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COMPARISION SPECTRAL ANALYSIS METHODS ACCORDING TO THE PERFORMANCE AND SELECTIVITY FOR THE S1-S2 HEART SOUNDS

ABSTRACT

In this study, time-amplitude data were obtained by being analyzed heart sounds in the wav file format that were received from eGeneral Medical Inc. database with software which was developed in Visual Studio C#.Net. On these data, Discrete Fourier Transform (DFT), Periodogram Power Spectrum Density (PSD), Shannon Energy and Short-time Fourier Transform (STFT) methods were used besides Hamming, Hanning and Blackman windowing functions. These methods were compared in terms of code process time and graphically selectiveness. As a result, it is seen that the process time of Shannon Energy method was much faster than DFT, STFT and Periodogram PSD methods and more efficient in classification of S1 and S2 heart sounds.

Keywords: DFT, STFT, Periodogram PSD, Shannon Energy, Windowing, PCG, Heart Sounds

SPEKTRAL ANALİZ YÖNTEMLERİNİN PERFORMANSA VE S1-S2 KALP SESLERİNİN SEÇİCİLİĞİNE GÖRE KARŞILAŞTIRILMASI

ÖZET

Bu çalışmada, eGeneral Medical Inc. ait veri bankasından alınan wav formatındaki kalp sesleri Visual Studio C#.Net'de hazırlanan yazılım ile çözümlenerek zaman genlik verileri elde edildi. Bu veriler üzerinde Hamming, Hanning ve Blackman pencereleme ile beraber Ayrık Fourier Dönüşümü (AFD), Shannon Enerji ve Periodogram Güç Spektrum Yoğunluğu (PGSY), Kısa zamanlı Fourier Dönüşümü (KZFD) teknikleri uygulandı. Uygulanan teknikler işletim performansları ve grafiksel seçicilik yönünden kıyaslandı. Sonuç olarak Shannon Enerji uygulamasının işlem süresinin AFD,KZFD ve PGSY uygulamalarına göre çok daha hızlı olduğu ve S1 ve S2 kalp seslerini tanımlamada daha etkin bir metot olduğu görüldü.

Anahtar Kelimeler: Ayrık Fourier Dönüşümü, Shannon Enerji, Kısa-zamanlı Fourier Dönüşümü, Periodogram Güç Spektrum Yoğunluğu, Pencereleme, Kalp Sesleri

1. INTRODUCTION (GİRİŞ)

The majority of death rates in the world consist of heart diseases. The success of treatment depends on the early diagnosis of heart disease [1]. One of the easiest methods used in early diagnosis is auscultation which began with using stethoscope by Laennec in 1816. The graphically display of heart sounds that is recorded by stethoscope is phonocardiogram (PCG) [2]. Nowadays, the analysis of PCG has an importance in clinical practice with being developed Digital Signal Processing (DSP) methods [3].

In literature about this subject, an algorithm was developed by the researchers in 1995 for classification of heart sounds. This algorithm was performed in heart sounds data of 30 patients and was searched the classification feature of heart sounds [4]. In 1997, Chen and his friends worked on S1 heart sound for evaluating accuracy rating of time-frequency technique [5]. In 2001 DeGroff and his friends analyzed the sounds which were taken from sixty-nine patients using an electronic stethoscope with Fast Fourier Transform (FFT) and they used artificial neural networks for classification [6]. In 2002 Dahl and his friends get heart sounds from 47 patients using a sensor-based electronic stethoscope and they send e-mail to medical specialists by recording these sounds in wav format [7]. Kumar and his friends worked on the classification of S1 and S2 heart sounds by using Shannon Energy and Fast Wavelet Transform (FWT) in 2006 [8]. Otherwise there are many thesis and articles about this subject. In the work of Debbal and Reguig, they work on analysis and comparison on PCG sounds of spectrogram, Wigner Distribution (WD) and Wavelet Transform [9]. According to literature, it is seen that researchers analyzed heart sounds using different DSP methods and decision systems.

