Poster: RADAR-base: A Novel Open Source m-Health Platform

Yatharth Ranjan
Institute of Psychiatry, Psychology & Neuroscience
King's College London
London, SE5 8AF, UK
yatharth.ranjan@kcl.ac.uk

Sebastian Böttcher
Epilepsy Center, Medical Center - University of Freiburg
79106 Freiburg, Germany
sebastian.boettcher@uniklinik-freiburg.de

Maximilian Kerz
Institute of Psychiatry, Psychology & Neuroscience
King's College London
London, SE5 8AF, UK
maximilian.kerz@kcl.ac.uk

Richard JB Dobson
Institute of Psychiatry, Psychology & Neuroscience
King's College London
London, SE5 8AF, UK
richard.j.dobson@kcl.ac.uk

Zulqarnain Rashid
Institute of Psychiatry, Psychology & Neuroscience
King's College London
London, SE5 8AF, UK
zulqarnain.rashid@kcl.ac.uk

Amos A Folarin
Institute of Psychiatry, Psychology & Neuroscience
King's College London
London, SE5 8AF, UK
amos.folarin@kcl.ac.uk

UbiComp/ISWC '18 Adjunct, October 8-12, 2018, Singapore, Singapore

ACM ISBN 978-1-4503-5966-5/18/10.
https://doi.org/10.1145/3267305.3267579

Abstract
Smartphones with embedded and connected sensors are playing vital role in healthcare through various apps and mHealth platforms. RADAR-base is a modern mHealth data collection platform built around Confluent and Apache Kafka. RADAR-base enables study design and set up, active and passive remote data collection. It provides secure data transmission, and scalable solutions for data storage, management and access. The application is used presently in RADAR-CNS study to collect data from patients suffering from Multiples Sclerosis, Depression and Epilepsy. Beyond RADAR-CNS, RADAR-base is being deployed across a number of other funded research programmes.

Author Keywords
mHealth; mobile context sensing; wearable sensors; data collection platform; mental health

ACM Classification Keywords
H.5.m [Human-centered computing (HCC)]: Ubiquitous and mobile computing.

Introduction
The opportunity for continuous monitoring of participants has steadily grown in parallel with the widespread availability of smartphones, more capacious mobile networks and the development of new wearable sensors that are able to

measure a growing set of physiological and phenomenological parameters.

The 22m Euro Innovative Medicines Initiative (IMI2) Remote Assessment of Disease and Relapse - Central Nervous System (RADAR-CNS) is a major research programme aimed at developing novel methods and infrastructure for measuring Major Depressive Disorder (MDD), Epilepsy (EPI), and Multiple Sclerosis (MS) using wearable devices and smartphone technology [4]. Beyond supporting the initial goals of the 3 disorder areas in RADAR-CNS, the **RADAR-base platform** aims to provide a highly extensible platform that enables remotely streamed data collection, secure data transmission and scalable solutions for data storage, management and access.

To facilitate the reusability by the wider mHealth community the RADAR-base platform was released under open source Apache 2 licence in January 2018. RADAR-base is composed of back-end infrastructure and two Android mobile apps. The cross-platform Cordova apps include **aRMT** for active monitoring of participants (**aRMT**), requiring conscious action (e.g. questionnaires, audio questions, timed tests), and a native Android app for passive monitoring of participants via phone and wearable sensors (**pRMT**). RADAR-base also includes capabilities for data aggregation, management of studies, and real time visualisation.

Related Work

A number of mobile platforms exist, here we provide a summary of the most relevant and highlight the advances made with the RADAR-base platform. The recently developed Non-Intrusive Individual Monitoring Architecture (Niima) platform is a prototype implementation used alongside an investigation of the key features of a mobile health data collection platform. Key points considered include integrating

