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

Phd research proposal

September 8, 2014

Student: **Rafael Pérez-Torres**

Advisors: **Dr. César Torres-Huitzil, Hiram Galeana-Zapién Phd**

Center for Research and Advanced Studies of the National Polytechnic Institute
LTI **Cinvestav**

STRUCTURE

INTRODUCTION

Mobile devices adoption by society

- Mobile devices are used massively around the world (**?**).
- Their high acceptance is due to their Internet-enabled features and increasing storage and computing capabilities.
- Mobile devices are shipped with sensors that enhance the interaction with user.
- Sensors allow mobile devices to become *omni-sensors* of the environment.
- By analyzing data from environment, smart devices become *context aware*.

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 (**?**).
- → A context aware mobile app detect changes in any context source of information and adapts its behavior accordingly.
- → A special subset of context aware mobile apps is conformed by location aware mobile apps.
- → Both types of apps can be categorized as **mobile sensing apps (MSA)** (**??**).
- → MSA core activities are sensing data from environment, analyzing these data and generating high level information that has a special meaning for final user.

The fully connected world idea

- MSA are contributing to the adoption of smart devices by society, creating a fully connected world of people.
- The idea has been also pursued in scenarios like industry, where the items to be connected are real world objects like tools, machines, etc.
- The items are enhanced with identification mechanisms and storage, computing and communication facilities, becoming *smart objects*.
- The interaction of smart objects creates a Machine-to-Machine (M2M) communication system.

CONVERGENCE OF MSA INTO THE INTERNET OF THINGS

The emergence of The Internet of Things

- M2M communication systems aim to be the base mechanism to interconnect any smart objects of the real world.
- MSA and M2M communication systems are pursuing a globally connected world of people and smart objects.
- They can be abstracted as systems that interconnect *things* in an evolved version of Internet called the *Internet of Things (IoT)*.
- IoT aims to produce a fully connected world with application systems that address any real world problem.

Motivation

- However, advances in battery research are not at the same pace than those related to other components of smart devices (**?**).
- The battery is a limited source of energy that is impacted by sensors and other embedded electronics usage.

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 (**?**))

Motivation

- → Therefore, despite the benefits of MSA the issue of energy reduces the time and diversity of tasks a smart device can be used for.
- → This issue becomes critical when performing continuous sensor access.
- → It is mandatory for any mobile application development to consider the energy constraint and implement mechanisms to optimize battery duration.

PROBLEM STATEMENT

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 (**?**).
- Current mobile platforms do not include mechanisms to perform periodical readings from sensors.

What do we need?

- API's[1] by manufacturers only accomplish generic tasks like turning on – off sensors
- **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).

[1] API refers to Application Programming Interface.

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 the user's context obtained from data delivered by sensors.
  - 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.

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 $Patterns_S$ that represents the activity of user.

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

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

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.

$$PolicyGeneration(Pattern_S, eh, ph, pc) \longrightarrow DutyCycle_S \tag{2}$$

HYPOTHESIS AND OBJECTIVES

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

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

- 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.

Examples of MSA

- *NeuroPhone* (**?**)
  - A brain-controlled address book dialing app that employs neural signals obtained from an EEG[2] headset.
  - The phone shows a sequence of pictures of contacts and a special signal is elicited when a photo matches the person whom the user wishes to call.
- *BeWell* (**?**)
  - BeWell continuously tracks user behavior along three health dimensions in an opportunistic sensing way.
    - Sleep duration →accelerometer.
    - Physical activity →accelerometer.
    - Social interaction →microphone.
- *WalkSafe* (**?**)
  - An app that aids people that walk and talk, improving the safety of pedestrian phone users.
  - WalkSafe employs the back camera of the mobile phone to detect vehicles approaching the user, alerting a potentially unsafe situation.