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

This paper determines the code process time and graphically selectivity of S1 and S2 heart sounds with spectral analyzing methods. Time-amplitude data will be obtained analyzing heart sounds in wav format, taken from eGeneral Medical Inc. (http://www.egeneralmedical.com) data bank. It will be implemented Hamming, Hanning and Blackman windowing techniques with STFT, DFT, Shannon Energy and Periodogram PSD techniques on these data. The spectral analysis methods will be applied in own software which will be improved at C#.Net language and these methods will be compared in terms of code process time and selectivity. As a result of analysis, the suitable method codes could be embedded to any medical systems.

3. EXPERIMENTAL METHOD (DENEYSEL YÖNTEM)

Heart sounds are originated by blood flow with opening and closing of heart valves during systole and diastole (Figure 1). Heart sounds consist of four basic sounds such as S1, S2, S3 and S4 [10 and 11]. S1 is the sounds which occur in 20Hz-45Hz frequency range with closing mitral and tricuspid valves at the left ventricle pressure reaches the pressure in the left atrium. S2 is the sounds which occur in 50Hz-70Hz frequency range, with decreasing under aorta pressure by falling the pressure in the ventricle and with closing aortic valve and then immediately pulmonary valve when relaxation begins by being completed convulsion in ventricles [12].

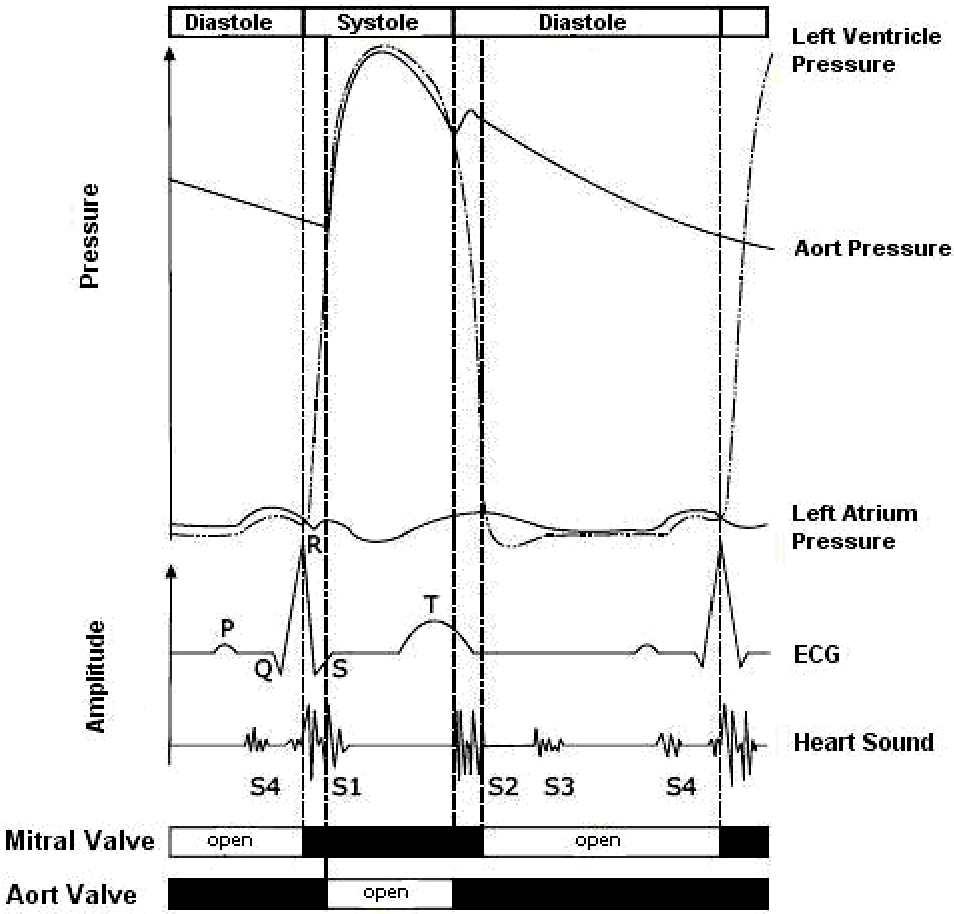

Figure 1. Heart ssound and its relations with different conditions
(Şekil 1. Kalp sesi ve değişik durumlarla ilişkisi)

