# An Example of Artery Pulse Data Analysis Using a New Time–Frequency Transform

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## ABSTRACT

A new time-frequency transform is employed to analysis a typical artery pulse data measured during one hour period after a 20 minutes run. The spectrogram of the transform is generated directly from the Fourier sine transform of the artery pulse data measuring at the wrist of the classical feel pulse technique. The Fourier sine transform discards data beyond two zeros around the two end of the data string and is believed to have a small spectrum. After imposing a window upon the spectrum, the spectrogram is obtained by the corresponding inverse Fourier transform. By examining 15 different samples, means and sample variations of frequency and amplitude show a reasonable trend from violent to normal states for the first six harmonic modes corresponding to the main organ meridian. Each sample mean and variance are calculated over a 10 seconds sampling period. The test topic shows that the traditional Chinese feel pulse technique can be restudied by the modern time series data analysis and related to modern medicine technology.

**Keywords:** time series data, Fourier sine spectrum, spectrogram, pulse data decomposition.

## 1. Introduction

The study of the organ-meridians of human body has obtained more attention in recent decades. Many investigations of this important issue have been done to re-examine this traditional topic by using the help of modern technology. Wang and coworkers had performed a series of systematical studies about the pressure pulse spectrum analyses of artery and peripheral pressure pulse spectrum analyses of the internal organs [1-3]. They concluded that these pressure pulse spectrums are closely related to the organ-meridians of human body. They also developed the pulse spectrum analyzer and had been widely employed as a diagnostic tool in many hospitals of Taiwan. It had been founded that the accuracy of the spectrum and spectrogram can be further enhanced by employing the Fourier sine transform and new spectrogram, respectively [4-6]. As a consequence, it is interested to apply these new technologies to study pressure pulse spectrum analyses of the internal organs. For the sake of demonstration, the recovery period after a violated run is chosen as a typical example.

## 2. Theoretical Background

It can be numerically shown that the Gaussian smoothing is a diffusive filter but the corresponding transition zone is too wide. In Ref.[3], an iterative Gaussian smoothing method was developed to narrow down the zone width and was proven to be diffusive too [7]. This iterative filter is employed to remove the non-sinusoidal and low frequency part of a time series data string. Starting from the two ends of the data string, zero points are identified by an interpolation method. Data beyond these zeros are dropped and the remaining data is redistributed to make sure of zero values at the two ends. The Fourier sine spectrum thus obtained is free from both the Direct Current (DC) contamination and error induced by the non-periodicities of either the data and its derivatives up to the ($N-1$)th order, where $N$ is the number of data points.

It can be shown that, if a Gaussian window is embedded to the integration formula of the Morlet or Gabor transform, a corresponding Gaussian window will be imposed on the spectrum of the resulting transformed data. Because we have a Fourier sine spectrum with low spectral error in hand, it is intuitive to impose a window so as to generate a new spectrogram to avoid the drawback of Morlet and Gabor transforms of using a finite data range [5,6]. The resulting spectrogram is shown to have a better visibility than that of all the existing spectrograms.

The sonocardiography system of Ref.[8] is employed to take the pulse pressure wave data. The measuring point is the maximum response point among the three attach points of the classical feel pulse technique. Once a data string is collected, the proposed Fourier sine and time-frequency transforms are employed to find the corresponding spectrum and spectrogram.

## 3. Results and Discussions

In order to test the performance of the proposed time-frequency transform, 15 pulse data of 23 to 30 years old young men after a 20 minutes run were taken. The data are measured at 5, 10, 15, 30, 45, and 60 minutes after the run which is in the recover period when the heart still beats faster than the normal state so as to sweep out the metabolic waste but the breath frequency becomes almost normal.

Figures 1a-1c shows a typical example of the raw data, Fourier sine spectrum and spectrogram whose original data is measured at about 5 minutes after the run, while Figs.2a-2c are the corresponding plots at 30 minutes after the run. On Fig.1a the rising curve around 2.5, and 3 seconds are corresponding to the eve of open the mitral-valve of left atrium, while that around 2.8 and 3.4 seconds are that of closing the valve. A comparison between Fig.1a and 2a shows their magnitude of the lower and upper bounds are not much different from each other but the heart beating rate of the former is faster than that of the latter. Moreover, their shapes during the period before open the valve are different. At the time 5 minutes after the run, the heart still beats very fast so that after pumping fresh blood one cycle the subsequent cycle is started immediately as shown in Fig.1a. After 30 minutes, the beating rate is slow down so that a short rest period exists.

According to the works of Wang et. al [1-3], spectrums of both Figs.1b and 1c do reflect the twelve organ-meridians corresponding to the twelve harmonic modes can be clearly seen, that are the heart, liver, kidney, spleen, lung, stomach, Gall bladder, bladder, large intestine, sanjiao, small intestine, and pericardium meridians, respectively. Moreover, every mode’s magnitude reflects the amount of blood spent by the organ. Note that most meridian modes spread over a finite bandwidth on the spectral domain and be explained as the frequency variation in terms of the corresponding spectrogram. Now it is not known the physical meaning of those harmonic modes beyond the twelve modes and further study is needed. At the 5 minute moment, the liver works busily to convert poisoned material in the blood so that it sucks most blood and other organs spend only a small amount of blood. Up to 30 minutes after the run, the kidney starts to work normal to remove uric acid in the blood. As a consequence, both liver and kidney suck most blood as shown. The corresponding spectrograms are shown in Figs.1c and 2c, respectively. These figures show that both the amplitude magnitude and frequency of all the organs are slowly varied with respect to time. It means that, in the recovery period, the whole system is eager to exclude all the poisoned material in the blood as soon as possible. Both liver and kidney work in a critical state around their limits. Meanwhile, all the other organs cannot get sufficient blood to work normally so that they are unstable [1-3] and generate serious variations of both amplitude and frequency too. Therefore, human body will adapt to the emergency case by adjusting blood supply arrangement and temporarily ignore those less important functions.