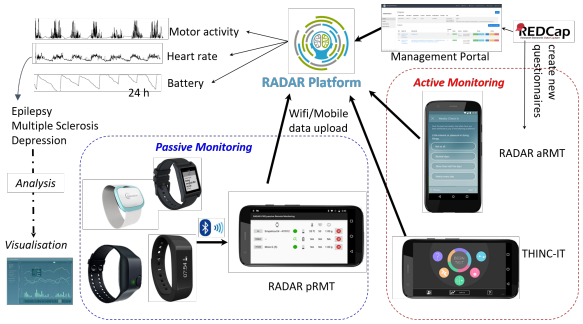

Figure 1: System Overview

data sources, a focus on privacy, and flexible user permissions [8]. The AWARE Framework is an Android platform for mobile phone based context sensing [2]. The Key to the RADAR-base platform is the use of the Confluent platform technologies [1] (based around Apache Kafka) as the underlying infrastructure to provide a scalable end-to-end solution for event driven messaging which is able to satisfy a wide variety of use cases; e.g high-throughput, low latency messaging, real time data processing, fault tolerance/robustness. The platform can be deployed as microservices with Docker containers and with minimal effort extended to integrate new sensors and data sources.

Methods and Procedures

The System Overview and Technical Architecture of the platform is shown in Figures 1 and 3 respectively. The platform consists of the following components: i) Data sources, ii) Study management iii) Ingestion / Data Collection Ecosystem, iv) Real-time processing, v) Visualisation, vi) Storage, vii) Security. **Data Sources** represent systems able to send data into the RADAR platform, including devices containing sensors, mobile phones, the pRMT (Android) and cross-

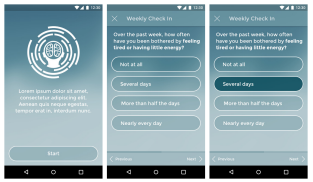

Figure 2: aRMT app interfaces showing the login screen and selected questionnaire

platform aRMT (Cordova) apps, and other 3rd party apps (e.g. THINC-IT) and 3rd party WEB API data sources e.g. the Fitbit REST-API. Figures 2 and 5 show selected screen shots of the pRMT and aRMT apps. **Study Management** is delivered through the Management Portal, the main user interface for creating and organising RADAR studies, enrolling participants and managing the association of participants with corresponding data sources. The **Data Collection Ecosystem** includes the core elements of the platform which are developed around Confluent/Apache Kafka providing a robust, scalable back-end designed to receive data via RESTful calls encoded as AVRO messages. **Real-time processing** functionality is built on top of Kafka Streams. It provides an abstract layer to monitor and analyse streams of wearable data and write aggregated and processed data to Kafka topics. **Visualisation**: The RADAR-platform exposes RESTful Services implemented using Jersey 2 and deployed on Grizzly server. Data collected in the platform is processed by a Kafka Streams application to provide aggregations (e.g. mean, max) at various time resolutions (second, minute, hour, day, week) and stored in MongoDB which is served through the REST-API. The Dashboard then presents data using Angular, RxJS and D3 to provide views of data from the REST-API. In addition to the real-time visualisation through the dashboard, the RADAR platform includes a python package for the processing and visualisation of raw historic data. **Storage** can primarily be divided into hot storage (MongoDb) and cold storage (Hadoop FS). The hot storage stores the aggregated and processed data while the HDFS stores the raw data. The OAuth2 workflow is utilised to provide authorization and authentication across the platform.

Radar-base Current Studies

As part of the RADAR-CNS programme RADAR-base is deployed to carry out RADAR-CNS studies at 8 sites

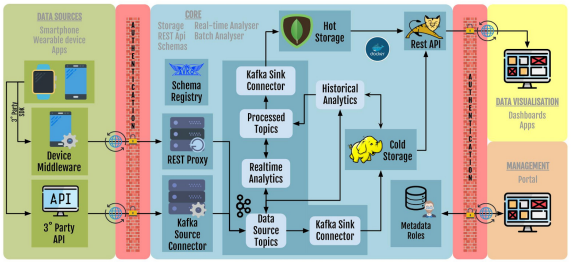

Figure 3: Technical Overview of the RADAR-base Platform Stack

across Europe, with the goal of enrolling MS (n=640), MDD (n=500) and EPI (n=200) participants. A central deployment is used for MDD and MS studies and an in-hospital deployment for EPI. For the EPI study, data (EDA/GSR, Accelerometer, ECG) from wearable sensors such as Empatica E4 and Faros 180 are synchronously collected with established hospital video/EEG monitoring units to test device viability for seizure detection. For MS and MDD studies a broad range of data from questionnaires, digital assays, Fitbits and phone sensors are collected with additional walking and balance tests collected in MS from Faros 180 devices.

