Guide for presentation 2

Total running time: 40 minutes.

*Hi, good afternoon all, in this presentation I will talk about the progress made during our first year of work in our thesis <<Smart usage… for mobile sensing apps>>, a collaborative work with my advisors Dr. CTH and HGZ PhD.*

*For this purpose, I will cover an agenda that is roughly focused on reviewing the problem statement, the review of state of art and the first experimental results regarding to our methodology.*

**Section Problem Statement (8 slides, running time of X minutes)**

Slide 3 [Introduction]

*One of the reasons smartphones are so popular is because of the advances produced in their computation, sensing and communication dimensions. In particular, the sensing facilities are helpful to aid interaction with user, and also for knowing about surrounding environment. Because of this, smartphones are achieving context-awareness, being able to understand aspects about user activity.*

*However, the usage of sensors cannot be indiscriminate because of associated energy consumption, especially in the mobile devices with batteries growing only 10% each year. This issue becomes critical for mobile sensing applications, which require continuous access to sensing infrastructure over the next stages.*

* Smartphones have achieved popularity because of the advances on their computation, sensing and communication capabilities.
* The sensing facilities improve interaction with user and turn such devices into Omni-sensors, gaining context-awareness about user’s activity and environment.
* However, such context-awareness gaining is not for free, there is an inherent energy consumption that constraints the usage of sensors. In this matter, the capacity of batteries grows only 10% each year.
* If we take into account that a core requirement for mobile sensing applications is precisely continuous access to sensors, then we can feel there is an emerging problem.

Slide 4 [Stages of mobile sensing applications]

*As we can see, there are several stages that resemble the classic pattern recognition procedures. Each of these stages present different challenges. Since the larger proportion of energy consumed is due to the access to sensors, one may try to use them less frequently, but this would reduce the accuracy on the activity being tracked, raising an accuracy-energy consumption tradeoff. How can this problem be faced?*

* Internally, most mobile sensing applications deploy these stages. Naturally, depending on the purpose of the app, elements inside each block are different. Nonetheless, there are challenges on each stage, and a tradeoff between the accuracy of the context information retrieved and the energy consumption emerges.
* How can we face this problem?

Slide 5 [Hypothesis]

*For this purpose, our hypothesis is that by using intelligent policies that are produced through context information built from sensors data, is possible to reduce the energy consumption of mobile devices when accessing continuously to sensors.*

*We refer to a policy as a special rule that defines how sensors should be selected and configured for reducing energy consumption and achieving mobile sensing app requirements. It is intelligent since it can self-adapt to changes in context information.*

*Our research is aimed at inferring this context information as mobility patterns, employing GPS and inertial sensors data, and consuming this information for energy efficient support of LBS. We focused on the GPS and mobility scenario, since:*

1. *GPS and mobility is a trend.*
2. *Offers the largest power savings when correctly employed*
3. *Mobility aspects are a transversal factor in mobile apps. After all, a mobile phone is mobile!*

* We consider in our hypothesis that intelligent policies produced with context information can help to make a better sensors management that reduces energy consumption while continuous access to sensors is performed.
* We say a policy is intelligent since it can self-adapt to changes detected in context information.
* We are focused on employing GPS, inertial sensors and other sources of context information as mobility patterns and employing such information for producing power savings.
* **The context inferred by the app is different from the employed for adapting sensory operations**
  1. **GPS and mobility is a trend.**
  2. **Offers the largest power savings when correctly employed**
  3. **Mobility aspects are a transversal factor in mobile apps. After all, a mobile phone is mobile!**

Slide 6 [Problem statement]

*Now, assessing such hypothesis is a hard task, since it should be performed lightweight in computation and sensing terms. In this regard, our hypothesis might be verified if the overall scenario is divided into two main problems. The first one is the identification of a mobility pattern, and it is defined as follows:…*

*Each of the mobility patterns has additional context information that involves time-domain attributes, for instance the ones shown in Figure…*

*Thanks to this context-information, learning from user is possible and from this we can improve the decision making for accessing sensors, which is precisely …*