3.1. DSP Analysis Program (DSP Analiz Programı)

The flow chart belongs to DSP analysis program which is prepared on C#.Net platform, is shown in Figure 2. Firstly, heart sound taken from data bank is analyzed reading bitpersample and sampling frequency and then time-amplitude data is obtained. By choosing one of the hamming, hanning and blackman windowing techniques is performed on the data and output coefficients are obtained. One of the DFT, STFT, Shannon Energy and PSD methods is applied to output data which is obtained as a result of window function. And then, analysis results are displayed in graphic panel and code process time is determined.

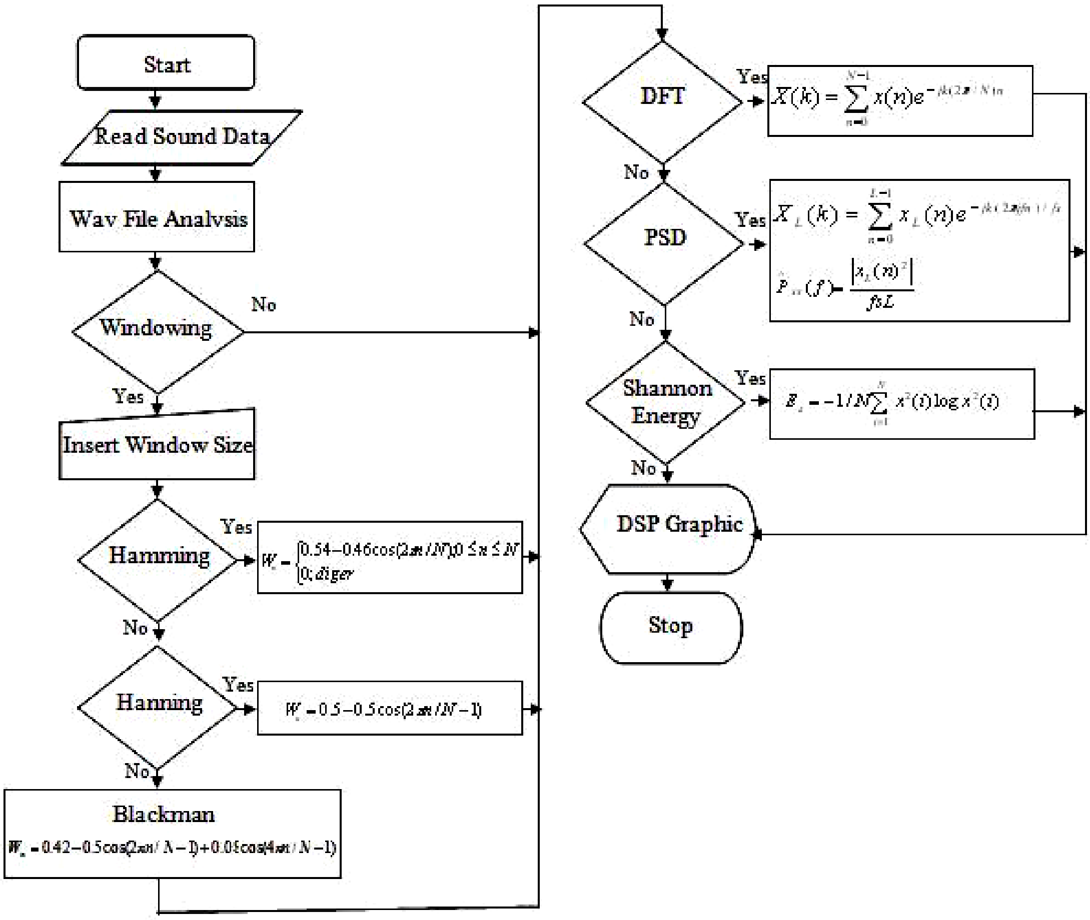

Figure 2. Flow chart of program
(Şekil 2. Program akış şeması)

