

A STUDY ON INTERPRETING MULTIRATE DSP ON THE HEART SOUND SIGNALS

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Abstract: The primary function of a coronary care unit is to monitor the rhythm of cardiac patients. The cardiac abnormality of the patients should be identified during the early stage. The heart sound recording is the phonocardiogram (PCG) signal. Stethoscopes are commonly used to hear the heart sound for diagnosis. In common, the heart murmurs may be caused by high blood pressure, heart attack, pregnancy, rheumatic fever, anemia or thyrotoxicosis. The healthy subject produces the clear “lub” and “dub” sound signals even can be heard by without stethoscopes. This study applies multirate digital signal processing (DSP) on the heart sound signals, especially the process of upsampling and downsampling with integer factor two. The spectrum views of the actual, upsampled and downsampled heart sound signals are viewed using Matlab software tool.

Keywords: Decimation, heart sound, multirate DSP, interpolation, Matlab.

1. Introduction

The heart is an essential organ with average size about 12 cm long (base-to-apex) and 8 cm wide. Its principal functions are to pump the deoxygenated blood to the lungs in which the exchange of carbon dioxide-oxygen takes place and to pump the oxygenated blood to the whole body. The right and left sides are the two functional sides of a heart. They are separated by the septum. They are further divided into chambers. The right-sided chambers contain the right atrium and the right ventricle; the left-sided chambers contain the left atrium and the left ventricle. Figure 1 shows the cross-section of a human heart [1].

The chambers are separated by unidirectional valves which control the blood flow too. The right atrium and right ventricle are separated by the right atrioventricular (AV) valve; the left atrium and left ventricle are separated by the left AV. The right ventricle and pulmonary artery are separated by the semilunar pulmonic valve; the left ventricle and aorta are divided by the semilunar aortic valve. The vibrations of from bumpy blood flow, heart's walls and valves

are heard as heart sounds through a stethoscope. During the cardiac cycle, the heart's walls and valves are flexible as they move in response to pressure [2].

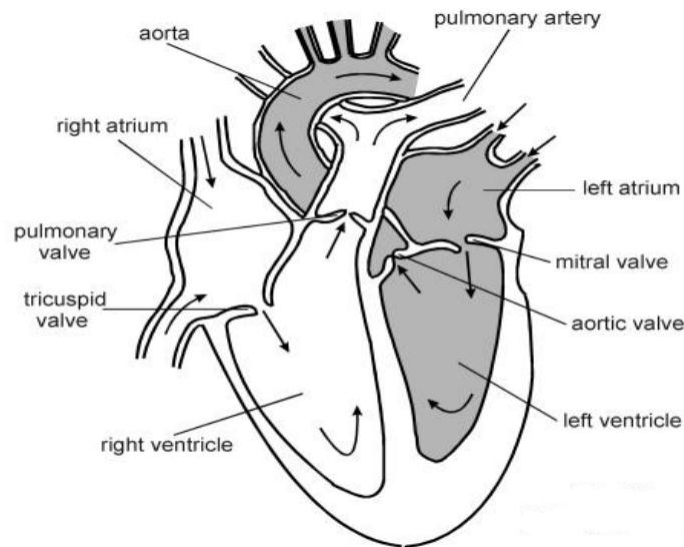


Fig. 1: Human heart cross section

In a human body, to diagnose the clinical auscultation, the heart sound (HS) is an important physiological signal [3,4]. Two basic heart sounds (S1 and S2) are produced from a normally functioning heart during a cardiac cycle. These sounds are caused due to the blood acceleration or deceleration in the heart's chambers. S1 produces the "lub" sound and S2 produces the "dub" sound, and hence "lub-dub", "lub-dub", sounds occur in a heart. Even an ordinary person can hear and identify or distinguish the different heartbeats such as normal heartbeat, fast heartbeat, slow heartbeat and irregular heartbeat [5,6].

