Mobile Technologies to Enable Users' Informed Decisions

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Abstract: The significant wide impact of mobile technologies (e.g., smartphones, tablets) and the difficulty of mastering their complexity (due to factors like constant emergence and evolution) pose new challenges to many (if not all) software engineering disciplines. We particularly see these challenges when thinking of average citizens that carry out their daily activities in smart environments where mobile technologies and sensors installed provide many potential advantages to support them. Applications that could enable informed decision-making are currently beyond what software developers can provide. This position paper discusses challenges, and highlights current approaches available in order to support decision-making for thoughtful living. We present an initial version of a comprehensive framework to overcome the challenges identified and analyse which software engineering research lines may help to implement it. A motivating scenario is used to conduct the discussion.

1 INTRODUCTION

The amount of software services available in the software market (in the form of web services, mobile apps, etc.) dramatically increases year after year. Service providers continuously emerge, and the portfolio they offer grows steadily. Mobile technologies provide access to these services and are therefore becoming ubiquitous in our society. This lead to a magnitude of growth that was hardly conceivable in the recent past (e.g., the number of mobile phone subscriptions reached 5.000 million in 2010). This opens a lot of unforeseen opportunities for citizens worldwide and it is a fact that this huge offer has improved citizenship's quality of life (West, 2012). We are particularly interested in supporting informed decision-making with novel mobile applications and services. We envision that such services can further improve individual citizen's quality of life and will also lead to more thoughtful use of resources and therefore thoughtful living of citizens. However, this vision currently goes beyond state of the art software engineering techniques and approaches. We have identified work in the following areas as most promising to realize our vision: context-awareness, personalization and evolution of services. We claim that advances in these areas are necessary to boost the impact of current software service technologies at the individual and the society level. In this position paper, we discuss a proposal to improve aggregation, awareness, personalization and evolution capabilities in current software service technologies. For awareness, we propose to include knowledge about the individual and about the environment in the heart of mobile technologies. For personalization, we propose as ultimate goal the (semi-) automatic orchestration and enactment of software services according to a user's past behaviour. For evolution, we propose that it is driven by needs of individual citizens rather than developer assumptions.

We foresee that achieving these goals in the near future is plausible due to the significant and continuous advances in mobile technologies. However, we also see that software engineering methods and tools are lacking behind the fast advances in mobile technologies. We have identified several challenges within the above-mentioned areas. Among them the fact that services nowadays lack a semantic layer and push their users to learn new rules which are imposed by its provider. This

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lack of standardization can demotivate potential platform users and contradicts with the interest of service providers who aim at increasing the usage rate of their services.

In this paper we also present our vision on a semantic service engineering framework, which could allow users to interact seamlessly with mobile technologies. Such an easy-to-use approach would encourage all different kinds of potential users to adopt the framework. Automatic service enactment would allow exploiting techniques from other fields, such as machine learning.

The rest of the paper is organized as follows. Section 2 presents a scenario highlighting today's decision-making approaches and section 3 discusses issues with regard to the presented scenario. Section 4 highlights how decision-making support could look like in the future. In section 5 we discuss challenges in order to achieve our vision. Section 6 provides a first solution idea by outlining a platform supporting informed decision-making. Section 7 discusses the way ahead. In section 8 we highlight related work and section 9 concludes the paper.

2 MOTIVATING SCENARIO

Katie is the head of the paediatrics surgery unit at the Feeling Better International Hospital in Barcelona. Every day, her unit works with more than 100 patients. This work includes standard treatments that require only 30 minutes of their time, but also complex surgery lasting for several hours and involving several doctors. Her unit includes 30 doctors, 40 nurses and 10 administrative staff members. Most of the doctors are also academic members of the Medical School at the Barcelona University. This means that on top of their medical duties they have teaching responsibilities and need to take care of research projects (which might involve travelling).

