A Framework for Rapid Prototyping of Mobile and Context-Aware Pervasive Healthcare Systems

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Abstract — **The pervasive healthcare field would benefit from software development tools supporting rapid prototyping in order to evaluate the feasibility of novel approaches in healthcare by using technology. We introduce the lightweight framework Extended Advanced Context Sensing Evaluation Platform (EACSEP) for rapidly creating context-aware sensing prototypes within the pervasive healthcare domain. A smartphone application prototype, called 'Extended Adherence Logger', is built using EACSEP, as a case study. This prototype uses the smartphone's built-in sensors and an external Bluetooth sensor node. The built-in sensors monitor position and movement using GPS and accelerometer. The external Bluetooth enabled sensor node is used for measuring ambient temperature. We verified that the EACSEP framework was useful for rapid development of an Android application for using both the smartphone's internal sensors and external Bluetooth enabled sensors. We found that the prototype application feasibly could measure the ambient temperature for a 1-minute data collection at a 15-minute interval during a 30-hour period, while simultaneously collecting data from GPS and accelerometer sensors with Wi-Fi enabled.**

Keywords: Rapid Application Development; Smartphone; Context Aware; Context Tagging; Pervasive Healthcare

I. INTRODUCTION

Rapid Application Development (RAD) is a software methodology that involves methods such as software prototyping. Use of prototyping frameworks has proven to be an efficient method of developing prototypes and proof-of-concept applications. The aim of this study is to evaluate the feasibility and applicability of the Extended Advanced Context Sensing Evaluation Platform (EACSEP). This is a lightweight prototyping framework, to be used as a tool for creating context-aware mobile applications for the pervasive healthcare community.

The EACSEP framework is the continued work of ACSEP [3]. This is a lightweight framework for developing context-aware sensing research prototypes for the Android platform. The intended use of the prototypes is for the pervasive healthcare domain.

The ACSEP framework makes it easy to monitor internal sensors in the smartphone. In the prototype application 'Adherence Logger'; this was used to sample data from the internal GPS and accelerometer sensors.
The EACSEP framework extends the functionality of ACSEP by enabling monitoring of external Bluetooth enabled sensors using a standard smartphone. The prototype application from ACSEP [3] forms the basis for the prototype built in this study.

In order to evaluate the framework, a case study based on 24-hour Ambulatory Blood Pressure Measurement (ABPM) is carried out. ABPM is used to measure blood pressure on a patient over a 24 hour time period. The patient is outfitted with an automated measuring device placed on the arm, which continuously, every 15 minutes, measures blood pressure of the patient. ABPM requires the patient to follow a set of recommendations, at the time of measurement, in order for the measurements to be considered reliable for diagnostic use. The primary recommendations are [4]: The patient should not be talking and the patient should be relaxed.

II. METHODS AND MATERIALS

A. Methods

We developed the EACSEP framework based on requirements originating from a case study on ABPM [3] co-developed with this lightweight framework. The case study is based on the ASEF (Adherence Strategy Engineering Framework) [6] methodology. This framework defines a set of phases, steps and guidelines for designing and building self-care solutions using adherence strategies.

B. Evaluation

We evaluated the feasibility and applicability of the EACSEP framework by creating a prototype Android application, and by performing several performance and battery tests, and evaluating the results thereof. The electronics box used in this project was developed in the CARSEP project [5]. If EACSEP is to be feasible and applicable for creating pervasive self-care solutions, is must be possible to leverage sufficient battery life for making realistic evaluations. In the case of the 24-hour ABPM project, we needed a prototype that could log relevant data for at least the 24-hour measurement period. Also, data should be sampled at a sufficient frequency in order for it to be of real diagnostic value.

C. Case study

When a patient submits to 24-hour Ambulatory Blood Pressure Measurement (ABPM), the patient will be fitted with an ABPM device at the clinic. The ABPM device is attached to the arm of the patient, following usual clinical practice, and a smartphone is attached on the opposite arm.

