Respiratory Rate Determination by Non-Invasive Means

Assignment, The Art of Scientific Computing — Due Date: 01/01/2014

1 The Problem

One of the most useful non-invasive markers of respiratory illness is the respiratory rate – the number of complete breathing cycles per minute. In children brought to a small clinic in a low-resource setting (e.g. much of Africa) with a complaint of cough and/or difficult breathing, the respiratory rate is a useful way of distinguishing the child who can safely be sent home from the child who needs further investigation and may benefit from antibiotics and/or supplementary oxygen.

However, counting a child's respiratory rate is actually quite difficult and time-consuming, and in a busy clinic the health workers often 'make do' with an inadequate examination. The result is either the waste of scarce resources like oxygen and antibiotics, or sending home children who should be admitted to hospital. This is one of the reasons pneumonia still accounts for over 900,000 deaths in children under the age of five every year.

2 A Potential Solution

A simple, painless, non-invasive method to automate the counting of a child's respiratory rate – preferably in the waiting room – would contribute greatly to the diagnosis and care of children with pneumonia and other severe respiratory illnesses. The electrocardiogram (ECG) is a measurement of the heart's electrical activity using contacts placed on the skin, that is non-invasive and relatively simple to acquire. An example ECG is shown in Fig. 1. It is known that ECGs contain a respiratory signal, an algorithm that could reliably and accurately detect the respiratory signal in a child's ECG would be extremely useful, especially if it could be run on low-cost hardware such as a mobile phone.

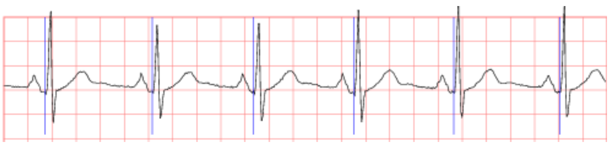

Figure 1: An example of an ECG signal.[1, 2] The sharp peaks are called R peaks and the R-R interval is the spacing between sequential peaks.

3 Some Underlying Physiology

The intra-thoracic pressure, the position and shape of the heart, and stimuli to the sinoatrial node by the vagus nerve, all vary rhythmically with inspiration. In young, healthy people, these lead to the pulse rate increasing slightly during inspiration and decreasing again during expiration. This is visible in the standard ECG as changes in the measured interval between successive R-peaks: the R-R interval is shorter during inspiration and longer during expiration.

4 The Computational Challenge

Factors other than respiration can alter both the heart rate and the shape and structure of the ECG. The effect of respiration on the ECG varies between individuals and in the same individual with varying variations in breathing; depth of respiration, etc. In general the older the person the less marked the respiratory signal. Other electrical signals (e.g. from skeletal muscles) can mask the ECG and/or make its baseline wander. Any useful algorithm will need to filter out non-respiratory effects as well as perform the basic functions of finding the component parts of the ECG signal (especially the R-peak) and calculating the R-R interval over time. The best algorithm will be one that can simply, accurately and quickly calculate the respiratory rate.

5 Getting Started

Task 1 Download the data set from: `https://www.physionet.org/physiobank/database/apnea-ecg/`, this is a publicly available ECG data-set of both healthy patients and patients with apnoea that you will be analysing to produce your algorithm. More information about the data-set can be found in the link. After downloading the data move the relevant files to a directory structure that you are comfortable working with.

Task 2 Write a program to read the ECG data and convert/save it to a useful format.

Task 3 Experiment with visualising the data. Produce accurately scaled plots, Voltage vs Time, for several of the signals. Produce a plot of a section of the ECG showing the 'typical' features. Using the accompanying annotation files plot a section of the ECG that highlights the presence of apnoea.

Task 4 Begin your own investigation and use the following questions to prompt discussion with your group. How might the data be processed to find the underlying respiratory signal? How might you find the R-peaks and R-R interval, will these change over time? Is any filtering of the signals required? Can you find any relevant correlations?

References

[1] Thomas Penzel, George B Moody, Roger G Mark, Ary L Goldberger, and J Hermann Peter. The apnea-ecg database. In *Computers in cardiology 2000*, pages 255–258. IEEE, 2000.

[2] Ary L Goldberger, Luis AN Amaral, Leon Glass, Jeffrey M Hausdorff, Plamen Ch Ivanov, Roger G Mark, Joseph E Mietus, George B Moody, Chung-Kang Peng, and H Eugene Stanley. Physiobank, physiotoolkit, and physionet. *Circulation*, 101(23):e215–e220, 2000.