Results

The catalogue of devices currently integrated into the pRMT app includes on-board Android smartphone sensors, Empatica E4, Pebble 2 smartwatch, Biovotion Everion, Faros 180 and Fitbit. Pluggable capability is provided to integrate new wearable devices offering a native SDK (e.g. Empatica E4) or through 3rd-party vendor's REST-API (e.g. Fitbit). The aRMT app provides highly extensible active remote monitoring functionality to the platform, rendering questionnaires from a JSON configuration file, e.g. questionnaires used with the aRMT app in RADAR-CNS include RSES,

Figure 5: pRMT app interface showing the connected and disconnected devices with server status

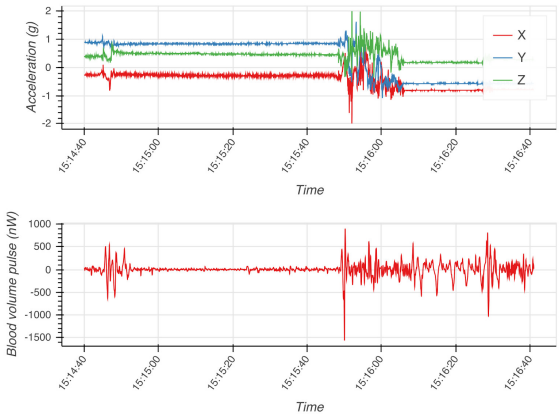

Figure 4: Example of data collected as part of the RADAR-CNS Epilepsy study: Empatica E4 Accelerometer & Photoplethysmography

PHQ8 and ESM. Figure 4 shows some example data collected as part of the EPI study.

The RADAR-base platform is freely available as an open source GitHub repository [5]. More details of the platform can be found at the official RADAR-base web site [6]. A detailed quickstart, deployment details and developer documentation are made available at Confluence Wiki [7]. The Docker images for all the components are available at Docker Hub [3].

Conclusion and Future Works

RADAR-base aims to stimulate the field of mHealth by providing an off-the-shelf platform for general data collection. Beyond RADAR-CNS, RADAR-base is being deployed across a number of other large EU IMI2 funded programmes including RADAR-Alzheimer's Disease (RADAR-AD) and BigData@Heart for remote monitoring in an atrial fibrillation treatment trial (the NIHR funded RATE-AF).

Acknowledgements

This work has received support from the EU/EFPIA Innovative Medicines Initiative Joint Undertaking 2 (RADAR-CNS grant No 115902). We would like to acknowledge The Hyve and RADAR-CNS Consortium (http://www.radar-cns.org/partners) for their support. Backend Infrastructure facilities were provided by King's College London Rosalind. The Authors receive funding support from the National Institute for Health Research (NIHR) Biomedical Research Centre at South London and Maudsley NHS Foundation Trust and King's College London.

References

[1] 2014. Confluent Technologies. https://www.confluent.io/. (2014).

[2] 2017. AWARE: Open-source Context Instrumentation Framework For Everyone. http://www.awareframework.com/. (2017).

[3] 2017. Radar-base Docker Images. https://hub.docker.com/u/radarbase/. (2017).

[4] 2017. Remote Assesment of Disease and Relapse - Central Nervous System. https://www.radar-cns.org/. (2017).

[5] 2018. Platform. https://github.com/RADAR-base. (2018).

[6] 2018. RADAR-base. https://radar-base.org/. (2018).

[7] 2018. RADAR-base Quick Start. https://radar-base.atlassian.net/wiki/spaces/RAD/overview. (2018).

[8] Talayeh Aledavood, Maria Ana Triana Hoyos, Tuomas Alakörkkö, Kimmo Kaski, Jari Saramäki, Erkki Isometsä, and K. Richard Darst. 2017. Data Collection for Mental Health Studies Through Digital Platforms: Requirements and Design of a Prototype. *JMIR Res Protoc* 6, 6 (09 Jun 2017), e110.