Heart sound or phonocardiogram (PCG) signals do have high similarity with the electrocardiogram (ECG) signals. In ECG, during the cardiac cycle, the activation of the atria belongs to P wave; the activation of the ventricles belongs to QRS complex; the recovery wave belongs to T wave [8,9]. The ventricular contraction is the reason for the first heart sound "S1". This S1 sound occurs at the same time as the QRS complex in the ECG signal with a low-frequency band about 10 – 120 Hz. The second heart sound "S2" is due to the closing scene of the pulmonary and aortic valves, which occurs during the end of the T wave in the ECG signal. The S2 sound frequency is normally higher than that of the first sound with a low-frequency band about 10 – 200 Hz [10].

The actual sample rate of the signal depends on the hardware and hence may be lower (or higher) than needed. For example, if we demodulate a 9600 baud modem signal, the required sample rate should be a multiple of 9600. Hence, there is always a demand to change the sample rate in real-time applications. The sample rate modification can be done using decimation,

interpolation or the combination of both. The objective behind the multirate DSP is to alter the sample rate with preserving the same signal (or spectrum) and also to remove the noise during the process [11].

This paper is organized as follows. Section 2 contains the spectrums of the actual, upsampled and downsampled of S1 and S2 sound signals respectively. The conclusions are finally described in Section 3.

2. Multirate DSP on Heart Sound Signals

2.1. Upsampled spectrums of heart sound signals

The upsampling with a factor two is applied to the heart sound signal (S1) of a normal person [10], and the results of the spectrum are shown in Figure 1. The actual spectrum has the period 2π while the upsampled signal has the spectrum with period π as illustrated in Figure. Figure 2 shows the same with the S2 heart sound.

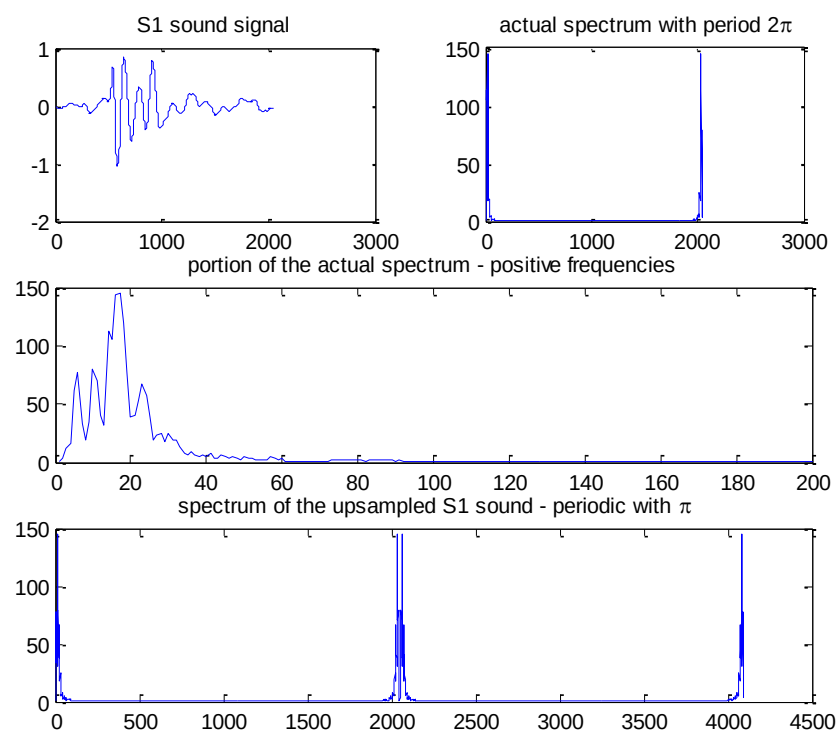


Figure 1. Spectrums of the actual and upsampled S1 sound signal.

