ADVANCED BLOOD-PRESSURE MEASUREMENT AT HOME

András Mersich
Advisor: Ákos Jobbágy

I. Introduction

Hypertension is the characteristic disease of the men of our time, about 30% of the total adult population is involved. Known also as the "silent killer", it is responsible to a grate extent for the development of cardiovascular disease, stroke, diabetes and certain renal diseases. Presently doctors diagnose hypertension by every person, whose blood-pressure (BP) is higher than 140/90 mmHg at three different measurements. This is an unreliable criterion since the blood-pressure, despite the homeostatic control, is a parameter with high variance. It depends on age, elasticity of arteries, posture, part of the day, effects of several medicines and drugs, respiration, psyche, etc. It is not uncommon to have 20-30 mmHg daily differences even for healthy subjects. Diagnosed hypertension can be well treated with adequate life style and proper medication, however the tuning, the establishment of the necessary dose requires sufficient and regular BP monitoring. Although there are lots of different home measuring instruments, they are all so imprecise that their results are taken by doctors with reservations.

The goal of this research is to develop a non-invasive measuring method that characterizes BP, a variable physiological parameter. This protocol could serve as a basis for the bias – variance based redefinition of BP, which provides a doctor with far more information on the patient than a momentary value.

II. Materials and Methods

A. Available indirect methods

The most common indirect BP measuring method is based on the detection of Korotkov-sounds. It is used for more than 100 years still it has two major deficiencies. First, the applied cuff grossly intervenes in the measured parameter and second, it determines the pressure only at a single point of time. Oscillometric method, applied in automatic home BP-meters, apart from the aforementioned insufficiencies has also a great built-in uncertainty: it empirically calculates the systolic and diastolic value from the measured mean pressure. Tonometric devices, the best on-the-market continuous BP-monitors however are too expensive.

B. Pulse wave velocity

Pulse wave velocity in the brachial artery can be calculated by recording the ECG and the photoplethysmographic (PPG) signal. The velocity of the pulse wave, progressing through the arteries depends among others on blood pressure. Based on the pulse wave velocity blood-pressure variation can be estimated even without using a cuff [1].

$$BP = \frac{1}{\alpha}\left[\ln\left(\frac{L^2 d\rho}{E_0 h}\right) - 2\ln(\Delta T_{PT})\right] \qquad (1)$$

where E is the Young modulus of arterial wall (E_0 is its value at zero pressure), h is the thickness d is the inner radius of the artery, ρ is blood density, α is constant, L is the distance between the heart and the PPG sensor and ΔT_{PT} is the pulse transit time.

ΔT_{EP}, the time delay between the ECG and the PPG signal, is the sum of the pre-ejection time and the pulse transit time. ΔT_{PT} cannot be measured easily, ΔT_{EP} is used instead.

C. The measurement set-up

The measurement set-up was built around a PIC16F877. Four channels (cuff pressure, Einthoven lead I ECG, 2 PPG signals) were sampled at 1 ksamples/s each and the sampled data were transferred to a PC via serial I/O. The control circuitry of the motor inflating the cuff has been developed. This makes possible the realization of various pressure-time profiles. ECG and PPG signals were converted to 10 bits, cuff pressure was measured with a resolution of 0.05 mmHg.

III. Results

According to Eq. 1. BP variation can be calculated by measuring the time delay between the ECG and PPG signals. However there are different other factors influencing ΔT_{EP} (e.g. respiration, arterial distensibility) which make the method applicable only for about as long as five minutes. After that the actual pressure value has to be newly re-determined. This can be done by the examination of the PPG amplitude during the slow inflation of a cuff wrapped around the upper arm (cc. 3 mmHg/s). Fig. 1 shows the PPG amplitude during this maneuver.

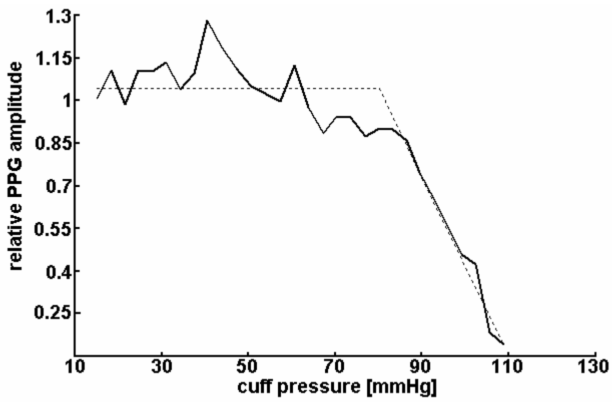

Figure 1: PPG amplitude during cuff inflation

Reaching the diastolic value the pulse amplitude begins to drop resulting from the partly closed artery (85 mmHg on the picture). Above the systolic pressure there is no pulsation to be recorded distal from the cuff (cc. 115 mmHg). Unfortunately respiration modulates the PPG amplitude making the determination of diastolic value unreliable. Recent work is about to eliminate this effect based on either the heart-rate, the ΔT_{EP} or the direct impedance-measurement between the two ECG electrodes.

IV. Conclusion

A recording device has been constructed for the continuous, indirect blood pressure monitoring. A measuring protocol has also been defined which delivers the mean value of the systolic pressure and its variance during a five minutes interval. This averaging eliminates the effects of the cuff and the respiration thus it contains more information on the condition of the patient than the presently available home BP-meters. Diastolic pressure is still determined at a single point of time.

References

[1] W. Chen, T. Kobayashi, S. Ichikawa, Y. Takeuchi, T. Togawa, “Continuous estimation of systolic blood pressure using the pulse arrival time and intermittent calibration,” *Med. Biol. Eng. Comput.*, 38:569–574, 1986.

[2] Á. Jobbágy, “Photoplethysmographic signal aids indirect blood-pressure measurement,” in *Conf. proc. of MEDICON 2001 IX, Mediterranean Conf. on Medical and Biological Engineering and Computing*, pp. 262–264, Pula, Croatia, June 12–15 2001.