[2] EEG, electroencephalography

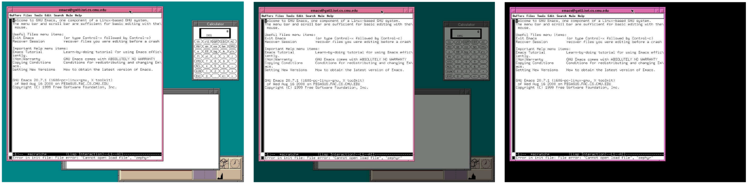
Energy issue in MSA

- Actual fact: The usage of components of smart devices implies energy consumption.
- Several efforts have been done in the field to address the issue. They can be categorized as:
  - General guidelines.
  - Focused on sensors' usage.

ENERGY ISSUES IN MSA: GENERAL GUIDELINES

General guidelines

- Authors in (**?**) introduced the idea of the *requirements-aware energy scale-down* approach.
- It states that energy consumption should be reduced as possible and still achieving mobile app requirements.



(a) Original interface (b) Background half dim (c) Background fully dim

Figure: An example of energy aware GUI proposed by (**?**)

ENERGY ISSUES IN MSA: EFFORTS FOCUSED IN SENSORS' USAGE

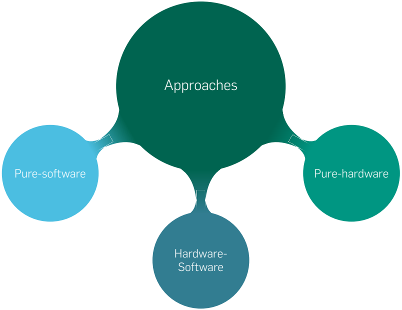


Figure: Approaches for solving the energy issue.

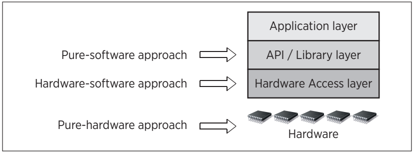


Figure: The relation between approaches for solving the energy issue and layers of a mobile platform.

ENERGY ISSUES IN MSA: EFFORTS FOCUSED IN SENSORS' USAGE

Pure-hardware approach

- Electronic level techniques like DPM[3] or DVFS[4] are not enough to mark the energy issue as solved (**?**).
- Current architecture of mobile platforms requires that for the correct operation of the phone other components have to be operational
- This approach aims to redesign the hardware platform of current mobile devices, by isolating sensors inside a unit with a dedicated low power processor.
- While the extra unit is working the rest of the smartphone hardware platform can reach its sleep mode.

[3] Dynamic Power Management.
[4] Dynamic Voltage and Frequency Scaling.

Examples of works following a pure-hardware approach

- LittleRock (**?**) designs a special unit in charge of the execution of sensor readings. It includes:
    - Processor module.
    - Digital sensor module.
    - Analog sensor module.
    - Reset and wake up logic.
- (**?**) implemented a mobile sensing platform with embedded sensors and a low power processor. Includes also bluetooth communication interface.

Hardware-software approach

- This approach aims to contribute with new drivers, tunned versions of mobile OS's or an improved software API for allocating computational and sensing tasks in components others than the predefined by the platform's original design.
- It is possible to instruct an additional low power processor in the smartphone to execute any arbitrary instruction.
- Since the smartphone's processor can be kept idle there is a potential energy saving.

Examples of works following a hardware-software approach

- The study presented by (**?**) leverages the presence of low power processors (LP) in the latest smartphones, exposing their functionality through a layered API.
- It describes two challenges:
  1. The selection of a suitable LP: any processor with a small wakeup transition delay is suitable as LP.
  2. Guidelines for deciding where to allocate the execution of a given task:
     - Execution in main processor.
     - Execution in LP.
     - Execution in main or in LP.

