The Characteristics of Korotkoff Sounds Using the Instantaneous Frequency Method

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Abstract— The Systolic and Diastolic blood pressure can be measured by using Korotkoff Sounds, which been characterized into five phases. These five phases are important to measure both of the Systolic and Diastolic blood pressure. In this paper, the Korotkoff sound from 15 healthy volunteers has been recorded. The characteristics of the Korotkoff sounds signals are then analyzed by using the Instantaneous Frequency (IF) concept. It was found that phase 1, phase 2, phase 3, phase 4 and phase 5 have the frequencies range between 5 to 32 Hz. The phase 3 has the highest amplitude and then starts to decrease in phase 4 and phase 5.

Keywords — Diastolic, Systolic, blood pressure, Korotkoff Sounds and Instantaneous Frequency (IF).

1 Introduction

Blood pressure is a good indicator to assess the state of the circulatory system [1]. Non invasive measurement methods have been used to obtain instantaneous values of blood pressure which correspond to the highest (Systolic) and lowest (diastolic) or the mean of blood pressure, but there is no known method allows us to directly obtain the three values. Normally the values of pressure can be calculated by using several mathematical relations, which have been studied by a limited number of researchers [2].

Generally, the most popular clinical measurement of the blood pressure been obtained by listening an osculation of the Korotkoff sounds [1]. The characteristic features of the Korotkoff sounds can been described as [3]:

Phase 1: the sounds have a high pitch with a clear-cut and snapping tone.
Phase 2: the sounds have a murmur-like quality.
Phase 3: the sounds are similar in character to the first phase sounds.
Phase 4: the sounds have a dull or muffled tone.
Phase 5: the sounds complete disappearance.

Phase 1 is important to determining the systolic blood pressure, while both of phase 4 and phase 5 are used to determining the diastolic blood pressure. Many researchers been studied the Korotkoff sounds by using various methods, and there were no common agreement for the range of frequency in the Korotkoff sounds [4].

In this work the characteristics of Korotkoff Sounds have been done from 15 healthy volunteer ages between 19 to 24 years old.

2 Method of Measurements and Analysis

2.1 Measurement Method

The Korotkoff sounds from the 15 healthy volunteers were recorded by using cardiology stethoscope (Littman Cardiology III stethoscope, 3M) attached with high sensitivity microphone (BL 1994, Knowles Electronics Company) and shortened (8 cm) piece of stethoscope grade tubing. The signal from the microphone has been amplified by connecting an amplifier with frequency response of 1Hz to 20 KHz. Then, the signal was captured by using a Data Acquisition with 16-bit resolution A/D converter (ADC216, Pico Tech.).

The blood pressure measurement of the volunteers was done in a quite noise free room at The Clinic of University Putra Malaysia by a nurse after each subject was at rest for 5 minutes.

2.2 Analysis Method

The time-frequency analysis techniques have been used for the analysis, since they have given the time and frequency components of a given signal simultaneously. Instantaneous Frequency (IF) is one of an important concept in time–frequency analysis [5]. The IF is a time–varying parameter which defines the location of the signals spectral peak at varies time. [5, 6].

If a Hilbert transform was used to generate the complex signal, a unique representation can be obtained for a given real time signal, s(t) [5]. Then, the signal s(t) of the IF can be uniquely defined by using the analytic signal. This is formally been expressed as:

$$z(t) = a(t)e^{j\phi(t)} \quad (1)$$

$$\phi(t) = \tan^{-1}\frac{\operatorname{Im}[z(t)]}{\operatorname{Re}[z(t)]} \quad (2)$$

Where Im[z(n)] and Re[z(n)] are the Imaginary and real parts of complex signal, respectively.

And

$$f_{i_f}(t) = \frac{1}{2\pi}\frac{\partial\phi(t)}{\partial(t)} \quad (3)$$

Where $f_{i_f}(t)$ is the Instantaneous Frequency of signal.

3 Results

Figure 1 shows a sample of the phases of the Korotkoff sounds, which then being used in the IF method. The analysis of the different phases using the IF method are shown in Figures 2 till Figure 6.