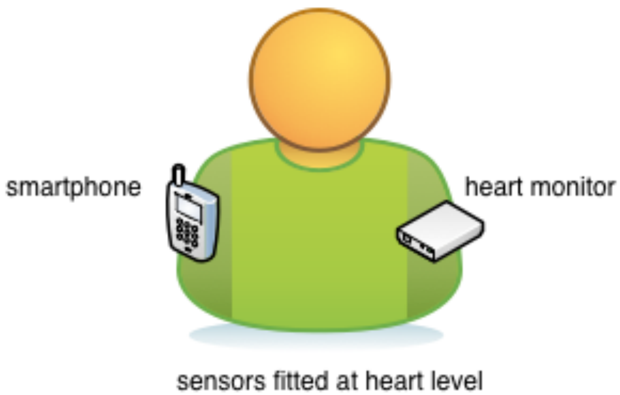

Figure 1: Smartphone and ABPM device fitted on patient

The smartphone need to connect to an external sensor, such as a temperature sensor. The EACSEP allows for dynamically adding and removing both internal and external sensors.

In order to verify that the framework is functioning correctly, and the prototypes are capable of context sensing for the required 24-hour period, a series of tests has been performed. The results of these tests are evaluated in the following sections.

Extended Adherence Logger System Overview

Every 15 minutes, for a 24-hour period, the application activates the sensors, internal or external, and save the data from the sensors, in the smartphone database. When the 24-hour period has passed, the application stops the recording of data from the sensors, and creates and sends an email with the results to the clinic. This case study uses a custom-made electronics box with a temperature sensor. The external sensor ideally has a size that easily fits on the arm of a patient.

The smartphone used for the measurement is a dedicated device, and not the patient's own Smartphone. This is to ensure, that the patient does not drain the battery by ordinary smartphone usage.

Test

The power consumption for the Bluetooth communication was tested in a series of different scenarios.
The evaluation focused on operation time / battery lifetime
With external Bluetooth device – 30-hours
Without external Bluetooth device – 30-hours
Without sensors at all and no Wi-Fi/3G

III. Results

The purpose of the tests is to evaluate and verify, that the framework can be used for rapidly developing prototype applications, and if such applications functioned satisfactorily.

Power consumption test was performed to determine how the prototype application and especially the use of the external Bluetooth devices affected the battery of the smart phone.
The results of the tests performed are displayed in Table 1.
For all tests follows:

- Each test was run for 30 hours
- For each entry in table, 2 tests were run and the table holds the average remaining battery
- Accelerometer sensor was enabled 1/15 (1 minute active every 15 minutes)
- Bluetooth communication exchanges data as fast as the test device (a CARSEP [5] device) can deliver data

Bluetooth (x minutes active)	GPS (x minutes active)	Wi-Fi	Battery remaining
Off	Off	Off	77%
1/15	Off	Off	63%
5/15	Off	Off	56%
1/15	10/60	Off	21%
1/15	5/60	On	50%
5/15	10/60	On	11%

Table 1: Results of battery test. Showing sensors and their status (On or Off) and time interval in which sensor is active (for example: 1/15 ~ 1 minute active every 15 minutes)

IV. DISCUSSION

We successfully constructed a smartphone prototype based on EACSEP using the built-in sensors and integrating with an external sensor node.
Thus, results indicate that creating context-aware mobile applications with the sufficient quality and battery life can be achieved using EACSEP.

Other frameworks for developing rapid prototype applications exist. Among these are BioMOBIUS [2], which aims at supporting application development for biomedical research.
SPINE[1] is likewise a rapid application development framework. It is based on Java and focuses on connecting to the test-platform via an IEEE 802.15.4 wireless connection. This means it is limited to devices, which are IEEE 802.15.4 compliant. This makes the framework unsuitable for mobile device integration, targeting the personal computer platform instead.

However none of these frameworks are capable of creating pervasive healthcare prototype applications for mobile platforms such as Android.

V. CONCLUSION

We constructed a framework for rapid prototyping of mobile and context-aware pervasive healthcare systems with focus on using Bluetooth enabled sensors. We evaluated the framework by successfully creating a feasible and applicable ABPM prototype as a case study on EACSEP usage.
We evaluated the ABPM prototype with regard to its ability to monitor a range of context-aware parameters, while maintaining minimum 24 hour battery life.
The EACSEP framework is able to monitor internal sensors in the smartphone and external Bluetooth enabled sensors. Monitoring sensors can be done while still achieving an acceptable level of operation time.

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