



# Zoom FFT Algorithm in Ultrasonic Blood Flow Analysis Using MATLAB

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## ABSTRACT

An adequate blood supply is required for the normal functioning of all organs in the body. However this flow can be impeded due to several reasons, thrombus or clot being a major one. Detection of such clots is done with the help of an imaging technique called “DOPPLER ULTRASONOGRAPHY” by transmitting an ultrasound pulse and calculating the frequency of the received signal. If there is no clot the reception is always a homogenous signal, whereas if a certain part being sonographed has a clot the received signal shows a variance in frequency which depends upon the distance from the receiver. Hence blood clot detection in ultrasonography is based on obtaining the frequency variance and applying adaptive thresholding. In this work we propose a ZOOM FFT based technique followed by automated adaptive thresholding to detect the clot. Data files are synthesized by simulation in MATLAB. Also the entire system is developed in a Matlab environment for the system to be both simple and cost-effective. Experimental results show that the accuracy of the system is very high even under noisy conditions.

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## Introduction

Blood circulation is essential for a healthy body. Every cell in the body needs to receive oxygen and nutrients. Blood rich in oxygen is sent to the body organs, tissues and cells to nourish them, and the waste products that result are disposed off through the same system. The circulatory system includes several common disorders among them is Embolism which is a blood clot that is able to travel. This is dangerous because it could travel to the brain, lungs or heart. In clinical practice such blood clots are detected using a technique called Doppler Ultrasound Imaging.

### Existing Systems

Blood clotting is currently detected in time domain based on Doppler delay which is the resonating time of ultrasound pulse from transmitter to blood surface and back to receiver. However time domain based analysis suffers from ripple and salt and pepper noise which affects the accuracy of the system to a great deal. In order to overcome this drawback a frequency-domain analysis based on FFT is adopted. However FFT-based techniques cannot detect minute deviations in frequency which represents minute clots or those present in the deeper vessels. Therefore we need methods to distinguish the peaks and existence of any secondary peak which is added by the presence of a clot. Hence ZOOM FFT technique is proposed.

### Proposed Method

Considering the above mentioned requirements, in this work we propose a novel method called ZOOM FFT with Adaptive thresholding to automatically detect blood clotting from Doppler ultrasound signal. We first simulate the ultrasonic blood flow signal as triangular pulses with sinusoid component followed by inducing delay based clot signal. FFT of this signal is filtered using Hanning window and then performing slicing based main and secondary peak detection.

### System Design Description

#### Methodology

I)Basics

“SOUND IS A COMPRESSIONAL WAVE” and is different from Electromagnetic waves in that it requires a medium to travel. The frequency spectrum of sound is shown in figure 7. The audible range of sound lies between 20Hz to 20 KHz. This frequency range of sound is perceivable to humans. Below this range is called infrasonic and is audible to animals. Above audible range are Ultrasonic which propagates as a wave and can travel through different media. Because of this property ultrasound waves find potential applications in medical and industrial diagnostics.

### Doppler Effect Phenomenon

Whenever an ultrasound wave propagates in a medium it undergoes various phenomena, the most important is the Doppler effect which is the basis of many diagnostic applications based on ultrasound.

The Doppler Effect is the change observed in the wavelength of sound (and other) waves due to relative motion between a wave source and a wave receiver. When a wave is reflected from a moving target, the frequency of the wave received differs from that which is transmitted. This difference in frequency is known as the Doppler shift. The amount of increase or decrease in the frequency depends upon (a) the speed of motion (b) the angle between the wave direction and the motion direction, and (c) the frequency of the wave emitted by the source. The Doppler Effect occurs for any kind of wave but is commonly experienced in life with sound. This is because speeds of motion experienced commonly can be a significant fraction of the speed of sound. With light this is not true and only astronomical motions provide speeds great enough to produce a readily observable Doppler effect.

As the ultrasound wave propagates a shift in frequency (f) of the wave will be expected due to the source and observer's motion relative to each other if the distance between them is reduced or increased. That shift in frequency depends on the velocity of sound which also depends on density of the medium,

in which it propagates. When a small object is situated in the path of the sound wave, the wave will be resisted (scattered). A direct measurement of this velocity will provide useful information about the dynamic property of the medium. The Perceived velocity is given by

$$V' = V - V_0 \quad \text{equation 1}$$

In terms of frequency (f), as a velocity dependent factor.

$$f_p = f_0 \frac{(V + V_0)}{V - V_s} \quad \text{equation 2}$$

for both objects moving towards each other.

$$f_p = f_0 \frac{(V - V_0)}{(V + V_s)} \quad \text{equation 3}$$

for both objects moving away from each other,

$f_p$ : Perceived frequency.

$v$ : velocity of wave.

$v_s$ : source velocity.

$v_0$ : velocity of observer.

Thus we get the perceived frequency proportionately changed with respect to changes in measuring media. The Doppler Effect can also be explained with respect to pitch or wavelength, since all are dependent to each other.

The Doppler shift frequency is given by the equation-

$$f_D = (2 f_e v \cos \theta) / c \quad \text{equation (4)}$$

- Where  $f_D$  = Doppler shift,
- $f_e$  = emitted frequency,
- $c$  = speed of sound in tissues,
- $v$  = blood flow velocity,
- $\theta$  = cosine Doppler angle

It is the Doppler shift that Doppler instruments detect. However, it is the speed of motion or flow of blood in which we are normally interested. The Doppler equation can be rearranged in this sense, to place the speed of motion alone on the left side of the equation.

$$v = (f_D / f_e \cos \theta) \quad \text{equation 5}$$

- The minimum detectable blood flow speed within Doppler ultrasound is few  $\text{mm.s}^{-1}$ . The maximum is determined by aliasing. The range of commonly detected normal flow speeds is 10 to 100  $\text{cm.s}^{-1}$ .