Therefore, it is normal that members of her team are active from early morning to late at night. Although a daily schedule is available, it has to be reorganized in many cases as there are unexpected events occurring (e.g., an operation takes longer). Observing the everyday work of her team, Katie has learnt that when this happens doctors feel distracted and even might think about possible appointments they have to cancel or reschedule while performing surgery. Furthermore, working late causes that doctors are tired and stressed. This is also worsened by the fact that most staff members live outside the city and have to travel for more than an hours on the average. Therefore, Katie has set up a new policy. In case a doctor finishes work later than 8pm, the hospital offers free accommodation for the night including the transportation to and from the selected hotel. Furthermore, the hospital offers the doctors to manage their agenda and to inform family and friends about re-scheduling and delays.

Although Katie was confident on the success of the initiative, she observed problems. Managing the transportation and accommodation issue was not trivial because a doctor has to finish the on-going task before he can be asked about his preferences, therefore: 1) secretarial support staff complained about staying longer to take care of this service, 2) the doctor had to wait for the service, 3) from time to time it was difficult to book a room or find transportation without previous booking. Furthermore, some doctors rejected to use the provided agenda management services, as they did not want to provide access to their personal calendar. Katie concluded that a different solution was needed.

3 ANALYSIS OF THE CURRENT SCENARIO

The scenario above presents some issues that make the current support for doctors unsatisfactory:

Individuality. Every doctor is an individual with very different preferences, abilities, resources, etc. A one-fits-all solution might not be applicable. Katie is aware of this fact and, therefore, she would like to offers services which are negotiated on an individual basis.

Privacy. Doctors are reluctant to make their private agenda public at the level required by the novel services offered. They do not want hospital staff to know about their private appointments. Therefore, Katie cannot have all the information needed to make the best possible decisions.

Agility. As a consequence of these factors, business processes around doctors' rescheduling are not as agile and flexible as Katie would like them to be. Furthermore, the current solution often results in loosing time and requires additional resources, which is all in all bad for the hospital.

These limitations make Katie wonder about the possibility of alternative scenarios that are able to better exploit current mobile technologies.

4 ENVISAGED SCENARIO

Katie consults the software engineering research team from the local university to find out how mobile technologies could support her in finding a solution. The researchers highlight that one possibility to achieve her goal could be to shift the focus: from a central, hospital-based perspective, to a distributed, person-based point of view: doctors themselves are the ones who have full responsibility so that the provided services fit with their own individual needs (also regarding privacy). Together with the researchers, Katie discusses a scenario where personal mobile devices suggest actions to doctors, or even execute them on their behalf. This approach avoids the assignment of new tasks to the hospital administrative staff, and simultaneously simplifies doctors' daily life. Austin, who is one of the most prestigious surgeons in the Feeling Better International Hospital, is the key person within this scenario. He is young, ambitious and loves his job, so he often accepts a certain overload in his daily work. On a particular day, he was expecting to finish at 19:30 but an unexpected problem with medical supplies has postponed the start of the last operation of the day (Norman's cardio-surgery) from 17:00 to 20:00. Katie offered him to delay the operation until tomorrow, but the next day Austin is flying to Brussels early in the morning for a project meeting, so he decided to go ahead.

Luckily, he recently bought a smartphone with access to a novel platform supporting informed decision-making. This smartphone offers a lot of capabilities whilst being quite simple to use. It reacts to changes in the agenda and reschedules appointments accordingly. What happens is:

- Katie reschedules Norman's cardio-surgery in the hospital information system to start at 20:00. This change is propagated to Austin's personal agenda.
- Two events are still scheduled in Austin agenda for after the operation. The first one is "buying a present for his mother's birthday next week". The platform just reallocates this task to another possible day before the birthday.
- The second event is different, a romantic dinner with his friend Angie at 21:30. Since the operation is expected to last 2:30 hours, the platform knows that it has to cancel this appointment (differently from above, the event cannot be rescheduled without interacting with the interested parties). The platform sends a nice apology message, specially designed by Austin in advance, to his wife.
- The platform detects the early morning flight to Brussels (leaving at 6:00). Considering Austin's travelling record track, the platform decides to book Austin a room in a hotel near the airport. Since the platform knows that, unless otherwise stated, Austin always drives his own car to the hospital, no taxi is needed.
- The platform sends Austin an e-mail with the summary of actions. This also includes a booking reference for the hotel and the parking space at the airport.