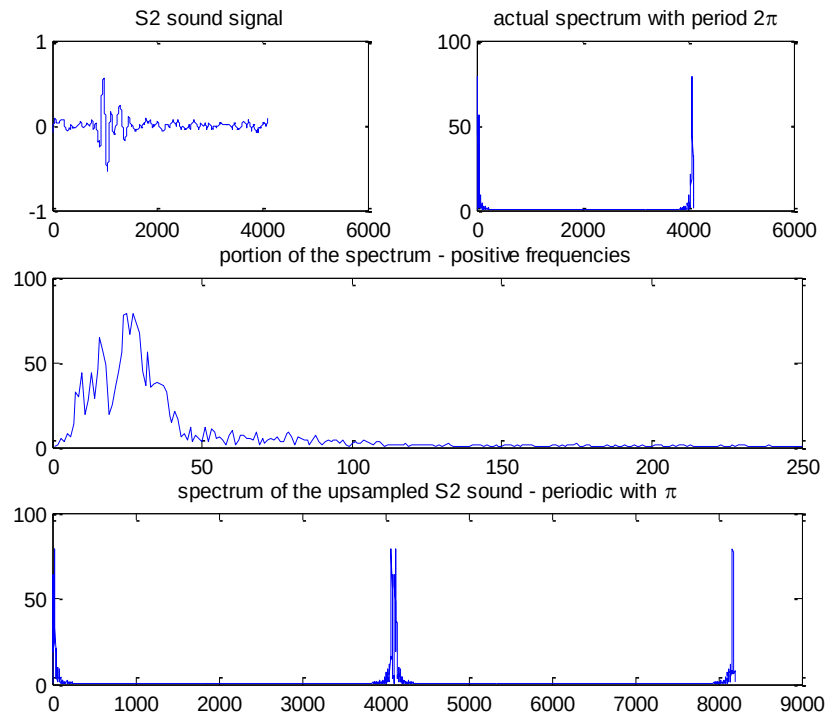


Figure 2. Spectrums of the actual and upsampled S2 sound signal.

Also, theoretically for better understanding, the spectrum of the actual sequence and the spectrum of the upsampled sequence are shown in Figure 3 and 4 respectively [12–15].

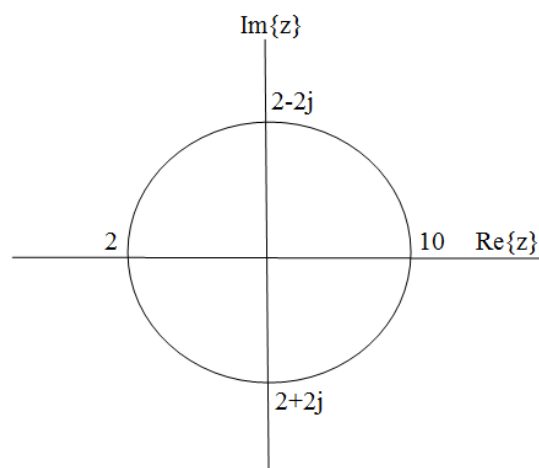


Figure 3. The DFT of the sequence $\{4, 3, 2, 1\}$.

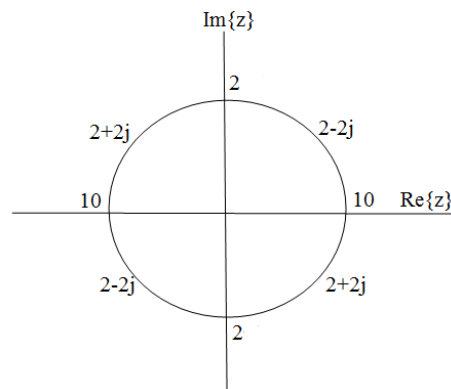


Figure 4. The DFT of the upsampled sequence $\{4, 0, 3, 0, 2, 0, 1, 0\}$.

