Using context-awareness to foster active lifestyles

Ana M. Bernardos, Eva Madrazo, Henar Martín, José R. Casar

Universidad Politécnica de Madrid, Av. Complutense 30, 28040 Madrid (Spain)
{abernardos, eva.madrazo, hmartin, jramon}@grpss.ssr.upm.es

Abstract This paper describes a context-aware mobile application which aims at adaptively motivating its users to assume active lifestyles. The application is built on a model which combines ‘motion patterns’ with ‘activity profiles’, in order to evaluate the user’s real level of activity and decide which actions to take to give advice or provide feedback. In particular, a ‘move-to-uncover’ wallpaper puzzle interface is employed as motivating interface; at the same time, context-aware notifications are triggered when low activity levels are detected. In order to accelerate the application’s design and development cycle, a mobile service oriented framework – CASanDRA Mobile - has been used and improved. CASanDRA Mobile provides standard features to facilitate context acquisition, fusion and reasoning in mobile devices, making easier access to sensors and context-aware applications cohabitation.

1. Introduction

Current mobile technologies may be especially efficient to support preventive-proactive healthcare protocols [1], as mobile devices are quickly augmenting their processing, communication, interface and embedded sensing capabilities. In the boost of mobile applications, personal healthcare has captured the attention of mobile application developers: according to a recent report [2], there are more than 5000 commercial mobile health applications available for general users, patients and healthcare professionals. The offer is wide, covering from cardio and sport training control to sleep or pregnancy monitoring or fulfillment of diet or smoking cessation programmes. For the most part, these applications include basic features such as information, monitoring, calendar, reminders, calories calculators, etc. and some of them are prepared to use location data and connect to online web 2.0 services. However they often require permanent feedback from the user, lacking automation and transparency and therefore, usability.

But mobile devices provide powerful elements to design next-generation healthcare applications, which are to be ‘context-aware and persuasive’ ones. The concept of ‘persuasive computing’ (or captology) was coined in the late nineties [3] to define the capability of technology to ‘shape, reinforce or change behaviors, feelings or thoughts about an issue, object or action’. Almost a decade earlier, pioneer context-aware applications began to show how the use of sensors and information processing could make possible to deliver applications capable of dynamically adapting their performance to the user’s situation [4].

In this paper we address the design and development of one of these persuasive context-aware applications, in particular designed to prevent sedentary behavior. It has been demonstrated that insufficient physical activity is a health risk, which is associated to other factors - such as overweight, stress or sleep problems – that worsen the quality of life and may contribute to develop serious diseases - such as cardiovascular problems or type II diabetes mellitus. As it may be difficult to adhere to healthy activity patterns in modern lifestyle, the application aims at persuading the user to reasonably move, taking into account his personal situation.

The application is developed on top of our embeddable framework to provide Context Acquisition Services anD Reasoning Algorithms, *CASanDRA Mobile* [5]. As described below, CASanDRA Mobile relies on a light data fusion service-oriented architecture (mOSGi) and offers a set of standard off-the-shelf features to accelerate the application’s design and development life cycle.

The paper is structured as follows. Section II reviews the state-of-the-art of context-aware mobile healthcare applications which use activity detection as input. Section III addresses application’s design aspects. Next Section IV explains how context information is managed to achieve the application’s persuasive objectives. Section V explains the implementation details on top of the CASanDRA Mobile framework. Finally, section VII concludes the work.

2. Related work

Up to now, a good number of mobile applications dealing with activity monitoring can be found in literature. Their target users include healthy people who want to keep fit or to adopt a healthier lifestyle [6-9], but also patients suffering different types of chronic diseases [10]. Following there is a short review of some applications which combine activity monitoring with social networks [6] [8], take into account past activity personal history [6], adapt their output to real-time biometric performance [7] or aims at providing fun interfaces [8] to guarantee user’s adherence.