Once Austin leaves the operating room, he checks his smartphone and reads those messages. He feels reassured that his new device works correctly. He remembers, that after he started to use the novel platform he needed some time to get familiar with the system and also the idea that the platform has access to all his personal data. With the current level of configuration and the history available, he is more than happy with the way it behaves.

5 CHALLENGES

In order to address the scenario described above we identified several challenges regarding software engineering. In the following we highlight key challenges identified, but also discuss strategies in order to overcome those issues.

5.1 Limited Context Awareness and Personalization Capabilities

Modern mobile devices, such as smartphones, are equipped with numerous sensors. However, approaches that allow determining a user's context, are still limited. Furthermore, services still require the end user to make a tedious personalization job. The support given by providers to adapt services to the needs of an individual user is quite limited and just includes some basic characteristics (e.g., language selection). These issues limit current services to react based on the given environment and particular user profiles and needs. In our scenario the hotel booking action is an example. Selecting an hotel that fits at best may depend on the place of the first morning commitment: next time that Austin needs a hotel room, it may be booked near the University for his Tuesday's 8:00 lessons.

Awareness. Decision-making may be improved by increasing the awareness about the environment. For instance, the platform could be informed about the current location of Austin's car. This could improve decision-making so that the need of calling a taxi for bringing him to the airport is automatically identified.

History. Individuals tend to apply patterns of behaviour. These patterns may be tacit but usually will emerge after some time. For instance, being

Austin young and energetic, he does not mind sleeping in hotels paid by the hospital, whilst other doctors with children will prefer to sleep at home and take a taxi early next morning to the airport. Their decisions along time will reflect their preferences. This means that decisions need to be monitored and analysed in order to support decision-making in the future.

Interaction. As part of the individualization aspect, some citizens may rely more than others in technology. Whilst Austin seems to be fully confident on the mobile platform, other doctors who have similar smartphones may choose the “Always Require Confirmation” option. Therefore, we need to be aware of and respect different ways of interacting with a possible solution.

Privacy. Success of an IT product like the new platform heavily relies on respecting privacy. Sensible data must be kept inside the individual’s boundary. For example, Austin prefers to keep his friendship with Angie confidential. A balance needs to be set up though: some kind of aggregated, anonymous data sent to the service providers may help them to analyse service usage and improve their products in the future.

Adaptation. The increasing availability of information paves the road for better decision-making. The best decision today may not be the best tomorrow. For instance, a hotel, which now has good ratings, might be a bad choice next year. Furthermore, sudden adaptation is required as unexpected events might occur (e.g., bad weather forecast in Brussels) may require unexpected reaction (e.g., Austin passing by his home for taking his coat). This means that services need to adapt constantly to a changing environment.

5.2 Limited Evolution Capabilities

Literature highlights that software must be adapted and enhanced continuously to remain satisfactory (Bennett and Rajlich, 2000). User needs and expectations change over time and services should provide the desired new features. Furthermore, they need to improve in quality. Currently, methods and approaches to identify changing user needs are limited and do not allow to continuously involve end-users in service evolution.

Incremental end-user driven evolution. Functionality provided by a service platform may grow by increments, as an average user needs some time to master a new service. Then new needs may be identified. For instance, Austin may at some time investigate how to use the invoice generation facilities by hotels in order to store a copy of such an invoice in his dropbox account for his own purposes or post this need to developers if not yet provided.

(Semi-)automatic identification of relevant novel services. The dramatic increment of available apps and services requires improved mechanisms to identify interesting functionalities that emerge from providers of any kind. For instance, Austin should be offered new services on transportation. In case Austin is interested to try these services should be automatically integrated into the workflow required. Filtering, recommendations and crowdsourcing become cornerstones of this idea.

In the next section we propose a high-level architecture that aims to overcome these challenges.