* Achieving and proving the hypothesis is hard, it should be performed lightweight in computing and sensing aspects.
* For proving our hypothesis, and from the overall scenario, we identify that there are two problems that need solution for achieving power savings.
* The first one is the actual identification of a mobility pattern and it is defined as follows…
* Now, each of these mobility patterns have associated meta-information, meta-data or additional context information that involves time domain attributes, for instance…
* Thanks to these additional information, a learning from user is possible and from this information we can improve the decisions for sensor access, which is …

Slide 7 [Problem statement]

*The policy generation problem. This policy generation refers to produce the most adequate set of sensors and their associated configuration for keeping the tracking of user as well as reducing the energy consumption. The generation of these policies must consider, or take as inputs, the information learned, mobile app requirement for accuracy, and the current battery level of the smartphone.*

*As can be identified, there is a link between these two problems …*

* … next problem. The policy generation problem refers to produce the best set of sensors and the associated configuration, from the learned information, mobile app requirements and energy status, for keeping the tracking of user as well as reducing energy consumption.
* As we can identify, there is a link between these problems as shown…

Slide 8 [Interaction between problems]

*As shown in this figure. Basically, once we learn mobility patterns, we can leverage on such information, and consider other aspects, for improving the access to sensors in energy terms.*

* … in this slide. Once we learn, we can leverage on such information and other requirements for improving the access to sensors.

Slide 9 [Objectives]

*Then, unpinned from this set of problems, we aim to achieve the next objectives… For the sake of clarity, the scope of these objectives and the general perspective of our research is depicted as this figure …*

* Now, from these problems and the overall problematic, we aim to achieve the next objectives [enumerate them].
* For the sake of clarity, the scope of these objectives and the general perspective of our research is depicted as this figure …

Slide 10 [Problem’s scenario]

*There is a user, permanently carrying a smartphone, moving between places along his-her daily activities, describing mobility patterns. We can observe that a perspective of this scenario consists on learning the places, and adequate sensing when the user is displacing between such places. For learning places, we can rely on the GPS, WPS, as well as on wireless finger-printing. For adapting sensing while user is in motion, we can rely on the accelerometer and orientation sensors for detecting changes in trajectory, as well as in the learned information.*

*As a way to organizing and dividing the whole set of tasks to achieve these goals, we established this methodology…*

* … A user carrying a smartphone follows mobility patterns.
* The user can go to workplace, and other points of interest.
* We can learn these places and associated *fingerprinting* from wireless signal strength of access points if available.
* We can also can detect changes in activity being performed and adapt accordingly.
* In general, we try to learn and detect stay points and perform tracking of user.
* As a way to organizing the different steps to achieve these goals, we established this…

**Section Methodology (1 slide, running time of X minutes)**

Slide 11

*Consisting on the listed steps. At the moment, we have finished or are working with activities up to the step 4.*

* … set of tasks as our methodology.
* It is noteworthy that at this point we are working on activities reaching up to the step 4.

**Section State of art (4 slides, running time of X minutes)**

Slide 12 (The smartphone as a three-dimensional device)

* This section of the presentation is focused on introducing state-of-art remarks found in literature and insights produced after scientific thinking.
* First of all, smartphone is able to perform a wide set of activities and tasks.
* It has hardware capabilities and software flexibility enough to perform as a general-purpose device.
* However, one has to abstract its operation and vision in order to identify the most important aspects and implications.
* We envision the smartphone as a mobile device that acts over three important dimensions shown in Figure.
* In fact, this figure is interesting since it can help to categorize different mobile devices depending on how high are their facilities over these dimensions. For instance, WSN nodes, tablets, laptops, and so on.
* What is important here is that the more developed is a dimension in a device, the more energy consumption is generated.
* When focusing on the sensing dimension, which is the objective of our research, we analyze state of arts solutions and find intrinsic features that help us to build…

Slide 12 (Taxonomy of state of art solutions) [The heaviest slide]