Walkabout [6] is a mobile application designed to propose motivating walking alternatives to ordinary routes. Apart from route planning and performance monitoring, the application includes a social component, which allows inviting people to walks and receiving invitations to walks from others. Similarly, Footpaths [7] aims at suggesting outdoors walking routes taking into account the user's cardio-respiratory fitness level (which is calculated by using the Rockport 1-Mile Walk Test). A network of body sensors (two accelerometers attached at both user's legs and one ECG sensor) and a GPS-equipped mobile phone are assumed to be worn.

The UbiFit system [8] encourages regular physical activity through a glanceable display which uses the metaphor of a garden that blooms as the individual performs activities. UbiFit is connected to the Mobile Sensing Platform; MSP transmits a list of activities (walking, running, cycling, using elliptical trainer and using a stair machine) and their predicted likelihoods to the mobile phone. UbiFit's authors state that the application capability to adapt to normal life breaks (due to multiple reasons, such as colds, work changes, etc.) is important not to discourage the user, and that social networking may be a two-edged sword when dealing with self-motivation.

Mattila et al. [9] presents two 3-months user studies on the Wellness Diary, a mobile application based on Cognitive-Behavioral Therapy (CBT), which tries to foster continue self-monitoring to make the patient aware of his health goals. The correct use of the application is very demanding from the user's point of view, as requires entering data manually each time he weights himself, exercises or eats or drinks. As a result, the number of entries decreases with the time of use of the application.

Finally, [10] presents a wearable assistant for Parkinson's disease patients with the freezing of gait symptom (a sudden and transient inability to move). It uses on-body acceleration sensors to measure the patients' movements, and generates a rhythmic auditory signal to help the patient to resume walking when the symptom is detected. The work underlines to which extent the system is sensitive to the diversity of gait patterns, requiring personal calibration and adaptation.

As the reader will notice, most of the applications are prepared to work outdoors, not giving advice when the user is working or performing daily tasks at home. [6] is useful to plan daily transportation events while [8] is also prepared to monitor sport activities. With respect to their sensing needs, [6] relies on the GPS sensor embedded in the mobile device, while others require wearable accelerometers [7] [8] [10], pedometers [9], biometric sensors [8] or data annotation delivered by different devices without a wireless interface (e.g. scales) [9]. *Motion state* estimation is considered in [7] and [10].

Every application above aims at informing the users to help them to make decisions, but varies in their data gathering strategy and level of adaptation when providing feedback to the user. For example, [9] claims that automation in data acquisition may not be effective from the therapeutic point of view, as the user loses awareness of his state. But very demanding applications in terms of user interaction (both for data acquisition and feedback) may result tiring and discouraging. [8] gives feedback in an attractive way, although a nice interface is not enough if individuals are not attracted to it in decision points.

From this analysis, in the next Section we gather the design principles of our persuasive application to control sedentary behavior.

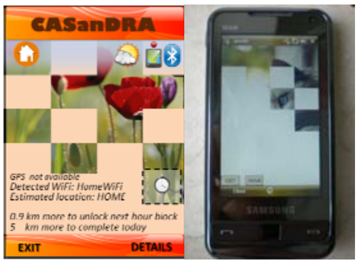
3. Design principles

Our objective is to build a persuasive context-aware mobile application to induce individuals to holistically modify their daily life activity habits, in order to make them internalize healthier motion behaviors when at home, at work, commuting or practicing sports. Basically, the application will process data coming from different sensing sources which will give sufficient information to infer (and store) the user's movements (*motion states*) which, combined with location and time data will deliver his *activity profile*. With this information, the application's logic will control the user's activity level. Each hour, the application will evaluate if the activity level is enough to show progress. If so, a block in the puzzle interface will be uncovered. The user will be able to see the complete image if he has maintained a satisfactory activity level. During the day, the application will deliver context-aware notifications in order to encourage the user to increase its activity when low levels are detected.

Fogg [11] states that there are three elements which guarantee that a person will perform a target behavior: ability, motivation and 'effective triggers' which remind and initiate the action. In our application:

- The user is assumed to have the necessary 'ability' to perform the proposed activities (walk, run, stand up, climb the stairs, etc.). For better adaptation, a configuration panel will get some input about the user's habits (e.g. no. of working hours, no. of weekly sport sessions, etc.) when starting the application the first time.