6 ENVISAGED PLATFORM

Fig. 1 shows a high-level description of the software ecosystem we are envisaging in order to overcome these challenges. Given their current predominance in society, smart mobile devices (smartphones, tablets, etc.) provide all necessary functionalities to help citizens organizing their daily activities. We envision that over time, the appropriate apps are discovered and installed according to the citizen profile. This profile resides in the citizen personal cloud that contains all sensible information that needs to be private. Being in the cloud, it is shared by all mobile devices used by the citizen, thus preventing problems in synchronization of data and profile. The profile goes beyond the typical concept that is applied for using applications today, we envision a social profile that emerges from past actions and feedback given by the citizen to suggestions that the mobile devices provide over time. The mobile device is tightly connected to the environment, especially to the smart city that

Figure 1: Software ecosystem of our approach.

surrounds the citizen, and any possible sensor that the citizen may use (e.g., smart clothes for medical monitoring). With all this information and also interoperating with more classical information systems that are of interest for the citizen (e.g., at work), the mobile device may take decisions on the go and inform other individuals about the consequences of these decisions.

Considering the logical architectures that can enable the described ecosystem, the choice of whether to put a decision-making component on-board of the mobile device or in the personal cloud or distributed on both, brings to a family of architectures. Fig. 2 zoomed in one member of this family, adopting distributed decision-making. Three main logical components are highlighted:

- Personal cloud. We identify four main resources, each controlled by a specific manager (not shown in the figure):
  - Agenda. Keeps track of the citizen's daily activities.
  - Context. Represents the context of the user, continuously updated.
  - Event history. Stores the activities of the citizen in the past.
  - Avatar. Creates a representation of the citizen that is used for decision-making. This can be done exploiting decision-making algorithms executing in the personal cloud, which, for instance, dynamically rank alternatives (e.g. services, or products) along the user's preferences.
- Mobile device. Composed of:
  - GUI manager. Intelligent interface of the mobile device with the user, supporting agile composition and personalization.
  - Decision-maker. Continuously decides about the next actions to make.
  - Environmental monitor and interoperability manager. Communicate with the outside world (smart cities, body sensors, information systems, etc.).
  - Service manager. Discovers and, when appropriate, installs services in the mobile device.
  - Service space. Set of services installed in the device. Some of them may be used to inform other users affected by decision-making.
- Semantic bus. A classical interoperability bus for event-driven communication, with the particularity that events have a high semantic content (see next section). It implements a publisher-observer pattern.

7 THE WAY AHEAD

The realization and adoption of the envisaged platform asks for the consolidation of research along several lines. In this section we enumerate the most important ones.

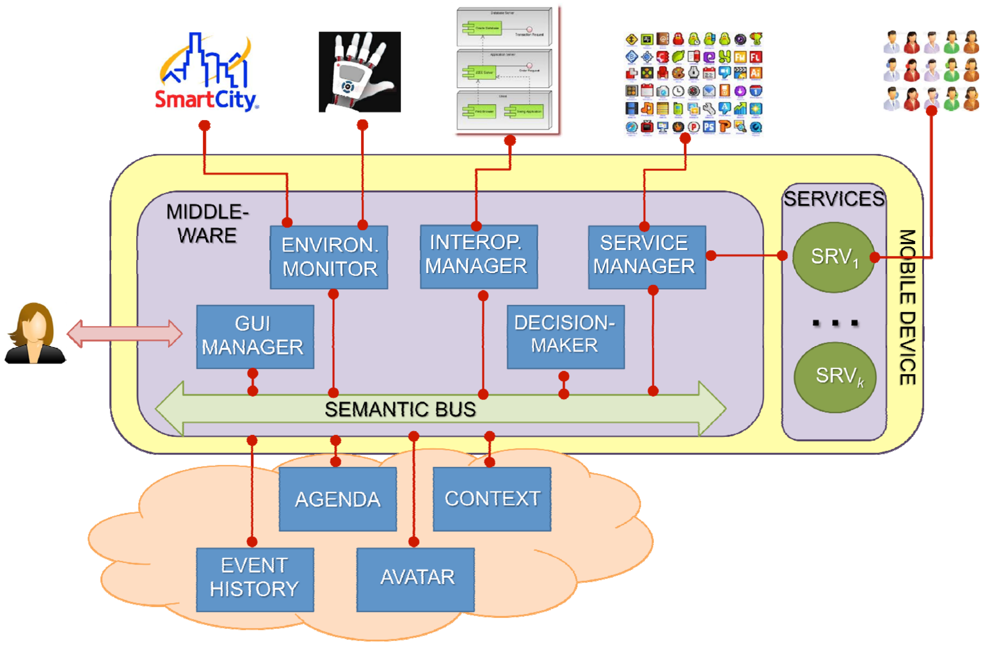

Figure 2: High-level architecture of a platform for enabling informed decision-making.