* This section of the presentation is focused on introducing state-of-art remarks found in literature and insights produced after scientific thinking.
* We didn’t only read, we analyzed and studied several aspects.
* A taxonomy of such solutions, consisting on three big families:
* The pure hardware approach is the lowest level at which power-aware optimizations are performed. It involves the selection of power-aware sensors and embedded components to deliver physical data to upper layers of mobile platform, as well as the definition of the different power modes of the hardware components through techniques like Dynamic Voltage and Frequency Scaling (DVFS).
  1. The ad-hoc acquisition variant only collects data power efficiently.
  2. The co-processing variant additionally offers a processing of sensors data, obtaining context information. However, it does not adapt its operation according to information found, it only detects with power efficiency.
* The hardware-software approach abstracts fine grain details and isolates the usage of hardware components for mobile applications and upper platform layers. This isolation is performed by applying system-wide policies that coordinate the operation and interaction of the whole set of sensors according to dynamic changes in their workload and global status of the mobile platform (like battery level). The hardware-software approach is aware of the hardware components of the mobile platform, and thus is able to define DPM mechanisms for turning sensors on and off, and adapt their configuration parameters.
* The pure software approach is aimed at modeling, identifying and even predicting details about context information and its dynamic changes from sensor data, in order to define smart mechanisms for power-aware adaptation of the hardware components usage. Because of the fully context-awareness that this approach can achieve, it is able to obtain high levels of flexibility for adaptive management of sensors, and put the context information detected from sensors data at service of the whole mobile platform.
  1. The variants can learn from user and adapt sensors usage by:
     1. Duty cycling
     2. Inferring next value avoiding access to sensor (low level, average, or interpolations)
     3. Recycle existing data (high level, longer time windows).
  2. The variants can replace sensors. Depending on the need of a mapping procedure for the new-selected sensor, replacement can be:
     1. Directly related
     2. Context related
* There is a chance-opportunity for our work, since variants can be implemented better (finer granularity on duty cycle or actual adaptive duty cycling), better classifier or machine learning techniques.

Slide 13 [Distribution of approaches]

* These approaches expose different levels adaptation to the dynamics in user activity.
* The highest position is occupied by the software approach, which due to its flexibility can detect changes in any source of context information and instruct adaptations on the hardware usage.

Slide 14 [Characteristics of pure software approach solutions]

* Speaking on the software works, the fact they employ the software facilities of the mobile platforms allow to implement an unlimited set of ideas and strategies for achieving power efficiency.
* Nonetheless, we identify the next attributes offered by some frameworks proposed in literature:
* Because of the aforementioned flexibility and heterogeneity, it is hard to produce categories of software works.
* However, we identify the granularity of the context information employed for adapting sensors operations as the pivotal characteristic to evaluate and describe works.
* Such granularity can be defined as follows…

Slide 15 [Framework for analyzing pure software solutions]

* The input of the data type, the classifier or underlying machine learning technique employed and the length of the time window in observed data.
* In this way, we can decompose the machinery of solutions as shown…
* … in this Figure [The big one].
* Here, we can identify the place where the unlimited ways of learning and different window lengths are implemented.
* After learning, there is the policy generator that uses the learned information for deciding how to use sensors.
* At the end, no matter the complexity of the information and of the policy generator, the final decisions or adaptations in sensors operation belongs to one or more of the software variants described in our taxonomy.

Slides State-of-art solutions

* Here, we present a list of software solutions found in literature.
* Our aim is not to describe the whole list, but to focus in how there are combinations of features, sensors employed, machine learning techniques follows and the complexity in the context information learned from user.

**Section Proposed solution (4 slides, running time of M minutes)**

Slide 16 [Proposed solution]

* This framework for evaluating solutions previously presented, helps to explain with a greater level of detail the different characteristics of the proposed solutions.
* As we can see, the sensors listed are the ones that are going to be employed as sources of context information.
* Also, we will employ the two different lengths of time window.
* We will use ANN and DT for classifying accelerometer information (based on previous works) as well as HMM to build an expanded spatial-time model of user mobility.
* For the policy generation, we will also rely on the HMM for user mobility. Recall that HMM also include a transition probability matrix that can be employed for predicting next location (with associated temporal information) and hence adapt sensors usage.
* In the hardware adaptation step, we will thoroughly use the different variants of the pure software approach.
* At the end we look for keeping the operation of sensors within a fixed interval.
* We try to adapt the frequency of readings between these intervals, moving the slider according to changes detect from context information as well as from application requirements.
* Now, in relation to architectural design, …

