Continuous Cuff-less Blood Pressure Monitoring and Measurement

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Abstract

Several techniques currently exist to measure instantaneous blood pressure in human subjects. However, attempts at continuously measuring and monitoring blood pressure values have met with successes that are few and far between. In this paper we discuss continuous cuff-less blood pressure estimation, using pathological signals like ECG and PPG.

1. Introduction

Arterial blood pressure (BP) measurement units, most commonly encountered in the form factor of a manual sphygmomanometer (Fig. 1), have been a major source of non-invasive pathological data for over a hundred years[1]. This is because blood pressure provides us with insights to various physiological phenomena and disorders, including hypertension and cardiac arrests, which cause close to 8 million deaths globally every year. Even non-cardiovascular diseases like diabetes and PCOS (Polycystic Ovarian Syndrome) have shown significant links to blood pressure[2] values. Thus, we can see the extensive reach and scope of blood pressure monitoring in the current medical setup.

Fig. 1. Sphygmomanometer [3]

However, a common challenge is that sphygmomanometers and other similar approaches do not allow for the possibility of continuous BP monitoring, resulting in missed diagnoses, and incomplete analysis of blood pressure information. Also, cuff based BP measurement approaches like the sphygmomanometer require medical training and/or an extra person for administration. They also cause occlusion of the blood vessel due to obstruction of blood flow by the inflated cuffs. This causes degradation of reading accuracy, while also affecting BP values in subjects.

Hence, there has been a recent surge in attempts to measure and monitor blood pressure continuously using wearable wireless sensors [4], [5], while reducing dependence on cuff-based solutions. Another common area of investigation involves retrieval and handling of such data remotely by medical professionals to simplify diagnostics related to BP measurement.

Recent studies in blood pressure monitoring[5], [6] strongly suggest that electro-optical signals such as Electrocardiography (ECG) and Photoplethysmography (PPG) can be measured and modelled with reasonable accuracy, to provide reliable estimates of blood pressure in human subjects. In this paper, we discuss the use of ECG and PPG signals to estimate blood pressure values.

2. Method

2.1. Signals and data used

Various signals are used to compute and estimate blood pressure values. ECG and PPG sensors are needed as they are used to compute the pulse transit time (PTT) and blood pressure, measure by an off shelf BP monitor. PTT is basically the time distance between the R-peak of an ECG signal and the corresponding peak in the PPG signal(Fig. 2). We have also used data from the Physionet database[7] for comparison of the estimation models.

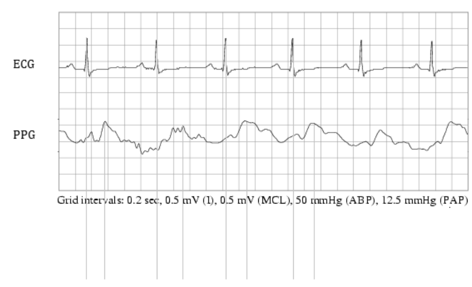

Fig. 2. Pulse Transit time (*data from PhysioNet*[7])

2.2. Processing

We attempt to obtain a statistical relationship between PTT and Average Blood Pressure (ABP), defined as,

$$ABP = \frac{1}{3}SBP + \frac{2}{3}DBP \quad ...(1)$$

where SBP and DBP are the systolic and diastolic blood pressure measured by the cuff-based BP device.

Current literature discuss several models. The most stable attempts provide a linear *(eqn. 2)* [8] and a logarithmic relation *(eqn. 3)* [9], between the two, i.e.

$$ABP \propto PTT \quad ...(2)$$

$$ABP \propto \ln PTT \quad ...(3)$$

3. Results & Conclusion

Our current data, from

- the PhysioNet database,
- preliminary testing using off shelf components
- vital signs for 500 PTT samples and computed BP values for every 10th sample (Fig. 3.)

suggest that *eqn. 2* provides the best fit for ABP to PTT modelling. Linear correlation is higher than logarithmic in all the datasets, which can be observed in Fig. 4., for the 3rd set above, which had the most data-points. This is in agreement with previous tests at our lab (Fig. 5.)[10]. This slope can then be used to compute estimated BP from future PTT values.

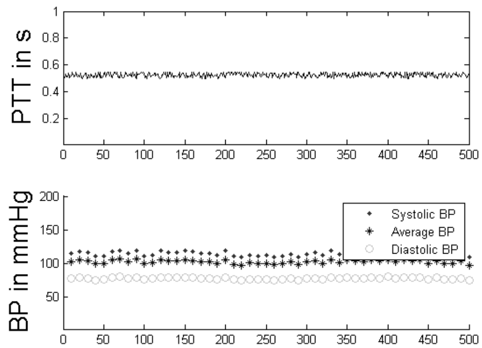

Fig. 3. Computed BP values based on PTT values

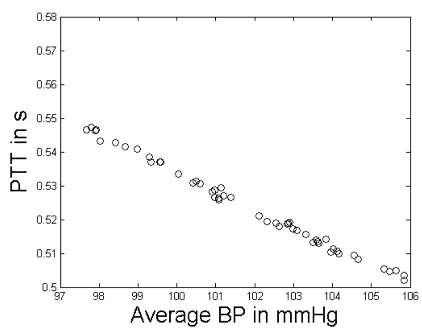

Fig. 4. BP & PTT relation based on Fig. 3.

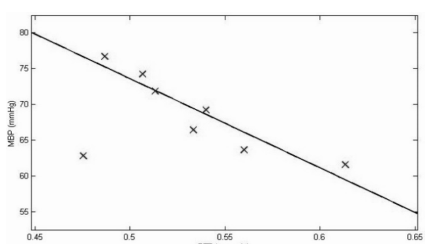

Fig. 5. BP & PTT relation in [10].

Further testing is required to conclusively provide a model and measure accuracy of PTT-based BP estimation and monitoring.

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