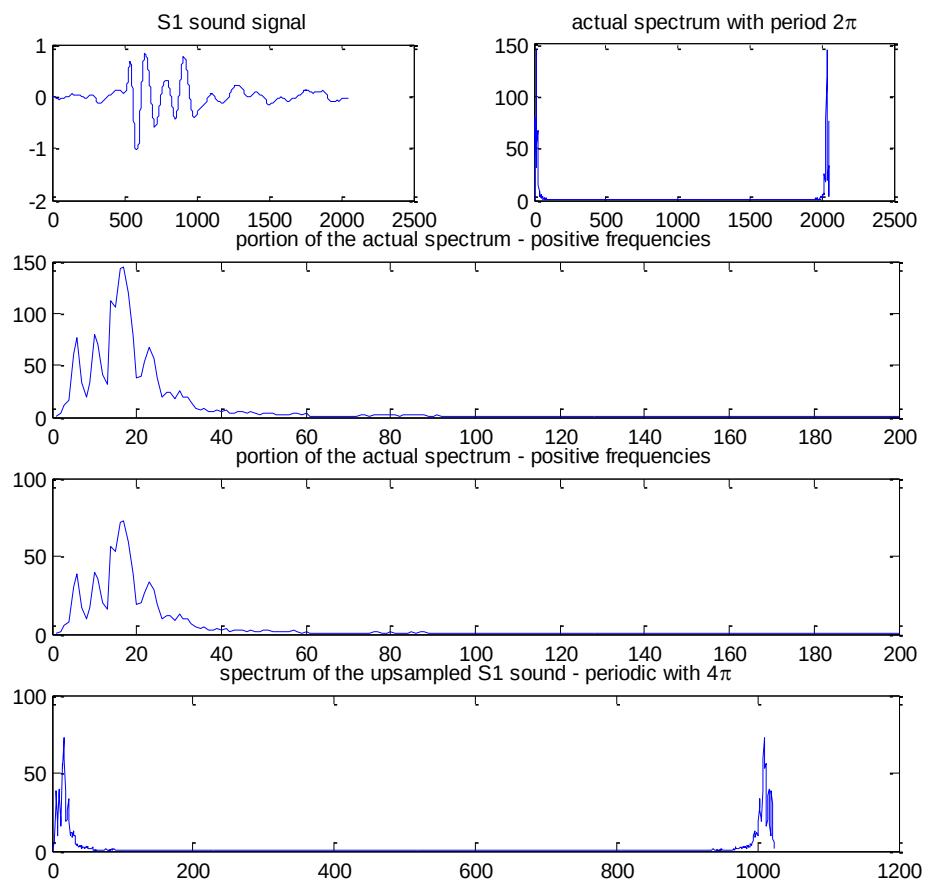


Figure 5. Spectrums of the actual and downsampled S1 sound signal.

2.2. Downsampled spectrums of heart sound signals

The downsampling with a factor two is applied to the heart sound signal (S1) of a normal person [10], and the results of the spectrum are shown in Figure 5. The actual spectrum has the period 2π while the downsampled signal has the spectrum with period 4π as illustrated in Figure. Figure 6 shows the same with the S2 heart sound.