3.2. Spectral Analysis Methods (Spektral Analiz Yöntemleri)
3.2.1. Windowing (Pencereleme)

Because physiologic signals are noisy, windowing functions are applied which filter on signals in order that sounds can be distinguished. Because signals do not lose its features and the information, Hamming at equation 1, Hanning at equation 2 and Blackman at equation 3 are used by choosing proper window length [14].

$$W_n = \begin{cases} 0.54 - 0.46\cos(2\pi n / N); 0 \le n \le N \\ 0; other \end{cases}, \tag{1}$$

$$W_n = 0.5 - 0.5\cos(2\pi n / N - 1), \tag{2}$$

$$W_n = 0.42 - 0.5\cos(2\pi n / N - 1) + 0.08\cos(4\pi n / N - 1), \tag{3}$$
$$n = 0,1,2,.............N-1$$

Where, W_n represents coefficients of windowing functions.

3.2.2. Discrete Fourier Transform (Ayrık Fourier Dönüşümü)

Discrete Fourier Transform (DFT) is called as a transformation which is identified for *N* samples of *x(n)* serial and proper spaced *N* frequency point around unit circle. After digital signal on issued finite length is made periodic, DFT is implemented with finding coefficients of Fourier series. The DFT may be expresses as [14, 15 and 16],

$$X(k)=\sum_{n=0}^{N-1}x(n)W_N^{kn} \quad , \; k = 0,\ 1,\ 2 \ldots\ldots\ N - 1 \tag{4}$$

Where, by definition,

$$W_N = e^{-j2\pi/N} \tag{5}$$

Where, $\{x(n)\}$ represents input signal, N represents the signal length. When the signal is transformed in polar notation, real and imaginary parts of the signal are defined by

$$\operatorname{Re}X[k]=\sum_{i=0}^{N-1}x[i]\cos(2\pi ki/N)\,, \tag{6}$$

And

$$\operatorname{Im}X[k]=-\sum_{i=0}^{N-1}x[i]\sin(2\pi ki/N)\,; \tag{7}$$

Where, $\{x(i)\}$ represents the input signals. Finally, estimated DFT is

$$X[k]=\sqrt{(\operatorname{Re}X[k])^2+(\operatorname{Im}X[k])^2} \tag{8}$$

3.2.3. Short-time Fourier Transform (Kısa Zamanlı Fourier Dönüşümü)

Spectral analysis of the signal is performed using the Short-time Fourier Transform (STFT), in which the signal is divided into small sequential or overlapping data frames. The STFT of $x(n)$ is a set of such discrete time Fourier transform corresponding to different time sections of $x(n)$. Time section for time t is obtained by multiplying $x(\tau)$ with a shifting sequence $w(\tau-t)$. In STFT analysis, the signal is multiplied by a window function $w(n)$ and the spectrum of this signal is calculated using the Fourier transform [17 and 18]. Thus,

$$STFT(t,f)=\left|\int_{-\infty}^{+\infty}x(\tau)w(\tau-t)e^{-j2\pi f\tau}d\tau\right|^2 , \tag{9}$$

Where, w referred to as analysis window. In this study, the STFT was performed using a 128 point Hamming, Hanning and Blackman windowing function.

3.2.4. Periodogram Power Spectrum Density (Periodogram Güç Spektrum Yoğunluğu)

Periodogram method based on Fourier transform at the same time is known as classical spectral estimation method. HFD-based spectral analysis methods are identified as nonparametric methods [19 and 20]. Periodogram spectral estimation of this method which is one of the HFD-based methods is stated like that [16],

$$P_{xx}(f)=\frac{1}{N}\left|\sum_{n=0}^{N-1}x(n)e^{-jk(2\pi/N)n}\right|^2 = \frac{1}{N}\left|X(f)\right|^2 , \tag{10}$$

k = 0, 1, 2……. N-1

Where, *X(f)* is the Fourier transform of the sample sequence $\{x(n)\}_{n=1}^{N}$.

