ESTIMATING BLOOD PRESSURE FROM WEARABLE SENSOR SIGNALS

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SUMMARY

Cardiovascular disease (CVD) is a major health problem, accounting for approximately 18 million deaths worldwide per year. Blood pressure (BP) is one of the leading risk factors for CVD. However, it is difficult to measure in daily living. The proliferation of wearable sensors such as smart watches and fitness bands provides a new opportunity to monitor blood pressure unobtrusively. These devices measure the photoplethysmogram (PPG) signal to monitor heart rate. The shape of the pulse waves in this signal is influenced by both the heart and blood vessels. Consequently, it may be possible to derive estimates of BP from the signal, providing valuable information on cardiovascular health. The aim of this project is to develop a technique to estimate blood pressure from the PPG, and assess its performance on a large scale clinical dataset.

1. INTRODUCTION

Cardiovascular disease (CVD) is a major burden on individuals and societies worldwide. In 2015 it was estimated that 422 million people suffered from CVD, and it accounted for 18 million deaths [1]. There is, however, a clear route to reducing the burden of CVD: improving cardiovascular health. Several low-cost strategies have been proposed to reduce one’s risk of CVD, including lifestyle changes such as regular exercise, improved diet, cessation of smoking, weight control, and reduced alcohol intake [2]. Consequently, approaches to identify individuals who are at risk of CVD, and to encourage them to make lifestyle changes, may help reduce the impact of CVD on mortality, morbidity, and healthcare costs.

Elevated blood pressure (BP) is a strong risk factor for CVD. Approximately 73% of deaths due to CVD occur in people with systolic BP of $\geq 140$ mmHg [3]. However, over half of those with hypertension are unaware of their condition [4]. Furthermore, it is not yet clear which daily activities lead to elevated BP.

The proliferation of smart wearables provides a new opportunity to monitor BP. Wearables such as fitness bands and smart watches currently measure the photoplethysmogram (PPG) signal to monitor heart rate (HR). The PPG is a measure of the arterial pulse wave. Changes in BP affect both the timing and the shape of the PPG pulse wave. This is because the stiffness of the arteries increases with BP [5], and this results in the pulse wave propagating faster through the arteries. Consequently, the pulse wave arrives sooner at higher BPs. This effect can be detected from changes in pulse transit time, the time taken for the pulse wave to propagate between a central site (close to the heart) and a more peripheral site [6]. Whilst this is promising for continuous monitoring of BP, it has the disadvantage that two signals are required: one close to the heart, and one further away (such as at the wrist). Recent research has investigated the possibility of estimating BP from a single pulse wave, an approach which could be used with smart wearables. The underlying hypothesis is that the PPG pulse wave consists of an incident wave from the heart, and a reflected wave from the periphery, and that the relative timing and amplitude of the reflected wave changes with arterial stiffness, and therefore blood pressure. The aim of this project is to assess the performance of techniques to estimate BP from a single PPG pulse wave using a large clinical database, and to develop an improved technique if possible.

2. METHODS

The MIMIC database will be used for this project. It contains photoplethysmography (PPG) signals alongside reference invasive blood pressure signals for thousands of critically-ill patients. Since these patients were critically-ill, many experience acute changes in BP, making it an ideal database for assessing the performance of algorithms to estimate BP.

The algorithms tested will initially be based on those which have been previously reported in the literature. The algorithms will be implemented in Matlab® and the BPs estimated from the PPG will be compared to the reference BPs. The performance of the algorithms will be assessed using statistical techniques. It is hoped that the student will refine the best algorithm to increase its performance.

3. OUTCOMES

In addition to the core outcomes of the Summer Research Module, this project provides opportunity to create a publicly available repository of BP estimation algorithms, providing the student with experience in making research resources publicly available. It is hoped that the student will submit a paper on their work to the 6th International Conference on Sensors and Applications, providing valuable experience in disseminating research to the wider scientific community.
4. RECOMMENDED READING

The following publications are recommended reading, and should form the basis of the literature review:

- The clinical importance of BP: [3]
- Techniques for estimating BP from PTT and/or the PPG: [7, 8, 9, 10, 11, 6]
- The PPG signal: [12, 13]
- The role of wearable sensors: [14, 15]

5. REFERENCES