ENERGY ISSUES IN MSA: EFFORTS FOCUSED IN SENSORS' USAGE

Pure-software approach

- The goal of this approach is to give *smartness* or cognitive behavior to the software platform of mobile devices and derive into a better usage of sensors.
- Two main branches (not mutually exclusive):
  - Duty cycle manipulation
  - Next value inference

Examples of works following a pure-software approach

- *G-Sense* (**?**)
  - An architecture that integrates mobile and static WSN for location based services, participatory sensing and human centric sensing applications.
  - Include mechanisms to control the amount of generated and transmitted data: *client-sate machine*, *Geo-Sensing*, and *Time-Sensing*.
  - It was not implemented, only simulated.
  - Its mechanisms are a very broad genre of policies.
- EnTracked (**?**)
  - Platform to perform GPS readings in smartphones; employs also accelerometer to detect motion.
  - Employs a external server to detect the speed of user; scenarios without Internet connectivity are ignored.
  - Involve costs in data transmission.

Examples of works following a pure-software approach

Middleware in (**?**).

- A power-aware middleware for context aware mobile apps with cloud computing interaction focused on GPS data.
- Allows to schedule the next sensor reading according to the mobile app specifications and other policies.
- Includes rudimentary notions of policies, classifier and mobile app specific requirements.

Advantages of pure-software approach

- Modifying hardware and/or updating the mobile OS[5] 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.

[5] OS, Operating System.

Data transmission effects in energy consumption

- The energy consumption also represents a problem when transmitting data or performing computation offloading.
- This perspective of the problem has also been addressed in literature and several solutions have been provided.
- Computation offloading is advisable only when large amount of computations are needed with relatively small amounts of communication (**?**).
- The transmission of data can be guided by the presence of changes in the data collected by sensors (**?**).
- In relation to MSA, this issue becomes critical when the mobile apps focus in the community sensing scale.

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

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.

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 **??**.

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

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.

Workflow of methodology

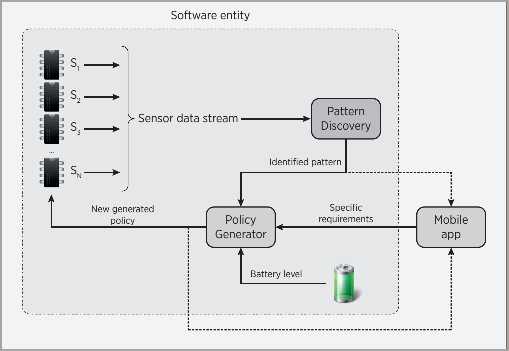


Figure: Workflow described by the proposed methodology

CONTRIBUTIONS

Contributions

- A mechanism for detecting patterns (contextual information) from the data read by sensors of mobile devices (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

		SEP '14 - AUG '15			SEP '15 - AUG '16			SEP '16 - AUG '17			SEP '17 - AUG '18		
		1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
	Step I												
1	Research on characteristics of data delivered by GPS receiver	■											
	Step II												
2	Coding a sample app to gather GPS data from smartphone	■											
3	Analysis of data delivered by the mobile app	■											
4	Selection of the mobility patterns	■	■										
5	Creation of the formal definition of mobility pattern		■										
	Step III												
6	Research on algorithms for pattern recognition from GPS data		■										
7	Definition of metrics for evaluating algorithms		■	■									
8	Evaluation of algorithms			■									
9	Selection of proper algorithm(s)			■									
	Step IV												
10	Definition & representation of parameters accepted by PIE				■								
11	Elaboration of the PIE				■	■							
	Step V												
12	Definition & representation of parameters accepted by PGE						■						
13	Creation of the formal definition of policy						■						
14	Elaboration of the PGE						■	■	■				
	Step VI												
15	Analysis of elements involved into software abstractions								■				
16	Research on Android API for specialized								■				
17	Coding-development of the SE								■	■			
	Step VII												
18	Definition of experiments									■			
19	Development of mobile apps for running the experimentation									■			
20	Execution of the experimentation									■	■		
21	Results analysis										■		
	Required tasks												
22	Related subject courses	■	■	■									
23	Publication of results										■	■	■
24	Thesis writing										■	■	■

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