Processing and Visualizing Data Set Acquired from a Near Infrared Photo-Plethysmograph

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Abstract: Blood volume in different body segments fluctuates at the same frequency as cardiac ejection. A small device called photoplethysmograp can measure these pulsating changes. We developed a software tool extracting and visualising the data flow obtained from a device mentioned above. The results are presented in numerical and graphical forms, provide diagnostic value in assessing the patient's vascular health.

Keywords: vasography; PWA

1   Introduction

With some latency relative to the heartbeat, blood volume fluctuation can be measured in different, easily accessible body parts such as finger tips or ear lobes. Measuring and displaying these pulsating changes, called pulse waves, along with first and second derivative, the cardiologist can yield relevant physiological information, such as the diagnosis of aortic and arterial occlusive diseases, deep vein thrombosis and primary/secondary varicosity of veins. This Pulse Wave Analysis [14] or PWA for short, is a relatively new technique, and can also be used for the assessment of valvular diseases of the heart, congenital septal disorders, cardiac function in ischaemic heart disease, pulmonary congestion in respiratory disorders and therapeutic response in all of the above conditions. For further details see [1]..[11] The goal of the presented program called Vasographia is to supply appropriate information to the physician.

2   The Pulse Oximeter

The input data correlated to the pulsatile blood volume obtained by photoplethysmograph, containing a Pulse Oximeter probe (Fig. 1).

Figure 1
Pulse Oximeter probe

The probe can clip on to the patient's finger (Fig. 2) or ear lobe, monitoring the percentage of haemoglobin which is saturated with oxygen. [5] and is linked to a computer USB port after an A/D converter unit (USB-1608FS [13]). For the analysis we use an approximately one minute long data flow.
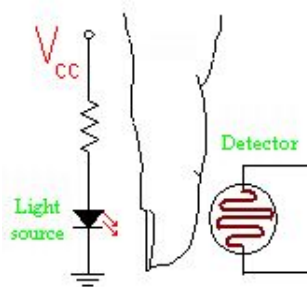

Figure 2
The working principle of the photoplethysmograph

3 Data Processing

The analogous signal is sampled every 10 milliseconds. 6000 consecutive values are processed, which is one minute of continuous data. The incoming data flow contains date and time stamps as well, but we use only the measured value, and call it as raw data flow. The raw data is a superposition of different effects. The pulsatile changes are in the range of 10 to 500 mV. The valuable data sits on the top of about 2 to 4 V DC, and a low frequency AC signal caused by breathing, but also suffers from other irregular abrupt changes like body movement among others. (Fig. 3)
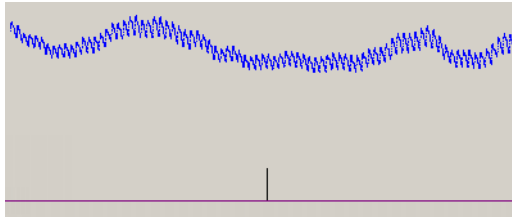
Figure 3
An example of the raw data flow

The goal is to clean the signal, decompose to a primary (arterial), and a secondary (venous) components and extract valuable information for the cardiologist. A typical cleaned portion of the above signal is shown in Fig. 4.
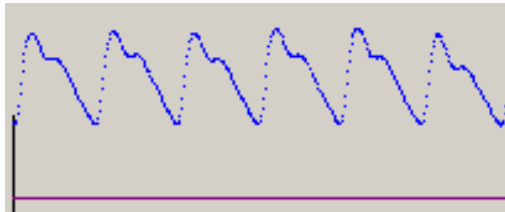

Figure 4
The arterial and venous pulses are clearly seen after cleaning up he raw data

3.1   The Algorithm

The main steps of the data processing we used in the program called Vasographia.exe are the followings:

- calculate and remove DC offset
- calculate and smooth first
- calculate second derivative
- find minimum and maximum positions
- find secondary peaks, using the second derivative
- remove low frequency component
- stack pulse waves for the selected window
- find secondary peak
- calculate heart bit rate
- find amplitudes for both peaks
- calculate statistical data (time and beat energy)

3.2   The User Interface

The user interface has controls, numerical values, a main graphic and a small graphic window for the stacked and decomposed pulse wave. (Fig. 5) Because usually not all parts of the acquired data equally solid, the user (i.e. cardiologist) has many controls on the screen for manipulating the data in order to extract as many information as possible. He or she can zoom in, or can select a specific portion of the data flow to carry out the computations.
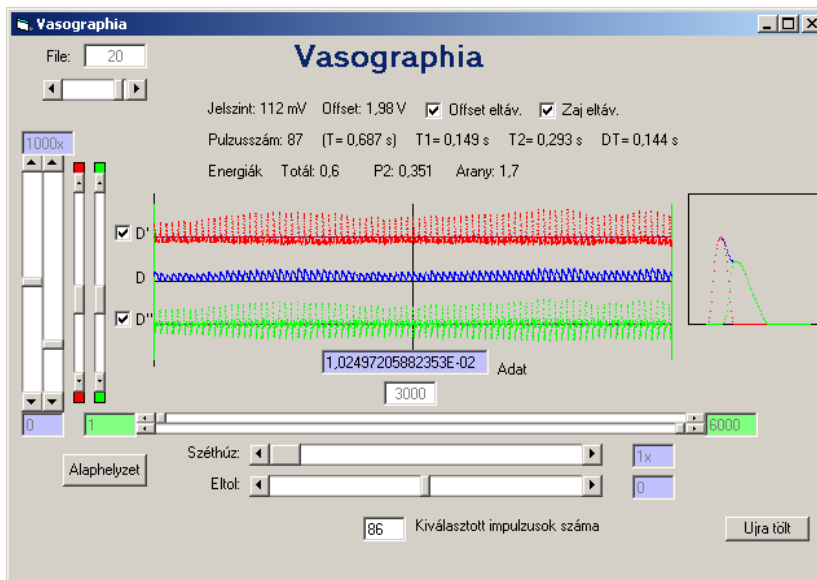

Figure 4
The user interface of the vasographia.exe

In the followings we give a short explanation of each element shown on the screen. Some controls have a default value, which is indicated in parenthesis after the name.

1, Controls:

> Datafile/Patient selection
> remove offset (ON), remove noise (ON)
> data graph shift up/down
> data amplification
> magnify first and second derivative
> show first (ON) and second derivative (ON)
> Reset controls, Reload data
> select window (set left and right index)
> shift graph (0) and zoom graph (1x)

2, Main graphs:

   - original data (D, blue)
   - 1st (D', red) and 2nd derivative (D", green)

3, Pulse window:

   full (blue), arterial (red) and secondary (green)

4, Numerical values:

   summary:

      offset value, heartbeats/min
      average time between beats (T)
      main (arterial) peak rise time (T1)
      secondary peak time (T2)
      time delay (DT)
      total energy of the pulse and
      energy of the secondary pulse
      energy ratio of total/secondary

   additional data (below the graph):

      signal amplitude at the cursor position
      cursor absolute position (data index)
      data window (from - to)
      magnification
      cursor relative position/shift
      number of pulses in the window

Conclusions

We were able to develop an algorithm to extract and visualise useful information for the cardiologist from a sometimes very haphazard changing data flow obtained from a photoplethysmograp containing pulse oxymeter. After extensive testing and feed-back from the physicians we could enhance the above presented diagnostic system, or completely redesign to a lightweight standalone device using reconfigurable arrays [12]. The data could be sent wirelessly to the nearby computer or access point in order to monitor the patient or even several patients simultaneously.

Acknowledgement

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