Evaluation Of Alternative Derivation Areas For Plethysmography And Pulse Oximetry

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Abstract

To make plethysmography and pulse oximetry more comfortable during sleep monitoring and mobile assistance the quality of plethysmograms have been evaluated and compared at different areas on the human body using different sensors. Most of the results have been expected but some results can be seen as a way for new much comfortable to wear sensors for plethysmography and pulse oximetry which makes a long-term monitoring of pulse rate, pulse transit time, pulse wave velocity and systolic continuous non-invasive blood pressure much comfortable and in some cases actually possible.

1 Introduction

In general plethysmography and pulse oximetry are both based on the same measurement principle. A plethysmogram provides a basis for vital signs like pulse rate, pulse transit time [1], pulse wave velocity, systolic continuous non-invasive blood pressure [1], mental stress and heart rate variability. Arterial blood oxygen saturation can be derived by using pulse oximetry, which can be seen as an extended version of plethysmography. All these vital signs play a role during sleep monitoring and driver assistance. But one general disadvantage of pulse oximetry systems is the inconvenience to wear the transmission sensor, because it is usually applied to patient's finger or ear. Our investigation is to derive these vital signs more comfortable [2] for the patient to avoid effects on the measurement itself. Beside this, it is necessary to derive the signals in good quality to avoid false alarms and missed events. Therefore, a set of common and custom transmission and reflectance sensors have been applied to different areas (Figure 1) on the human body to derive primary signals and to evaluate their quality.

2 Methods

To derive the pulse signals from different incompatible sensors a signal acquisition system has been developed. Sensors from different manufacturers can be connected to the same data acquisition system. This action makes the sensors' data more comparable. The quality was evaluated by measuring the signal-to-noise ratio in frequency domain, in a band depending on the heart frequency from the fundamental wave to the second harmonic (Figure 2). The fundamental wave has been weighted more than the harmonics as many our algorithms for extraction of vital signs work with the fundamental wave only. Beside this depending on some factors like the volunteers age, lifestyle and health the harmonics trend to lower or rise compared to the fundamental frequency [3]. By giving equal weights to each signal-to-noise ratio, as consequence the signal quality would be evaluated less good as it really is, because most of our algorithms pay more attention to the fundamental wave as to their corresponding harmonics. And the most important reason for paying more attention on the fundamental wave is the dependency of patient's age and health. To suppress the effects due to this dependency, the signal-to-noise ratio of the fundamental wave was weighted at 46 %, the first harmonic was weighted at 36 % and second harmonic was weighted at 18 %. This method has been used to pay attention to the signal processing algorithms for calculation of vital signs in plethysmography and pulse oximetry.

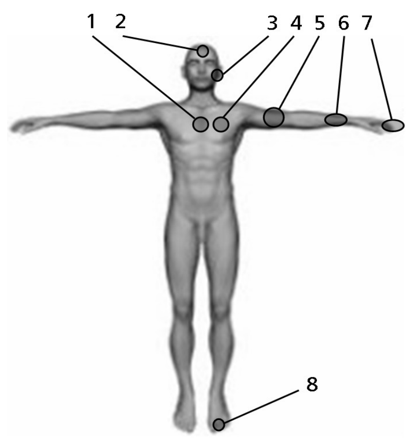

Figure 1 Different areas on the human body to derive a plethysmogram

Reflectance and transmission sensors have been applied to common areas as fingertips, earlobe and forehead; also to alternative areas like upper arm, breastbone, chest, toe and wrist. Beside this, some custom reflectance and transmission sensors have been tested and evaluated the same way. Four persons aged between 22 and 40 years have been tested five times.

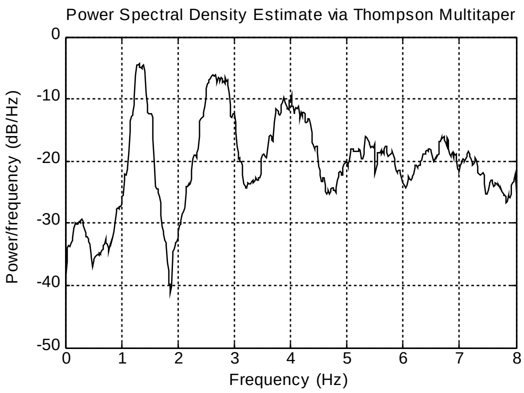

Figure 2 Power density spectrum of a plethysmogram

3 Results

The best results (Table 1) were gained by the finger clip sensor applied to the finger tip. That was definitely expected as the finger clip is the most used sensor. The second best results – approximately 5 dB less – were given by any other kind of reflectance and transmission sensors at the finger tip, followed by the ear lobe sensor – approximately 6 dB less then the finger clip. Some good results, comparable to the quality of signals from earlobes, could be shown using reflectance sensors at the upper arm.

Mean SNR [dB]	Area	Sensor
23,4	7	MCC Finger Clip
18,0	7	MORES V12
17,4	3	Nonin Ear Clip
15,6	7	Nonin Reflectance
15,5	5	Nonin Reflectance
14,0	2	Nonin Reflectance
10,5	8	MCC Finger Clip
9,7	6	MORES V12
8,9	6	Nonin Reflectance
6,3	1	Nonin Reflectance
5,5	4	Nonin Reflectance

Table 1 Mean Signal-to-Noise-Ratio (SNR) of plethysmograms derived using different sensors at different areas on the human body

4 Discussion

The best quality is provided by ear and finger transmission sensors and this is possibly the reason why those sensors are most used for plethysmography and pulse oximetry. But for continuous long-term monitoring (from 24 h up to a week) this type of sensors is very uncomfortable for the patient. In general, long-term, ambulatory monitoring systems have not yet reached a technical level that is widely accepted by both clinicians and patients [4]. A sensor at upper arm can be interesting as an excellent alternative to sensors at fingertips and earlobes. The sensor at the upper arm is much more comfortable to wear for the patient as other sensors on the market, as the patient has free fingers, hands and there are any disturbing sensors applied to the head. Nevertheless by evaluating the quality of plethysmogram only within this study the capability for pulse oximetry is crucial, but this was not been definitely researched. Beside of this, depending on the sensor type and the derivation area different effects due to movement were observed – some sensors are less sensitive to motion artefacts than others. The wrist is a preferred derivation area as a device at the wrist could be designed as a watch without any cables. However, another conclusion of the measured data in Table 1 is the lowest quality of the plethysmogram at the chest, breastbone and wrist using reflectance sensors.

5 Literature

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