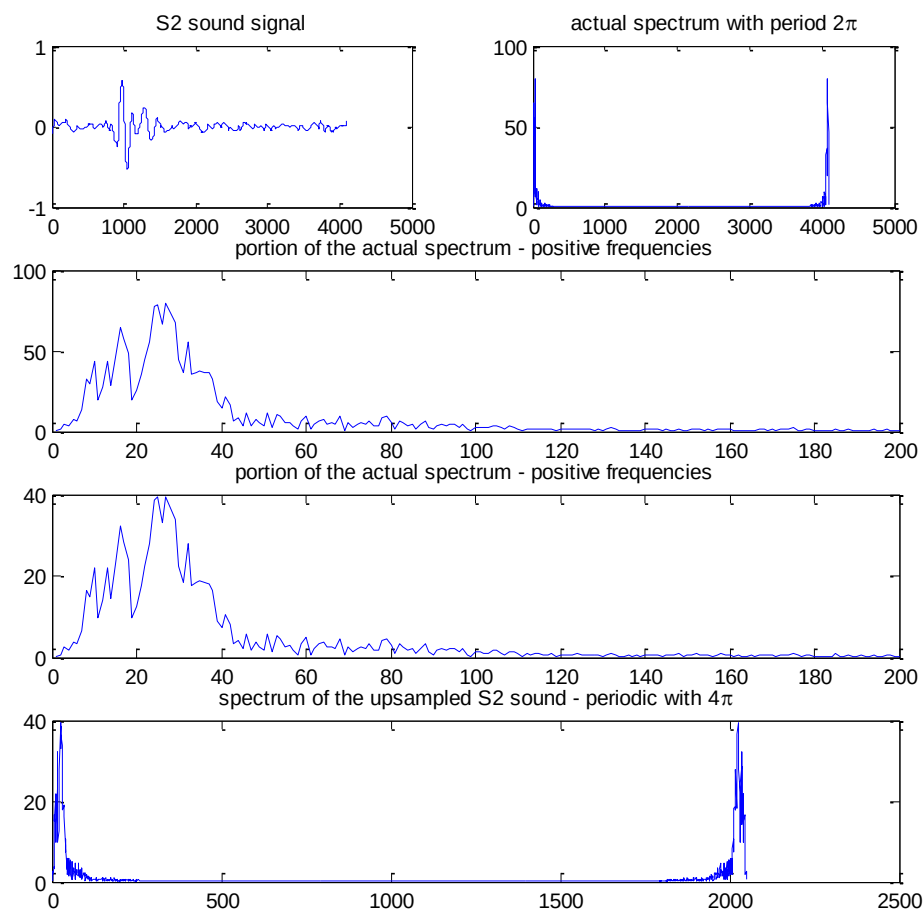


Figure 6. Spectrums of the actual and upsampled S2 sound signal.

Also, theoretically for better understanding, the spectrum of the actual sequence and the spectrum of the downsampled sequence are shown in Figure 7 and 8 respectively [12–15].

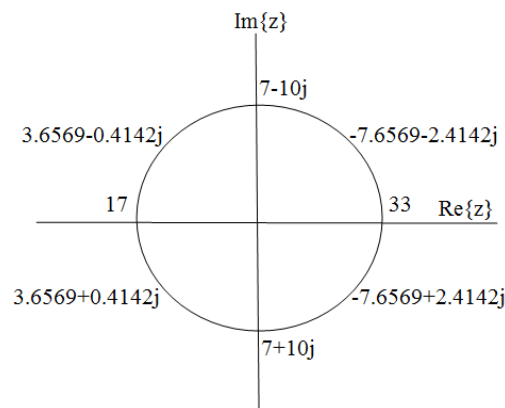


Figure 7. The DFT of the sequence $\{7, 3, 5, 2, 9, 6, 4, -3\}$.

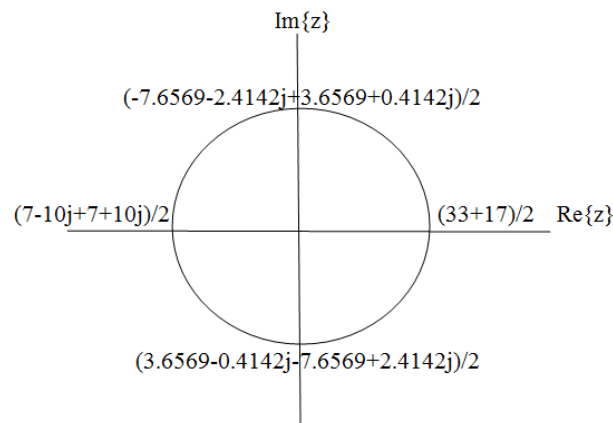


Figure 8. The DFT of the downsampled sequence $\{7, 5, 9, 4\}$.

3. Conclusion

The motive of this study is to provide more clarity on the interpolation and decimation process through spectrum views. For example, how the spectrum is compressed and stretched is analyzed through heart sound signals. This work can be further extended to design suitable multi-rate filters, the sampling rate conversion by non-integers (resampling), the design of polyphase filters, etc.

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