It was found that for phase 1; the frequency range is between 6 to 29 Hz, and the frequency at the start of the phase is the highest and then starts to decrease with time to 6 Hz. For phase 2 the frequency range is between 15 to 32 Hz; and the frequency at the start of the phase is the highest and then a start to decrease with time to 15 Hz but the amplitude in this phase has increased. For phase 3 which has the largest amplitude, and the frequency at the start of the phase from 30 Hz and then decrease with time to 13 Hz. For phase 4; the frequency range is between 11 to 23 Hz, and the frequency at the start of the phase is the highest and then starts to decrease with time to 11 Hz. For phase 5 the frequency range is between 5 to18 Hz, and the frequency at the start of the phase is the highest and then starts to decrease with time to 5 Hz and then the sound in this phase has started to disappeared. In phase 4, the amplitude was also decreases and reaches to lowest amplitude in phase 5.

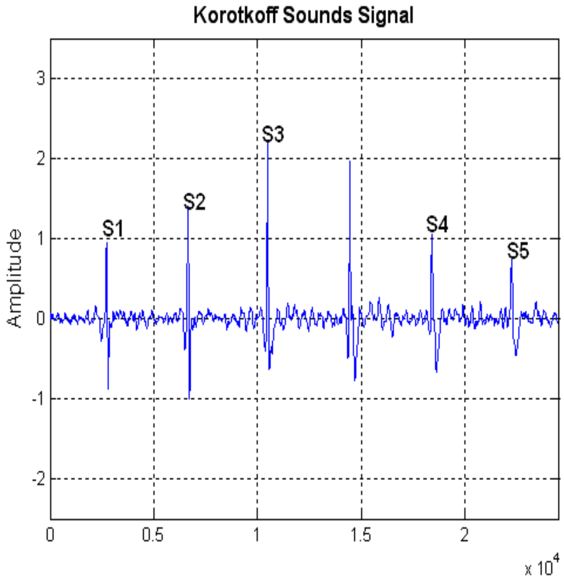

Fig.1. sample of the phases of Korotkoff sounds

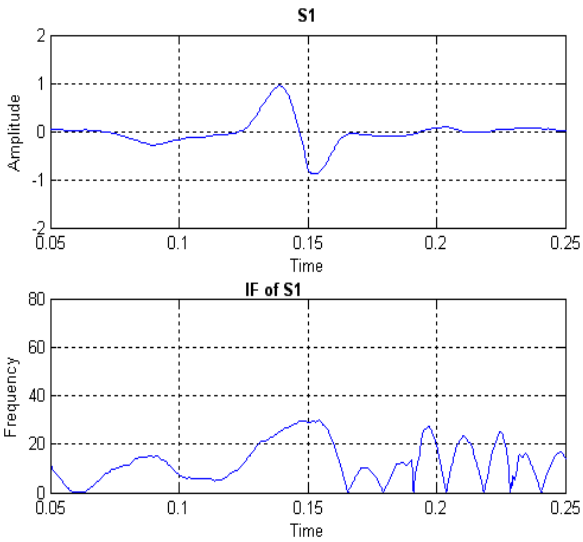

Fig. 2. Phase 1

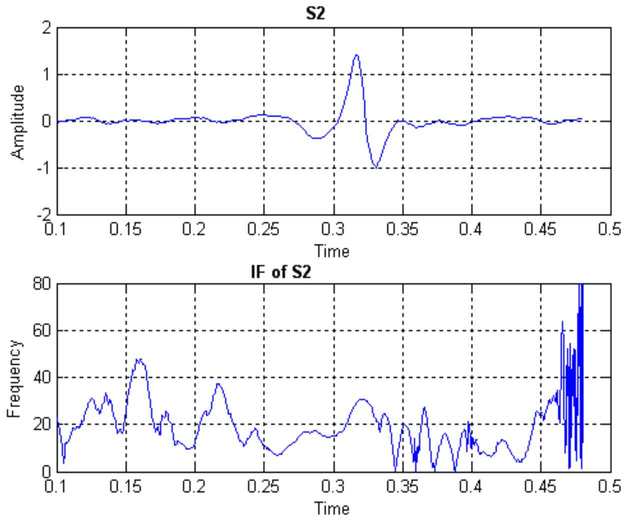

Fig. 3. Phase 2

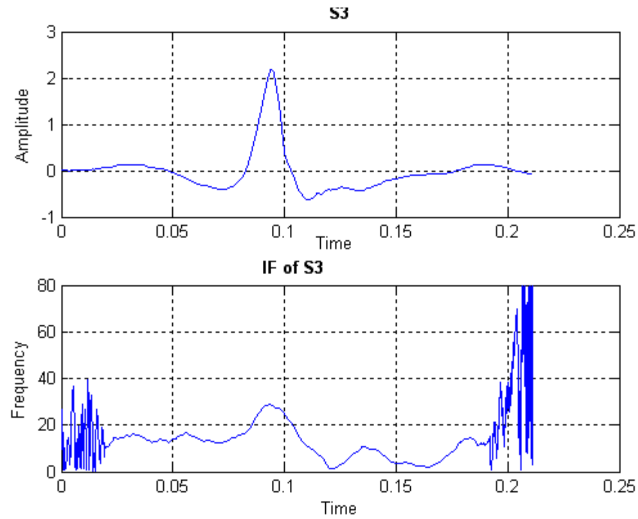

Fig. 4. Phase 3

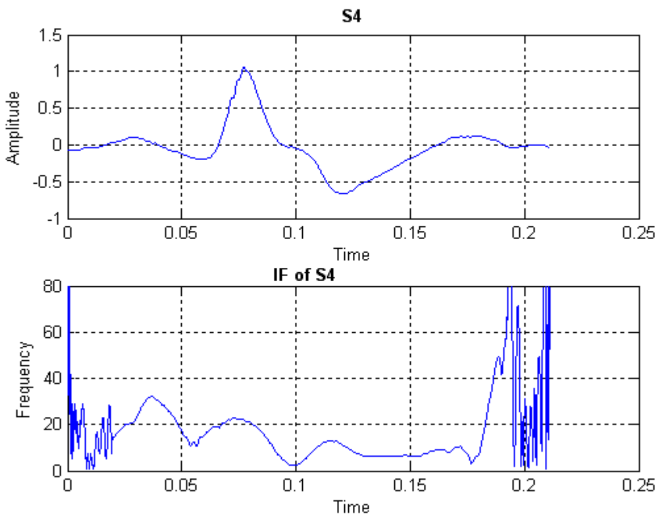

Fig. 5. Phase 4

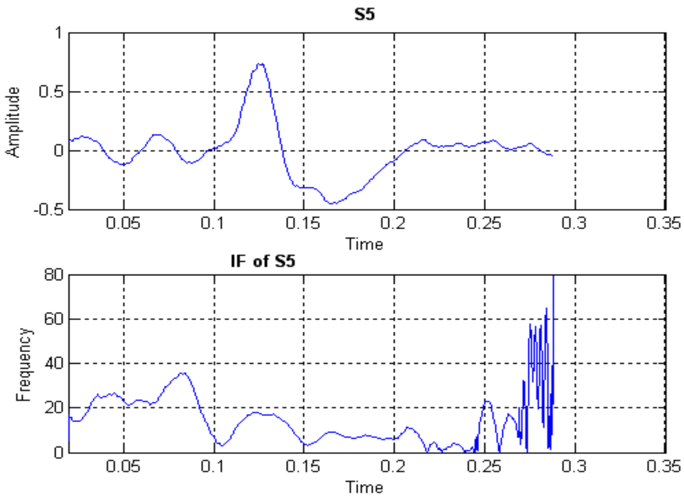

Fig. 6. Phase 5

3 Conclusion

In this paper it is shown that the frequency variations over time of Korotkoff Sounds are clearly represented by using the method of Instantaneous Frequency (IF) where the frequency range of the phases of Korotkoff sounds is between 5 Hz to 32 Hz.

4 Acknowledgments

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