

Blue Scale: a multi-sensing device for remote management of congestive heart failure

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Abstract—We describe the implementation of a second-generation device for remote monitoring and management of cardiovascular diseases called Blue Scale aimed at overcoming issues of usability, data transmission and sensitivity learnt from pilot studies previously performed with a handheld device. Blue Scale measures electrocardiography (ECG), systolic time intervals through photoplethysmography (PPG), weight and whole-body bioimpedance. Collected datasets are transmitted to a central database using a secure Wi-Fi 802.11b/g protocol for remote data analysis and disease management. In this pilot study, we deployed Blue Scale in different population and connectivity settings to assess improvements of the current implementation in preparation for a larger clinical investigation.

I. INTRODUCTION

Congestive heart failure (CHF) is a chronic illness in which effective management requires consistent monitoring of cardiovascular parameters. However, CHF patients are usually able to monitor their cardiac health only when they visit an ambulatory or emergency care facility. In order to enable more frequent, timely CHF monitoring, we previously designed and implemented a handheld device called BlueBox that allowed daily self-measurements of electrocardiography (ECG) and photoplethysmography (PPG) in a seamless fashion. Although BlueBox yielded promising preliminary results [1], it suffered from usability and connectivity drawbacks that limited its applicability in larger scale studies. A second-generation device called Blue Scale provides a friendly interface and improved physiological sensing, allowing seamless daily monitoring particularly in elderly and underserved populations [2]. Blue Scale can lead to early detection of degrading cardiovascular health and can assist in early intervention before an acute cardiac event occurs.

II. DEVICE AND PRELIMINARY TESTING

Blue Scale is a free-standing device consisting of a modified bathroom scale and a vertical pole with hand electrodes and an optical sensor embedded in the handlebars. Blue Scale measures 3-lead ECG, PPG, whole-body bioimpedance, and weight. From ECG and PPG signals,

systolic time intervals are computed as pulse transit times (PTTs) (i.e. the time interval between the peak of the ECG R-wave to the foot, maximum slope and peak of the pulsatile PPG waveform). The self-measurement is guided by instructions displayed on a large touchscreen and it takes less than one minute to complete.

Following a measurement, the raw dataset is immediately transmitted to a central database where ECG and PPG waveforms are processed into meaningful metrics, such as RR variability, QRS time, and PTTs, among others. The Blue Scale paradigm for CHF management is based on the analysis of individual historical data to detect a significant deviation from that patient's daily norm. Three prototypes of the Blue Scale system were deployed at a local university, an urban community center (Technology for All [3]) and a private residence. Twenty-two healthy volunteers took daily measurements with the scale for anywhere between one and four weeks following an IRB-approved protocol.

Early results indicate a much improved usability of Blue Scale, yielding a high adherence rate, and higher quality of the physiological signals over the handheld device. These factors allowed us to establish each subject's individual baseline and to successfully test preliminary algorithms of cardiac anomalies simulated artificially. Participants suggested the provision of daily feedback of cardiovascular health through the device to maintain adherence over a long period of time.

Management of CHF through a comprehensive infrastructure including ubiquitous cardiovascular sensing/monitoring, case management center and caregivers (clinicians, relative) has the potential to improve outcome and reduce the cost of the disease, particularly in underserved communities.

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