In order to examine details of the amplitude and frequency of main organs, their mean and percent of sample deviation (during the 10 seconds sampling period) are calculated from the spectrograms of 15 samples. Figure 3 shows the variations of mean amplitude with respect to the measuring time. At the instance 5 minutes after the run, the heart amplitude is even larger than that of the liver and then gradually decay as shown. During the whole 60 minutes period, the liver has almost the largest amplitude because it works very hard to remove the poisoned material from the blood. At first the kidney is ignored and then speeds up its performance. After one hour, the kidney and liver have almost the same amplitude. The mean amplitudes of spleen, lung, and stomach do not have much variation that reflects they are not switched to emergency during the recovery period.

Figure 4 shows the variations of the mean frequency with respect to the measuring instance. All the first six main organs have similar trend of decreasing mean frequencies to the normal state because their frequencies are controlled by the heart directly. These two mean plots show that the human body system increases the performance to remove harmful material in the blood after the run in terms of increasing the heart beating frequency and power.

According to argument of Ref.[1-3], variations of amplitude and frequency with respect to time reflects the efficient of pumping blood into a organ and/or its health condition. The mean normalized sample deviations of amplitude are shown in Fig.5. The mean normalized sample deviations of frequency are shown in Fig.6, where the normalization factor uses the heart frequency. Since the heart and liver work very hard to remove the bad material of blood, their performances close to their upper limits. Consequently, their variations of both amplitude and frequency are not obvious as comparing with that of other organs. Except the kidney, during the one hour period after the run, the functions of other organs are effectively suppressed. In the first 10 minutes, all the idle organs have small deviations because the deviations of heart and liver are relatively small. After the kidney speeds up its function, its amplitude deviation decreases (because of increasing the normalized factor, say its amplitude) but the frequency deviation increases. This means that their amplitude and frequency deviations are increasing. Since spleen, lung and stomach are partially ignored, their blood supplies are highly insufficient. Therefore, their deviations of both amplitude and frequency are serious.

The above discussions show that, with the help of the Fourier sine spectrum and new spectrogram, the main trends of the first six organs' performance can be reasonably explained in terms of the harmonic modes' behavior.

## 4. Conclusions

A system consisting of new Fourier sine and time-frequency transforms are employed to decompose the pulse data during the recovery period after a 20 minutes run. From the resulting spectrograms the main trends of the heart, liver, kidney, spleen, lung and stomach are grasped. The results show that the future studies about all the invasive and noninvasive measuring techniques to collect time series data can be start out.

## 5. Acknowledgement

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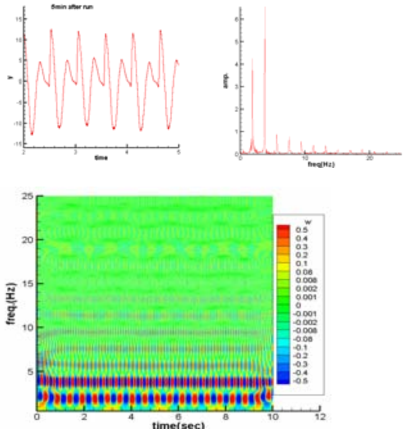

Fig.1 The raw data (top-left), spectrum (top-right) and spectrogram of 5min data after the run.

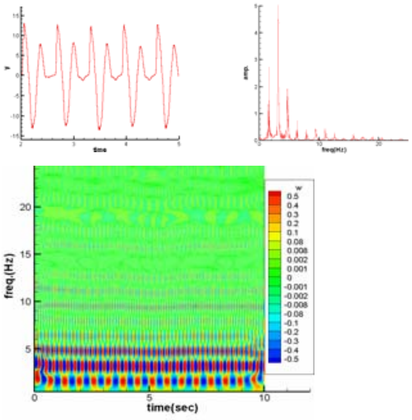

Fig.2 The raw data (top-left), spectrum (top-right) and spectrogram of 30min data after the run.

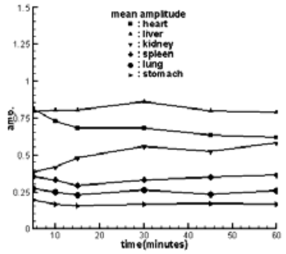

Fig.3 Mean amplitude plots of 6 main organ meridians vs. measuring time.

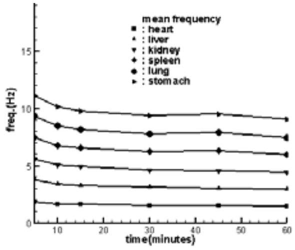

Fig.4 Mean frequency plots of 6 main organ meridians vs. measuring time.

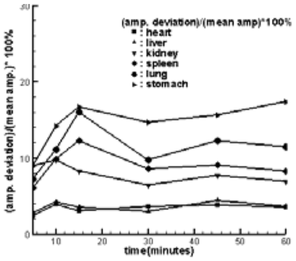

Fig.5 Mean amplitude deviations plots of 6 main organ meridians vs. measuring time.

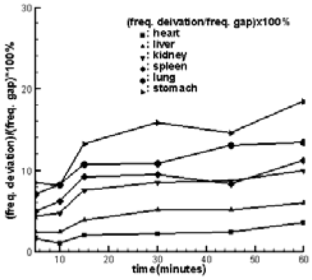

Fig.6 Mean normalized frequency deviations plots of 6 main organ meridians vs. measuring time.