Slide 17 [Proposed solution (Figure overview)]

* …, this Figure shows the different architecture’s modules and their interactions.
* Note the employment of different modules for each sensor, with specific classifiers and semantic outputs.
* Each output is employed to learn or identify current user state. The US is employed for policy generation and is also absorbed by the machine learning module.
* Recall that the output of each of these layers can be distributed along the rest of layers and with running LBS.
* The LBS requests and interacts only with a power-aware context provider, which for sake of specificity is a power-aware location manager.
* The status of constrains, mobile app requirements, identified US and learned US are employed by the policy generator.
* As can be seen, the policy generator will select and configure sensors for achieving mobile app requirements and reduce power consumption.
* For the policy generator, a great deal is related with the information learned at a given instant and historically, but what does that information look like?

Slide 18 [The model of information learned in proposed solution]

* As can be seen by the Figure, each of the identified locations can be modeled as a stay point with the associated meta-information (the expanded spatial-time model).
* There are directed transitions (trajectories) that can have a probability and associated motion (way of transportation).
* But having a fixed structure is not likely to reflect the evolution of the mobility patterns along the different days.
* Because of this, the learning stage will also encompass…

Slide 19 [The model of information learned in proposed solution 2]

* … information regarding the different weekdays and weekends.
* Recall we are learning patterns, mobility patterns.
* So it is useful to split and recognize that such patterns can reflect information coming from longer time windows.
* The limit for these levels of hierarchy are not limited, one can structure for instance spatial-time models for months, quarters, semesters, years and so on.
* However, we restrict our scope to this level as it can deal with interesting information that is very likely to exist on the device and within its capabilities.

**Section Important results** (3 slides, running time of YY minutes)

Slide [Results]

* We have launched several experiments targeted at ensuring the learning of places of interest locally at the mobile device.
* We have adapted classic algorithms for stay point’s detection.
* Such versions originally are intended for off-line analysis.
* We have tuned them for running with an event-oriented paradigm, and processing the trajectory online.
* We say that proactive is a necessary feature since smartphone should know how to autonomously react and adapt to such changes without user interaction.
* This figure shows the steps for on-device stay points’ detection.
* As we can see, a policy generator block can instruct how to react to changes detected in collected locations through several families of policies.

Slide [Results of early experimentation + Results]

* These are the main results achieved by several runs of one experiment.
* This experiment is prepared for ensuring that calculating stay points locally on the smartphone (on-device) is feasible.
* We implemented several policies.
* Recall that the smartphone was able to calculate stay points even in the highest frequency of GPS usage tested.

Slide [Scientific products]

* Basically, we have worked on a wide range of elements that have empowered us to produce the next outcomes:
  1. A survey focused on studying the different techniques and strategies for conducting smartphone-based sensing within a power-aware perspective. [Read and describe the bullets]
  2. The results that we have presented are being further expanded and more scenarios are going to be tested for preparing an article focused on [Read and describe the bullets]

**Section Future work**

(4 slides, running time of FF minutes)

Slide [Future work]

* Here, we present the remaining steps aimed at achieving the proposed solution.
* We have covered the next activities of the first two steps.
* In this sense, we have successfully covered important aspects of our research.
* [Pass to last schedule slide]
* We still have a few steps related to the identification of mobility patterns, but the performed activities have brought added value to our work and have acted as a scientific booster for improving and achieving our solution.

**Section Conclusions**

(1 slide, running time of FF minutes)

Slide [Conclusions]

* In this talk, we have covered the latest advances in our research.
* Particularly we have presented a brief analysis of the research problem.
* Also, we have described a summary of state-of-art solutions, including a taxonomy for analyzing them from the perspective of sensors operation and a framework for studying and decomposing solutions components.
* We also have talked about the proposed solution for building intelligent policies aimed at continuous user location tracking.
* [The other bullets can be exactly described-read]