- The 'motivation' aspect will be mainly driven through a visual interface capable to feedback the user at a glance: a wallpaper puzzle (Fig. 1) hiding an attractive image will be completed according to the periodic evaluation of motion levels. Additionally, alerts giving advice when low motion is detected may include quiz questions to increase the user will to uncover the whole wallpaper puzzle.



GPS not available
Detected WiFi: HomeWiFi
Estimated location: HOME

0.9 km more to unlock next hour block
5 km more to complete today

Fig. 1 Snapshot of the user interface. Prototype and implementation.

- With respect to ‘effective triggers’, aforementioned context-aware alerts will be generated when convenient to attract the attention of the user towards the interface. It is important to note that the delivering period of alerts is not previously set, but handled in an adaptive way depending on the user situation. We aim at providing the user with adequate information at point of decision.

From user studies such as [9], it is possible to understand the convenience to reduce to a minimum the interaction episodes with the user, as very demanding interaction schemes usually have discouraging effects. For this reason, our application will automate data gathering as much as possible; the user will need to provide data for configuration just when starting the application for first time.

4. Managing the user’s context: sensing needs and reasoning patterns

In order to infer *activity profiles*, it is necessary to handle a set of sensors delivering raw data which will be fused to extract context features. Most of sensors will be available in the mobile device, but in order to have better activity estimates, a external Shimmer mote [12] (equipped with a 3-axis accelerometer, gyroscope and ZigBee and Bluetooth interfaces) is assumed to be permanently attached to the user’s instep. Following there is a summary of the context parameters needed and its relationship with sensors:

a) *Motion state:* Still-walking-running states will be detected by using both the accelerometer available in the mobile device and the Shimmer mote; an algorithm using thresholds on variance data will be used for this purpose. This redundancy of sources for motion estimates will help us to have better quality of context and failure tolerance. Transitions between motion states will generate detectable events.

b) *Indoors location:* As GPS is not available indoors, two indoor location systems are featured in the application. One of them connects to an infrastructure-based location system [13] which combines Bluetooth and WiFi received signal strengths (RSS) to calculate the user’s coordinates (which will be translated into zones). The second one bases on a continuous scan of the WiFi and Bluetooth environment, in order to recognize common scenarios which may be identified by networks and devices (e.g. when the user arrives at work, his mobile device will detect his colleagues’ mobile phones). Both of these algorithms require previous knowledge of the environment or additional infrastructure. Input information for the second method is to be added in the configuration interface.

c) *Outdoors location:* GPS will be used to locate the user when outdoors. In order to enhance the battery use, roaming between indoors and outdoors will be managed by a software component (the Location Fusion Enabler), which will be in charge of powering the GPS and the communication interfaces on and off in indoors to outdoors transitions and the other way round.

d) *Walked distance:* The walked distance will serve as primary input for activity inference. It may be calculated from location systems output (more accurately with GPS than with indoors positioning technology). Nevertheless, the most reliable way to have permanent feedback on the walked distance is to implement a step counter (pedometer). The number of steps is calculated by using a threshold on the envelope signal which combines the 3-axis acceleration signals. In order to calculate the covered distance in each step, some user information (gender and weight) is gathered in the configuration interface.

e) *Date & time:* All the gathered data need to be date and time stamped, as time is an essential input for context inference.

Using several sensors which may infer the same context parameter can cause conflicts when inferring the user activity; for example, the accelerometer sensor can inform of user movement while the GPS sensor is reporting stillness. It is necessary to have this aspect in mind when implementing the application logic, as the system will need to have a conflict strategy resolution and to determine which the most reliable estimates are.