3.2.5. Shannon Energy (Shannon Enerji)

With choosing proper window interval *(N)* by applying Shannon Energy equation which has noise suppression effect on signal, auxiliary data to determine characteristic of signal are produced [21].

$$E_s = -1/N\sum_{i=1}^{N} x^2(i)\log x^2(i), \tag{11}$$

Where, *x(i)* is the analyzed signal and *N* is the signal length.

4. FINDINGS AND DISCUSSION (BULGULAR VE TARTIŞMA)

With performed software, heart sound in wav format has 11025 Hz and 16 bit resolution and was received from data bank belongs to the eGeneral Medical Inc. was analyzed on machine which has Intel Core2 T7200 2Ghz processor and 3GB Ram capacity. As sampling frequency proportionally, corresponding to two or more than heartbeats with 16384 data length was chosen and then comparison was made between the different windowing and spectral analysis methods. Without being applied window function to heart sound data, when DFT method was used (Figure 3), 16384 output coefficients were obtained at 8.12 seconds.

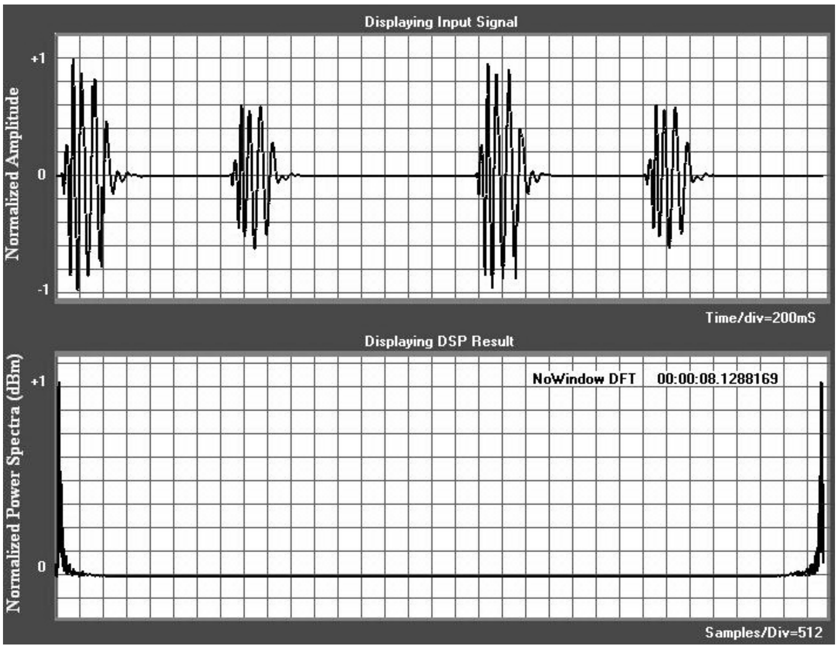

Figure 3. DFT applications
(Şekil 3. AFD uygulaması)

When STFT was applied (Figure 4) by subjecting to 128 window size and hamming window function to the heart sound data, 8192 output coefficients were obtained at 0.33 seconds.

