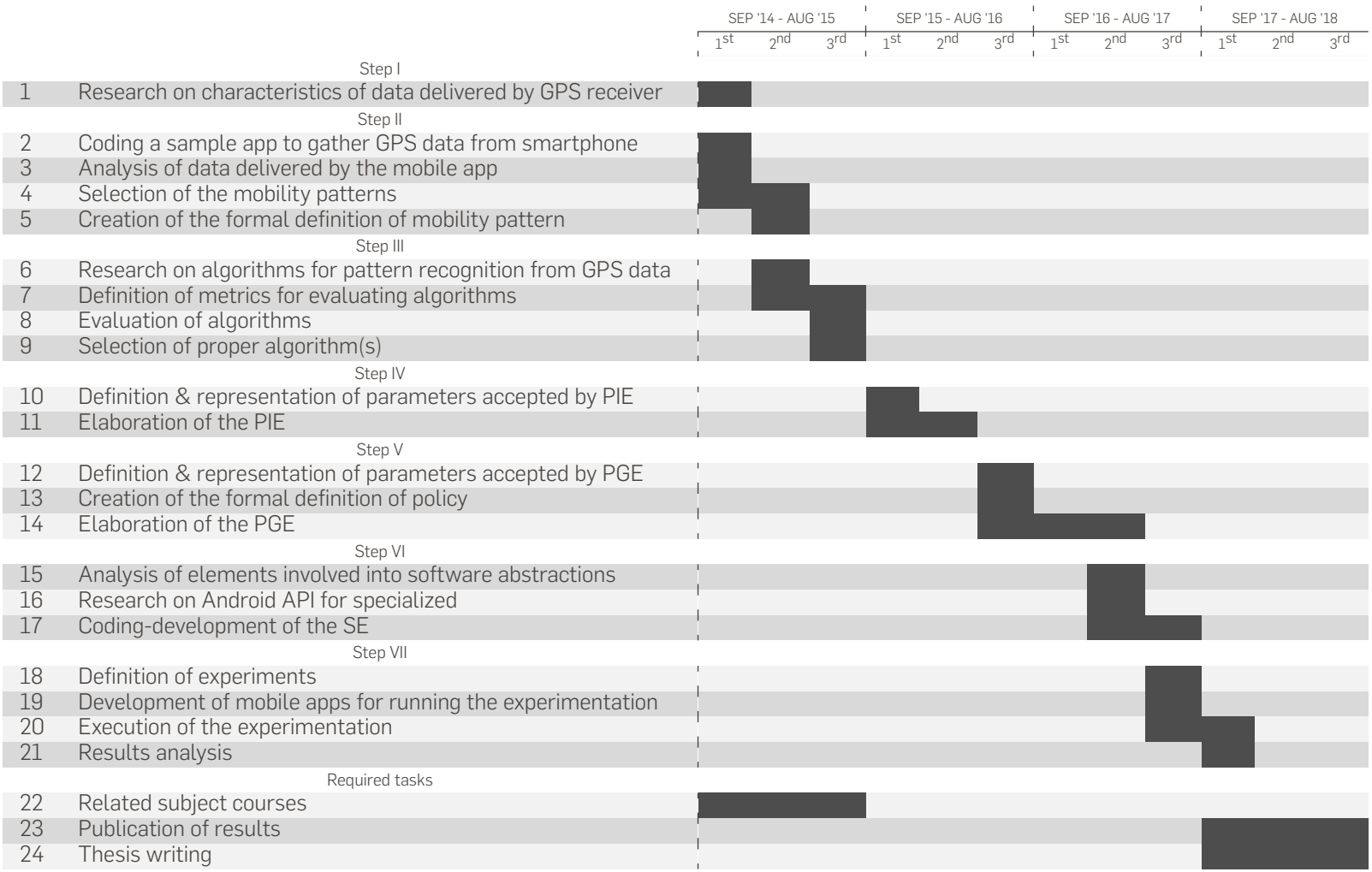

Table: Schedule of activities (each column represents a four months period)

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