The location information will be fused with date and time in order to infer the most probable *activity profile* for the user at a given time of the day. Initial *activity profiles* include AT WORK, SLEEPING, TRANSFERRING, AT HOME and PRACTICING SPORTS, although the list will grow to detect other sedentary activities (e.g. watching TV at home). Every *activity profile* has an associated *motion pattern* that user is expected to fulfill (e.g. one move every hour when the user is working, or 1 km walked when user commutes from his place to work). Conjoint processing of *motion state and location* data will be used to infer the user's *motion pattern*, which will be stored during an hour. At the end of the hour, the application will evaluate how the user is doing (by comparing the stored *motion pattern* to the predefined one) and if the evaluation is positive (>75% of the expected motion level), the interface will be conveniently modified. Depending on the evaluation result, context-aware alerts will be queued to be delivered at the right time. Each *activity profile* will have predefined rules to handle notifications (*alerts pattern*), to avoid interaction overload.

Table 1. Overview of activity and motion patterns

Profile Name	**Profile Properties**	
	Activity level	**Motion pattern**
WORK	Low	One move every hour
SLEEP	Very Low	10 hours máx.
TRANSFER	High	Walk 1km at least
HOME	Low	One move every hour
SPORTS	Very High	Run 4km at least

5. Description of the application components and development issues

The application has been built using the CASanDRA Mobile framework [5], which architecture (Fig. 2) is composed by three building blocks - Acquisition Layer, Context Inference Layer and Core System. The Acquisition Layer decouples the access to embedded and external sensors from upper processing levels by using software ‘Sensors’, which deal with low-level hardware information retrieval. The Context Inference Layer gathers a number of ‘Enablers’ - modules that process data coming from ‘Sensors’, fuse them, and infer complex context parameters. Finally, the Core System provides several features to integrate these components in the middleware, such as discovery and registry management of new elements and some common utility libraries. Both ‘sensors’ and ‘enablers’ publish their output data in the middleware through an event manager. Applications run on top of CASanDRA Mobile middleware, consuming context information provided by Enablers and Sensors and using its standard features.

The first step when building an application on top of CASanDRA Mobile is to define and separate every sensor or enabler module in an independent OSGi bundle. Fig. 1 shows all the bundles needed for the application to work. Using top-down design, firstly we define the application bundle including the application logic and also the user interface module. This application will program the rules that define the different *activity profiles* in the reasoning tool, will subscribe to that activity profile context parameter, and will perform an evaluation every hour according to this profile and to user activity stored during that hour. It will also show progress and alerts to user through the designed user interface.

Then, given the rules, four enablers need to be developed to infer context parameters. A *Step Counter Enabler* will process the external accelerometer measures using appropriate algorithms for detecting and storing every step user takes. The *Indoors Location Enabler (ILE)* will use an infrastructure positioning service [13] for providing location. The *Nearby Resources Location Enabler* (NRLE) will be used when the infrastructure service is not available, it will use a visible device and networks fingerprint to estimate the user’s position. The *Location Fusion Enabler* will combine the indoors location and the GPS available data, in order to handle roaming and resources. With respect to persistence requirements, besides the context history, the database also will store other configuration parameters, e.g. the map of known devices and networks needed to make the NRLE work when the ILE is not available.

Finally, it is necessary to identify the sensor bundles. The Step Counter Enabler needs an external accelerometer bundle to access the Shimmer device using Bluetooth; an internal accelerometer bundle providing data about mobile internal inertials will be used in some rules; a GPS bundle will access internal GPS data when available; a Wi-Fi bundle will detect visible Wi-Fi networks and also provide RSS data to the RSS Indoors Location Enabler; a Bluetooth bundle will provide a list with close Bluetooth devices used in the other NRLE. GPS, internal accelerometer and Bluetooth bundles have been already developed as reusable bundles and are available to use in CASanDRA Mobile.

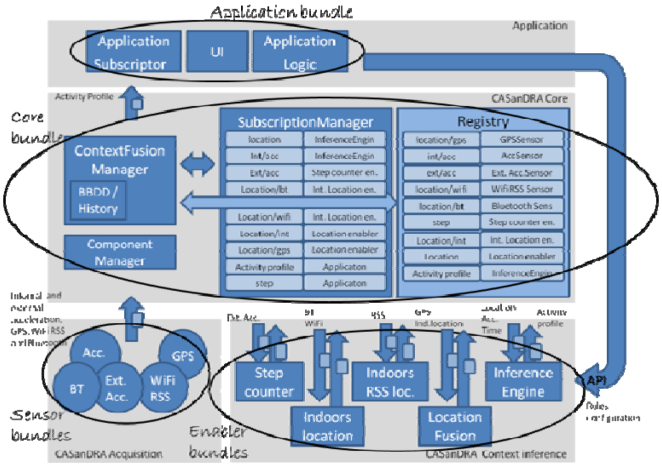


Fig. 2. Bundle deployment over CASanDRA Mobile.

