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# Leveraging Multi-modal User-labeled Data for Improved Accuracy in Interpretation of ECG Recordings

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## Abstract

This paper presents our preliminary design of the Reaching the Frail Elderly Patient for Optimizing Diagnosis of Atrial Fibrillation (REAFEL) system that helps to improve accuracy in interpretation of Electrocardiography (ECG) recordings by leveraging multi-modal user-labeled data and other contextual information from mobile devices. We describe the methods to collect and visualize the data, discuss the challenges associated with the project and conclude the paper by outlining future work.

## Author Keywords

Personal Health Technology; mHealth; User-labeled data; Patient Reported Outcomes

## ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

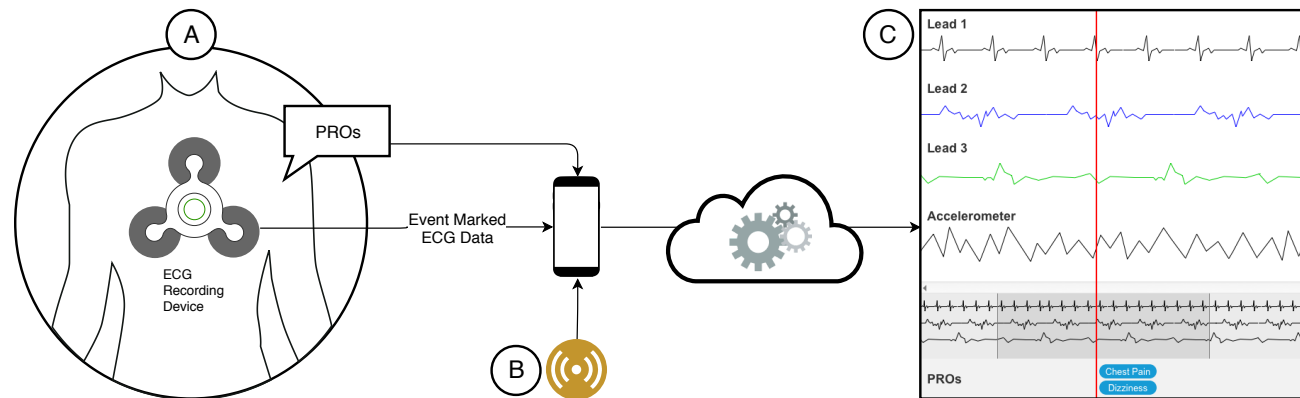
## Introduction

Heart related diseases are the most common causes of death worldwide [16]. The Electrocardiography (ECG) is a standard, low-cost, noninvasive, and effective tool for diagnosis and classification of heart rhythm disorders, also known as arrhythmias [4]. A number of systems have previously been developed using different techniques to record, auto-detect and classify heart rhythm

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**Figure 2:** REAFEL system overview – (A) User-labeled data: event marked ECG data and PRO (B) Contextual information such as physical activity (walking, running, cycling etc.) from smart-phone sensors (C) ECG data visualization with contextual information.

in the hospital, PRO data from patients are collected using paper-based diaries, as shown in Figure 1. However, the clinicians stated that they could not rely on the PRO as they may be inaccurate and flawed because they are often based on patient recalls and not *in situ*, i.e., they do not represent a valid ecological momentary assessment (EMA) [10].

To address this issue, the proposed system will allow collection of event marks on ECG data and PRO *in situ*. Patients can press the button on the ECG recording device when they experience any symptoms. This creates a mark on the ECG data and prompts the patient to enter more details regarding the event via the smartphone application. The clinicians can view this information along with other contextual data from smartphone sensors, which will help to improve accuracy in interpretation of the ECG data.

#### *Contextual information*

Patient's physical activity such as walking, running, biking, etc. influence ECG data and often decrease its diagnostic

quality due to motion artifacts [6]. In the current system, clinicians often have to guess certain patterns of motion artifacts based on their experience and expertise.

The cardiologist stated that physical activity of the patient is an important information to complement and interpret certain patterns of ECG data. The cardiologist gave an example of a telemetric ECG monitoring scenario where the ECG device stops sending the ECG signals because the device might have been unmounted, which could be interpreted in many ways.

In the current design, the following contextual parameters have been included by the cardiologist as relevant information in monitoring and diagnosis of heart-related episodes.

- Accelerometer and gyroscope data from the ECG device to determine the position of the patient (standing, sitting, laying down).

- Location, step counts, physical activity (e.g. walking, biking, running etc.), sleep, and external temperature from the smartphone.

This kind of data can help understand the state of the device and the patient, as well as his or her activity, sleep patterns, and surrounding environment, which is an important information to contextualize and interpret certain patterns of ECG data.

## Discussion

In our design, we have identified a set of challenges in collection and visualization of multi-modal ULD and contextual information from the ECG device and smartphone sensors.

### *Collecting PRO in situ*

Collecting PRO *in situ* may not be feasible in cases where the patients experience severe symptoms and suffer from associated physical limitations. For example, if the patient is dizzy and is about to faint, it is unlikely that the patient will be able to enter the PRO in the smartphone application. An alternative could be to allow patients to enter PRO for the marked events at a later time when they have recovered from any physical distress. However, this will overrule the idea of collecting multi-modal ULD *in situ* to avoid inaccuracy due to patient recalls. In the workshop, we would like to discuss better approaches in collecting ULD *in situ*.

To avoid manual entry of the PRO data, the smartphone application could start recording the patient's voice as soon as the event marker button is pressed. Alternatively, an algorithm could be developed to automatically start recording as soon as it detects a certain pattern of rhythm disorder. Nevertheless, both of these solutions raise privacy concerns because the smartphone application may record sound from the surroundings as well. Therefore, we would

like to discuss the privacy issues and the solution in the process of data collection.

### *Visualizing ECG data with contextual information*

An ECG recording device collects 60-100 heart beats per minute for an adult with a normal resting heart rate [9]. Analyzing large sets of ECG recordings is a challenge in itself [17]. Inclusion of PRO and other contextual information from smartphone sensors will add complexity to this. To the best of our knowledge, no previous study has investigated visualization of ECG data with PRO and contextual information to improve interpretation of ECG data. Any input and suggestion on our preliminary design will be much appreciated.

## Conclusion and Future Work

To achieve the primary objective of the REAFEL project, we are designing a robust system that will help improve accuracy in interpretation of ECG recordings by collecting and visualizing multi-modal user labeled data (event marks and PRO) and other contextual information (patient's physical activities such as walking, running, cycling etc.) from smartphone devices.

Additional research is required to determine if any other information such as temperature, air pressure, humidity etc. collected via smartphone sensors are clinically relevant to improve accuracy in ECG data interpretation. Research is also needed to find the best way to visualize the heterogeneous data including PRO and other contextual information in a meaningful way so that it can help clinicians better interpret the ECG recordings.

We aim to implement a prototype of the system in a clinical setting and run a feasibility study. The study will recruit N=50 patients and 10 clinicians over the course of 12 months. This feasibility study aims to investigate system

usability as well as clinical usefulness in monitoring and diagnosis of heart-related diseases.

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