#### Why to zoom?

Minute variations in blood flow can be seen eg. starting stage of blood clot.

In clinical practice, situations arise wherein the clot in a vessel may be so small or deeper inside that it induces negligible frequency shift which is usually not detected with conventional ultrasonography. However its presence starts to manifest itself through various symptoms. Under such situations it becomes important to be able to detect and locate the clot to avoid undesirable complications and cost of the treatment.

This minute variation in frequency can be seen using Zoom FFT algorithm.

#### Zoom FFT

The Zoom-FFT is a DSP algorithm which is used to enlarge a portion of the signal. As the name implies Zoom FFT increases the frequency resolution of the desired portion of a signal thereby zooming it so that very fine details in the spectrum can be visualized. In this process an input signal is mixed down to a baseband frequency and then decimated, prior to passing it into a standard FFT. The advantage is for example that if you have a sample rate of 10 MHz and require at least 10Hz resolution over a small frequency band (say 1 KHz) then you do not need a 1 Mega point FFT, just decimate by a factor of 4096 and use a 256 point FFT which is obviously quicker.

Zoom-FFT uses digital down conversion techniques to localize the standard FFT to a narrow band of frequencies that

are centered on a higher frequency. The zoom-FFT is used to reduce the sample rate required when analyzing narrowband signals eg. in HF communications.

#### Design Approach

Zoom FFT for blood clot detection is based on detecting the additional frequency component added by the clot which is identified as a second prominent peak in the input signal.

The Algorithm can be presented in following steps

- 1) Take FFT of the Signal
- 2) Perform Zooming by applying Hanning Window
- 3) Adjust window parameter to get primary and secondary peaks.
- 4) Locate the peak of highest magnitude. Find its width and location.
- 5) Find if any other peak exists with amplitude and width atleast 40% of that of the primary peak.
- 6) If so then it is recognized as a clot. Amplitude of the secondary peak gives clotting depth.
- 7) If no secondary peak is detected then there is no clotting.

The steps involved in the process are explained below:

- Filter
- The input signal is filtered using a low pass filter to prevent aliasing when the signal is subsequently sampled at a lower sampling rate.
- Decimation
- Resampling at discrete instances, the already sampled wave. Decimation is achieved by applying the equation given below

$$Y(m) = \sum_{K=0}^{N-1} \text{Scale} * x(Mm-k), \quad M = \text{decimation factor}$$

Where Scale is the Zooming range and the value is between 0-1

$N$  = number of samples

#### FFT

The Fast Fourier Transform (FFT) is an algorithm that efficiently contains the frequency domain conversion. FFT of a signal is computed using the formula given below

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-j2\pi nk/N} \quad 0 < K < N-1$$

Where  $X(K)$  = FFT of input  $x(n)$

$N$  = number of samples

$k$  = index

Window

After computing FFT of the signal it is windowed. This is the core part of the Zoom process where zooming is actually achieved. The window function is used to select a particular portion of the spectrum. For this work we are using Hanning window which is a fixed type window defined by the formula

$$W_{HN}(n) = \{0.5[1 - \cos(2\pi n/M-1)] \quad \text{for } n=0 \text{ to } M-1 \\ 0 \quad \text{otherwise}$$

Where  $M$  = number of samples

All the above steps are carried out in a single MatLab program which offers built-in functions for all the steps.

#### MATLAB®

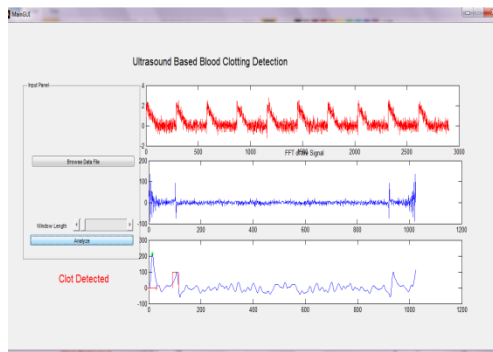
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### Result

Our system has been tested with normal and abnormal ultrasound signals under varying noise conditions. A snapshot of the result is shown in figure 1. It is apparent from the results that our system is capable of detecting clots with negligibly small magnitudes. It is also observed that the system is least affected by the presence and amount of noise in the signal.



**Figure 1. snapshot of the result with an ultrasound signal containing a minute clot along with heavy noise.**

### Advantages

1. Increased frequency domain resolution
2. detects the presence of clot at the initial stage itself
3. Reduced hardware cost and complexity
4. Wider spectral range
5. Can be used conveniently by both medical and paramedical staff
6. Accurate and reliable

### Conclusion

Currently the project has been tested on the simulation basis, the output of the simulations are satisfactory. In the simulation we generated the ultrasound signal with noise and without noise. Noise is added using AWGN. We take several signals which includes both normal as well as abnormal

signal. Abnormal signal is generated by adding a delayed signal with the main signal. We then use Zoom FFT technique to detect the abnormality. It is shown that we can detect the clotting with an accuracy of over 90%. The system also gives satisfactory result under heavy noise.

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