Semantic interoperability. In order to allow interoperability among all the platform components and the external services, ontologies are needed to represent the information that flows around according to some agreed conceptual reference framework (Uschold and Gruninger, 1996). General ontologies for time, localization, etc., from organizations like W3C, could be adopted to serve as lingua-franca for the platform. Data produced and consumed by services should be compliant to these ontologies in order to allow interconnection through the platform.

Artificial Intelligence (AI) techniques. In order to build an accurate and trustable knowledge base and infer the behaviour that better matches users' expectations, AI techniques emerge naturally. Recommender systems (Adomavicius and Tuzhilin, 2005) may provide (even automatically execute) recommendations on which services to apply; some applications in the marketing context, e.g. (de Bruin et al., 2008), have explored this particular aspect. Case-based reasoning (Aamodt and Plaza, 1994) may be useful to improve the knowledge and reasoning capabilities of individual users case by case.

Service solutions. A great deal of existing proposals in the service-oriented computing field clearly transfers into our envisaged platform. Approaches for service discovery (Ran, 2003), service composition (Rao and Su, 2005) (in particular using AI techniques (Beauche and Poizat, 2008)) and service adaptation (Di Nitto et al., 2008) are of application to satisfy some of the envisaged challenges.

Crowdsourcing and social networking. The active participation of a large number of people to perform particular tasks or solve problems is of great interest for our work. Lim and Finkelstein (2012) have investigated first approaches towards large-scale requirements elicitation using social networks. Furthermore, Onnela and Reed-Tsochase (2010) provide first insights on social influence within social networks.

Participatory sensing. Gathering contextual information in order to allow services to adapt to a particular user context is a key aim of our work. Research on participatory sensing (Burke et al., 2006) focuses on communities that use sensors as provided by mobile devices to retrieve information about the environment.

Change Management. Different sources of change need to be identified, classified and analysed. Service providers need to be aware not just of new needs coming from the potential customers (the citizens) but also new opportunities coming from other services and applications. To this end, very agile change management processes need to be designed. The concept of "fluidity of design" (Jarke et al., 2011) should be accommodated somehow in these processes. Of course one crucial question here is timing: when is the right moment to update the service, for which selected requirements? May some classical RE results on market-driven requirements (Karlsson et al., 2007) be transferred to this context?

Personal and social values. Beyond pure technological knowledge, personal and social factors need to be considered in this kind of solutions. Long ago Goguen (1994) already recognized this link in requirements engineering. The key value of requirements in this context was also recently highlighted by Milne and Maiden (2011) who demonstrated that requirements are socially constructed in a political context. This means that decision-making needs to consider all type of factors surrounding individuals.

Feedback/Communication channels. Continuous feedback on services is needed in order to ensure long-term user satisfaction. Approaches which allow end-user to give feedback on current context-aware services (Schneider et al., 2010) and which allow them to document their ideas on services in situ (Seyff et al., 2010) build a basis to satisfy some of the depicted issues.

Thoughtful living. Our vision includes the idea that people should benefit individually from the proposed solution. However, we also focus on the big picture and aim at a solution that does not only support the individual, but also the thoughtful use of resources and energy.

Platform independent services/apps. There are several mobile platforms available today. Identifying ways to make services and apps available on key platforms and limiting development effort at the same time is a key challenge. Work on approaches such as cross-platform development (Bishop and Horspool, 2006) needs to be considered to overcome this challenge.

8 RELATED WORK

In this position paper we have proposed a novel approach to close the gap among regular citizens and software services available in mobile technologies. We aim at simplifying the interaction of multiple internet services by means of a dedicated platform that is able to make decisions autonomously and also to learn from past decisions from the user. Our vision relies on several existing works both in the form of scientific contributions and existing technologies that we survey below.