6. Concluding remarks

From the design and development of our persuasive context-aware application, it has been possible to validate the CASanDRA Mobile framework and detect missing features which need to be incorporated to enhance the middleware. For example, the use of different context sources inferring the same context parameter may cause logic conflicts which have had to be directly handled by the application. CASanDRA Mobile will be improved to offer transparent management of Quality of Context in a probabilistic way, allowing the comparison of different conflictive measures in order to select one or combine both when possible.

To evolve the application, apart from adding new sensors and features working on them, it is necessary to study how persuasion may be modeled and translated into performance. For this reason, the next step is to proceed with a user study which, besides evaluating the application, will focus on shedding some light about how the system should learn from real user interaction in order to dynamically modify the application’s persuasion strategies.

Acknowledgments This work has been supported by the Government of Madrid under grant S-2009/TIC-1485 and by the Spanish Ministry of Science and Innovation under grant TIN2008-06742-C02-01.

References

[1] IPTS, “eHealth in 2010: Realising a Knowledge-based Approach to Healthcare in the EU”, (2004).

[2] MobiHeatlhNews, “The world of health and medical apps”, (2010).

[3] Fogg, B.J., “Persuasive computers: perspectives and research directions”, Proc. of the SIGCHI Conf. on Human factors in computing systems, p.225-232, Los Angeles, (1998).

[4] Schilit, B.N, Theimer, M.M. Disseminating active map information to mobile hosts. *IEEE Network*, pp. 22-32, September/October (1994).

[5] Bernardos, A.M., Madrazo, E., Casar, J.R., “An embeddable fusion framework to manage context information in mobile devices”, to appear in Proc. of the 5th Int. Conf. on Hybrid Artificial Intelligence Systems, San Sebastián (2010).

[6] Brehmer, M., El-Zohairy, M., Jih-Shiang Chang, G., Himmetoglu, H. G. “Walkabout: a persuasive system to motivate people to walk and facilitate social walks planning”, Proc. of CHI, Atlanta, (2010).

[7] Waluyo, A.B., Pek, I., Yeoh, W-S, Kok, T.S., Chen, X., “Footpaths: Fusion of mObile OuT-door Perosnal Advisor for walking rouTe and Health fitnesS”, Proc. 31st Annual Int. Conf. IEEE EMBS, (2009).

[8] Consolvo, S., Landay, J.A., “Designing for behavior change in everyday life”, Computer, pp. 86-89, June (2009).

[9] Mattila, E. et al., “Mobile diary for wellness management – Results on usage and usability in two user studies”, IEEE Trans. on Information Tech. in Biomedicine, vol. 12, no. 4, (2008).

[10] Bächlin, M., Plotnik, M., Roggen, D., Maidan, I., Hausdorff, J.M., Giladi, N., Tröster, G., “Wearable assistant for Parkinson’s disease patients with the freezing of gait symptom”, IEEE Trans. on Information Technology in Biomedicine, vol. 14, no. 2, (2010).

[11] Fogg, BJ, “A Behavior Model for Persuasive Design”, Proc. of Persuasive '09, Claremont, (2009).

[12] Shimmer motes: http://www.eecs.harvard.edu/~konrad/projects/shimmer

[13] Aparicio, S., Pérez, J., Bernardos, A.M., Casar, J.R., "A fusion method based on Bluetooth and WLAN Technologies for Indoor Location", IEEE Int. Conf. in Multisensor Fusion and Integration for Intelligent Systems, Seoul, (2008).

[14] 3APLm: http://www.cs.uu.nl/3apl-m/