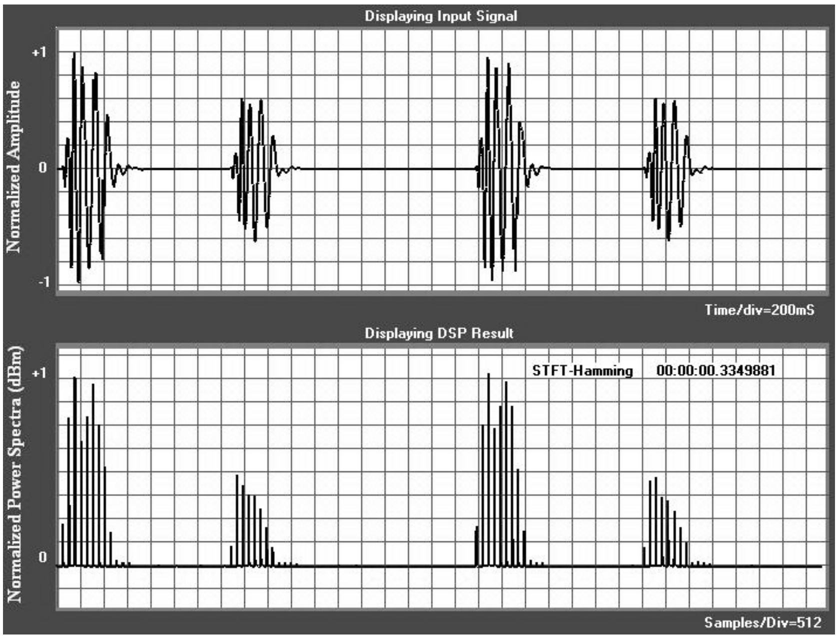

Figure 4. STFT with hamming function
(Şekil 4. Hamming pencere fonksiyonu ile KZFD)

When STFT was applied by subjecting to 128 window size with hanning function to the same signal (Figure 5), 8192 output coefficients were obtained at 0.14 seconds.

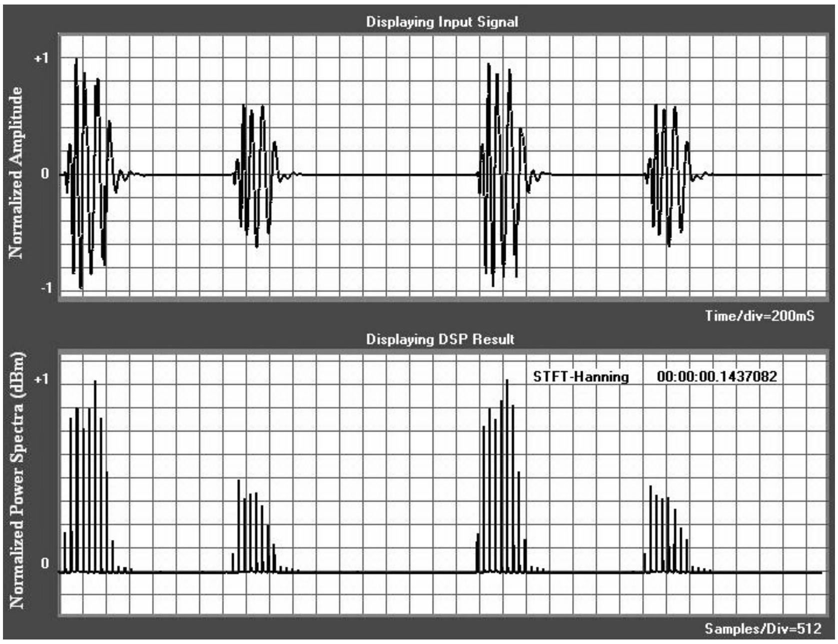

Figure 5. STFT with hanning function
(Şekil 5. Hanning pencere fonksiyonu ile KZFD)

When STFT was applied by passing 128 window sizes with Blackman function to the signal (Figure 6), 8192 output coefficients were obtained at 0.14 seconds.

