Cloud Based Patient Monitoring platform on Android smartphone sensors

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Abstract. This paper presents a proof of concept cloud based patient monitoring and self-care platform, powered by measurements provided from various smartphone sensors. The Cloud platform provides the infrastructure and computational capacity for the calculations of the navigation and motion tracking system, fall detection monitoring as well as emergency notifications. The navigation system uses the pedometer and fusion of the accelerometer, gyroscope and magnetometer sensors. It aims to estimate precisely the patient`s movement and location. While both navigation and tracking systems can independently determine the incremental movement and indoor localization of the patients, they are fused in order to provide more accurate estimations. The fall detection monitoring is enabled by processing raw data collected from the smartphone's accelerometer and gyroscope. Furthermore, the Cloud system provides various statistics for the physical activity of the patients, based on measurements from the pedometer. Consequently, this paper proposes a proof of concept cloud based platform that is scalable and highly responsive, used for real-time monitoring and tracking large number of patients. It also provides indoor navigation and other self-care features.

Keywords: self-care, home care, patient monitoring platform, android sensor fusion, step counter, cloud computing, indoor navigation.

1 Introduction

Emerging ICT technologies used to develop better healthcare platforms for patients are still exploratory. Despite the increase in research for improvement of the way we provide self-care and emergency care, many challenges remain in designing a more sophisticated, reliable environment. During time-critical health emergency situations, the ability to automate the tasks of monitoring and tracking patient`s condition is a key benefit for increasing the quality and quantity of patient care. In such environments where time is of the essence, there is a little tolerance for errors and unreliability.

We propose a cloud based Core System Architecture built on top of the Windows Azure cloud platform [1]. In addition, the cloud based architecture [2] is closely tied with the mobile platform architecture providing scalable platform services (SaaS, PaaS

adfa, p. 1, 2011.

and IaaS). Furthermore, these functionalities pose platform independence, simplify interconnectivity and interoperability and guaranty high-availability of services. These key benefits promote the cloud architecture as the most suitable for building a real-time high availability platform. Our goal is to provide a reliable cloud platform for monitoring numerous patients through the following technologies:

- Sensor measurements provided by the android mobile devices. Each mobile device carried by the patients, exports its sensor data to the cloud Core System. The sensors exported to the cloud are: accelerometer, gyroscope, magnetometer and camera [10].
- Cloud based Core System. Following the cloud architecture principles, the system is scalable, highly-available with virtually limitless computational power. By processing sensor`s data with different algorithms, the system provides several functionalities, such as: patient navigation and tracking, fall detection monitoring, emergency notifications as well as providing statistics for the physical condition of the patients.
- Secure user-friendly web interface, allowing authenticated users to preview and share real-time patient information, as well as various patient metrics and statistics based on the accumulated data for each patent.

2 Android sensors and sensor fusion algorithms

A lot of research has been done so far in the field of mobile sensors, their physical characteristics, techniques for noise reduction and sensor fusion techniques. In addition, the primary data feed in the Core System originates from the mobile sensors, so the system must implement algorithms for calibration, noise reduction and sensor fusion in order to provide reliable and accurate functionalities.

The Android sensor framework uses a standard 3-axis coordinate system to demonstrate data values. The coordinate system is defined relative to the device`s screen for most of the sensors. In addition, when the device is in its default orientation, the X axis lays horizontal pointing to the right, the Y axis is vertical pointing up, and the Z axis points normal to the XY coordinate plane. This coordinate system is applicable among all three hardware-based sensors: acceleration sensor, gyroscope and magnetic field sensor. Each sensor accumulates errors in the output resulting from the noise of the signal, the surrounding environment and stemming from the physical characteristics of the material that the sensors are made of. Thus, raw data from each of the sensors must be calibrated to remove the noise, before it can be fused with other sensor`s data. Different methods and techniques are used by applying Kalman filter, Particle filters and Complementary filters [5].

2.1 Navigation

There are various different functionalities so far that are implemented over the fused mobile sensors. As presented in [6], a complementary filter is used to calibrate the output offset and estimate the positioning of the device. Only short time intervals are taken in consideration to avoid the gyroscope drift. In addition, low-pass filtering is applied over the accelerometer and magnetometer, and high-pass filtering over the gyroscope signal to calibrate the drift and bias errors. With this fusion technique, the system calculates the dimensions of Roll, Pitch and Yaw of the device that are representing the rotation of the device. The author in [11] implements another methodology using Kalman filter to suppress the gyroscope drift and bias error from other sensors. Furthermore, an algorithm is proposed to deal with the calibration and output offset errors.

2.2 Pedometer

Another great functionality extending over the android sensors is the step-counting methodology. Based on the calibrated 3-axis accelerometer, authors in [7] propose an algorithm for efficient step-detection pedometer. The most important feature of this pedometer algorithm is that the method is effectively applicable to any variable speed of walking. Both rotation and pedometer data are fused to estimate the patient position and to provide navigation and tracking.

2.3 Fall detection

Fall detection of patients is another functionality provided by processing sensor`s data. As presented in [9], the algorithm uses the 3-axis accelerometer and gyroscope in order to determine the threshold value of falls. The algorithm recognizes four different states of the human body. On every transition between different states, the data from the accelerometer and gyroscope is processed to determine if a fall event has occurred.

3 Methodology

The proposed cloud based framework provides a communication protocol for connection with various Android mobile devices. The protocol is based on the pure HTTP [3] and WebSocket [4] protocols that have built-in features for two-way communication between the Core System and the devices attached to it. Each device connected with the Core Cloud System sends raw data from its sensors, such as: accelerometer, gyroscope, magnetometer and camera [10]. In addition, due to high computational power of the Cloud, the intensive computations over the raw data are processed only by the Core System. Consequently, the framework spares the CPU and reduces battery consumption in the mobile devices. Based on different fusion techniques and algorithms for processing sensor data, the Patient platform provides several functionalities, such as: navigation and tracking of patients, fall detection monitoring, emergency notifications as well as providing statistics for the physical condition of the patients.

The navigation functionality provided by the Core System consists of sub-functionalities. Main characteristics for determining a device`s physical position in the world`s frame of reference are rotation and translation values of the device. In addition, the first functionality is provided from the algorithms for navigation, which calculates the orientation of the patient. The second sub-function is provided from the step-counting functionality. The system fuses data provided from the rotation and pedometer components in order to estimate patient position.

Furthermore, the Core System monitors falls of the patient through fall detection module. When fall detection occurs, the alarm is triggered by the Core System with the estimated position of the patient.

Based on the data collected from the different sensors and implemented algorithms, the Core System provides different metrics and statistics for every patient. From the pedometer component, the system gives information for the physical activity, counting how many steps the patient has encountered. Furthermore, based on the fall detection component the system aims to find a related pattern of interconnection between the falls of the patients.

Eventually, the cloud aggregation of sensory data, provides for rapidly increasing datasets of raw data that will soon be subject of thorough data mining and additional research. Analysis of data about human habits, behavior, changes in movement will generate models for diagnostics, automated self-care and home care. Smart homes connected to the cloud will provide reliable and certainly more affordable healthcare for those in need, especially for the aging population in Europe.

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