The IFTTT Project (https://ifttt.com/) supports user-designed service composition. For example, a user can create a rule that is triggered when he uploads an image to Instagram that saves this image in his Dropbox account. Such rules (called *recipes*), can be shared among users or created in a personalised basis. Although the system is not designed to learn from the user behavior, it opens the path to communication between applications. Such a technology could be integrated into the GUI manager with the purpose of supporting the user to configure his personalized workflows.

Similarly, the on{X} project (https://www.onx.ms/#!landingPage) lets the user control and extend the capabilities of his Android smartphone using a JavaScript API. on{X} provides an API that allows the device to detect several user events, as for example the speed of movement or the arrival to the office. Applications can use this API to react to these events. This type of technology can be integrated in the environment monitor e.g. to update doctors' context when they park the car at the hospital.

Also several applied research projects tackle related issues. The PERSIST project (http://www.ict-persist.eu/) envisions a Personal Smart Space (PSS) that is associated with the personal devices carried by the user and which follows him, providing uninterrupted context-aware pervasiveness. This concept of PSS could be the basis of the avatar component in our platform. The SOCITIES project (http://www.ict-societies.eu/) aims at improving on-line community services, creating new ways of communicating, working and socialising. In their own words, "the vision of SOCITIES is to develop a complete integrated Community Smart Space, which extends pervasive systems beyond the individual to dynamic communities of users".

MUSIC (http://ist-music.berlios.de/site) developed an open framework for the development and deployment of context aware and self-adaptive mobile applications targeted for ubiquitous and service oriented environments. The framework offers a distributed context sensing and management system and supports self-adapting distributed mobile services collaborating in dynamically adapting ensembles. With the help of MUSIC, a developer can implement and deploy a custom context sensor specific to a given device (e.g. a sensor for handling compass data). Still, the framework requires significant effort and a case-by-case study to integrate new services into the user environment.

Some platforms start to be also available in mobile infrastructure. BLOCCO (Hagino et al., 2011) is a service linking system available in Android platform that enables the building of new application mash-ups by linking other existing Android applications. This was delivered in the form of an Android application. The main goal of the project was to enable users to combine functionalities provided by different applications and to implement automatic execution of applications according to user configuration. In addition, various events happening in one application could be detected and they could be used to trigger execution of other services, using parameter passing and processing techniques. Similar to IFTTT, BLOCCO focused on constant rules for end-user configuration and enabled end-users to build new applications according to their specific needs, in a user-centred fashion.

Finally, some academic works have already explored similar features or functionalities. An event-driven approach for business process modeling (Alexopoulou et al., 2008) was introduced to enhance agility by means of learning rules between events and actions. Similarly, the integration of *adaptive process management* and *case handling* was used to create a more flexible and user-friendly approach to process management (Gunther et al., 2008). Another noteworthy work (Mehandjiev et al., 2009) studies end-user service composition from the perspective of users. With this goal, the authors review users' perceptions, intuitions and requirements regarding bridging different services. Finally, Semantic Web Pipes (Le-Phuoc et al., 2009) is a mechanism that supports fast implementation of semantic data mash-ups while preserving abstraction, encapsulation, component-orientation, code re-usability and maintainability.

9 CONCLUSIONS

In this position paper, we have presented a short report of work in progress in the development of a platform for improving the state of the art on service oriented mobile computing with the goal of supporting context-awareness, personalization and evolution. We have analysed the different challenges to overcome, and depicted the main architectural components of such a platform, showing one among several different ways of organizing these components. We have reflected on the different research lines that may contribute to the realization of this platform.

Whilst certainly there is a long path to achieve the scenario presented in Section 4, we have tried to show that a lot of work is already there and can be used as the baseline for building such a platform. Still, many fundamental questions need to be addressed. For instance, recent findings dispute the idea that people are rational decision-makers (Lehrer, 2009). This opens an interesting debate: is it cost-effective to try to embody all possible preferences and attitudes of citizens in a computational form? Answers to this kind of fundamental questions allow us envisaging new emerging interdisciplinary research lines.

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