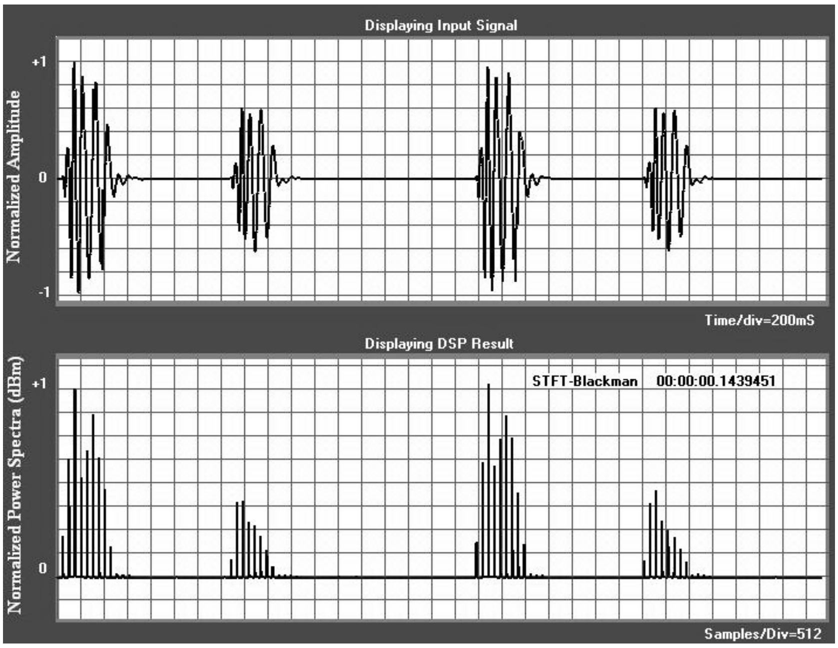

Figure 6. STFT with blackman function
(Şekil 6. Blackman pencere fonksiyonu ile KZFD)

When Figure 3, Figure 4, Figure 5 and Figure 6 were compared, it was seen that they were efficient in terms of code process time of windowing function and particularity of signal. It was determined that Blackman function had approximately same process time with Hanning function. But, Blackman windowing had higher noise suppression.

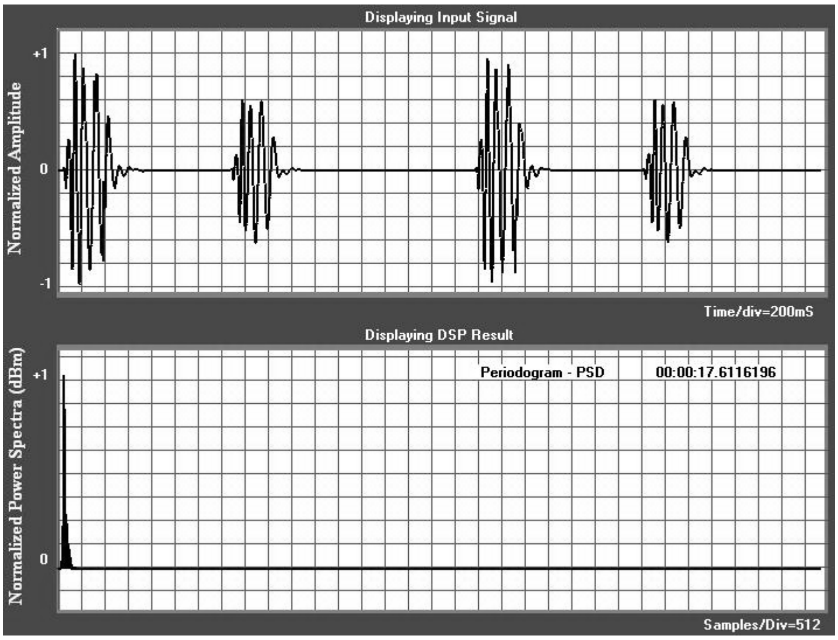

Figure 7. Periodogram PSD applications
(Şekil 7. Periodogram GSY uygulaması)

When periodogram PSD was applied to input signal (Figure 7), 8192 output coefficient were obtained at 17.61 seconds. It was determined that the code process time which belonged to the STFT-Blackman application at Figure 6 was shorter than periodogram PSD (Figure 7). However it was stated that output coefficients of periodogram PSD which indicated frequency components of power density in PSD application were fewer than DFT for feature extraction.

When 128 window length rectangle windowing functions with Shannon Energy equation was applied to input signal (Figure 8). 128 output coefficients were obtained at 0.0087 seconds.

