2.1 Introduction

When utilizing the various internal sensors and interconnection to external devices, modern smartphones can become on-body hubs for sensor data acquisition, processing, and feedback in personal health applications. The potential of smartphones has been widely recognized for medical training, monitoring, and assistance [18]. Evaluating smartphone-based solutions with patients often requires developing applications and re-implementing functionality. Smartphone-based software frameworks could reduce this implementation burden and enable developers to quickly prototype solutions. However, many existing smartphone frameworks lack essential features, including algorithms for sensor pattern recognition, signal processing, or software interfaces with different external sensors (see related work in the next section). Thus patients cannot choose and interoperate sensors. Since frameworks such as the Context Recognition Network Toolbox (CRNT) have been widely used with PC-based computer architectures [19], an integrating approach could leverage from existing algorithm implementations on smartphones. In this work, we present an open-source Android-based sensing and processing framework that integrates multiple sensing modalities especially suitable for patient monitoring. Our extended CRNTC+ framework integrates the complete CRNT functionality and provides additional input/output components to utilize smartphone-internal sensors and services as well as external devices attachable via wireless protocols, e.g. Bluetooth, ANT. The smartphone-specific framework and the CRNT were partitioned through dedicated interfaces and thus can be extended independently. Nevertheless, our partitioned design does not affect framework users during configuration and use. In particular, the research makes the following contributions: 1) we introduce our CRNTC+ framework design and present its application-independent implementation. 2) We formally evaluate our framework and consider extensibility, scalability, and energy consumption. 3) In an exemplary prototype design, we evaluate CRNTC+ for detecting epileptic seizure events. We chose epilepsy to evaluate CRNTC+, since patients suffering from epileptic seizures face various difficulties in daily life. In particular, major seizures may render patients unconscious and thus in potentially threatening situations. Thus, seizure detection could support patients and caregivers by alarming when a patient needs external help. Most sensor based seizure monitoring approaches used single modalities focusing on limb acceleration or heart activity during seizures [20, 21]. Our results show that CRNTC+ can be used as a flexible solution for recording and detecting epileptic seizures during daytime using smartphones.

2.2 Related works

Several frameworks have been proposed to facilitate smartphone application prototyping. A number of smartphone data processing frameworks addressed specific applications, e.g. Pocket-Sphinx [22]. Pocket-Sphinx is a continuous speech recognition tool ported to Android. Other approaches include the Dandelion framework that uses remote procedure call (RPC) for message passing [23]. More recently, some general purpose sensor processing frameworks have been proposed. While a full review is beyond the scope of this work, some examples are highlighted. The FUNF framework [24] and the SENSE Observation System platform[1] are able to acquire data

[1] The SENSE Observation System, http://www.sense-os.nl/home