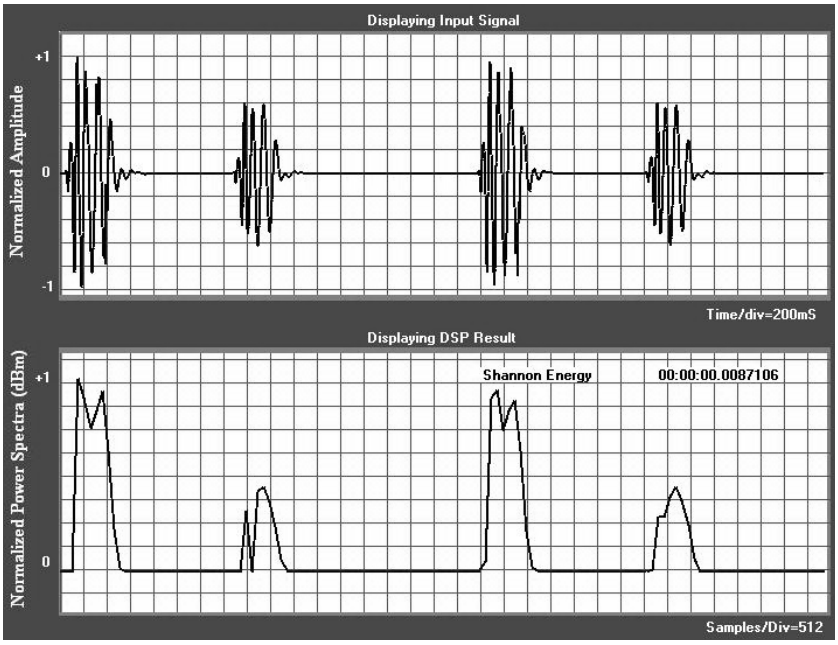

Figure 8. Shannon energy applications
(Şekil 8. Shannon enerji uygulaması)

When Shannon analysis graphic was examined in Figure 8, it was observed that Shannon method's filter effect was more efficient than the other window functions. Furthermore selectivity of S1 and S2 heart sounds in Shannon graphic was much higher than the graphic of DFT, STFT and periodogram PSD and also code process time was faster than other spectral analysis methods.

4. CONCLUSION AND RECOMMENDATION (SONUÇ VE ÖNERİLER)

Spectral analysis methods were compared in terms of graphical selectivity of S1 and S2 heart sounds and process time using windowing techniques (Hamming, Hanning, Blackman) with developed software (Table 1).

Table1. Comparision results
(Tablo 1. Karşılaştırma sonuçları)

DSP Methods	Windowing					Performance (s)
	Hamming	Hanning	Blackman	Rectangle	W. Size	
DFT	-	-	-	-	-	8,12
STFT	X	-	-	-	128	0,33
STFT	-	X	-	-	128	0,14
STFT	-	-	X	-	128	0,14
PSD	-	-	-	-	-	17,61
Shannon	-	-	-	X	128	0,0087

By looking parameters the sampling frequency of signal and suppressing the noise efficiently, the length of window to be used for a signal sampled 11025Hz was determined as 128. When compared windowing methods in terms of time process and filter effects, it was seen that Blackman function was faster and filtered the signal much better. It was observed that without applying any window function to the signal obtained DFT output coefficients were not efficient in selectivity of S1 and S2 heart sounds. When STFT was applied, it was seen that the choosing of proper window function and window gap increased the time of process and selectivity in analyzing sound data. Periodogram PSD application was longer than DFT in terms of process time; it did not increase selectivity of signal. But it was seen that Shannon Energy application was much faster than DFT, STFT and PSD in terms of process time and more efficient method in determining the S1 and S2 heart sounds.

The length of data to be used for determining the characteristics of signal and time of process have remarkable importance. Therefore, spectral analysis method should be chosen considering the output coefficient for deduction of feature extraction and time of process. As a result of analysis, the suitable method codes should be embedded to any medical systems. But, the system does not read heart sound data at real time. The system can be improved real time analysis and applied expert systems for classification of heart disease.

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