

Fast Fourier Transform and its Applications

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Abstract— This paper shows explanation of the theory of FFT, the difference between FFT and DFT, and visualize few applications of FFT in the real world. Then, we discussed one of these applications which is FFT in polynomial multiplication and showed all the related theories and explanation that verifies the relation between the two topics, and how FFT is used to reduce the complexity of solving such problem.

Keywords— Fourier, DFT, Signals, FFT, Inverse Fourier

I. INTRODUCTION

A signal can be considered as a physical variable that varies with time and have specific instruction or values. We can represent it in two ways: Continuous and Discrete. A signal, continuous or discrete, can be processed and analyzed using a method called Fourier Transform, in the frequency and time domain. Fourier Transform can be divided to 4 classes: Fourier Series, Discrete Fourier Transform, Discrete - time Fourier Transform and Fast Fourier Transform, where the latter will be discussed in this paper.

The Fast Fourier Transform is an advanced technology developed by Joseph Fourier in 1982, and re - studied later by 2 other scientists: James Cooley and John Tukey. FFT is a methodology that performs and computes the Discrete Fourier Transform (DFT) faster than any other method or algorithm.^[1] It converts any signal into spectral component and hence provide a frequency related information about the signal. Over a period of time, the signal will be sampled and distributed into frequency components.

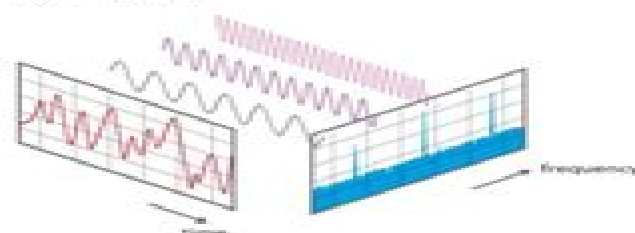


Figure 1: Signal in time and Frequency Domain

In Figure 1 we can see how the previously stated transformation is illustrated, and it is obvious how the signal is divided to 3 distinct frequencies.

II. DIFFERENCE BETWEEN FFT AND DTFT

Mathematically speaking, the Discrete - Time Fourier Transform (DTFT) is one type of the Fourier analysis that can be done to a sequence of values, that is usually used to divide a function to several samples and analyze them. It is considered to be continuous function of frequency, whereas the simple Discrete Fourier Transform (DFT) analyzes and studies the discrete samples.

Both methods are effective in the world of science and engineering, but here comes the importance of Fast Fourier Transform (FFT) technique. Basically, the difference between these techniques is that DTFT and DFT's work is being enhanced using FFT, where all of them uses Fourier series and transform but in different ways.^[2] The table below shows a brief idea about the difference between FFT and DTFT:

Table 1: Brief Difference between FFT and DTFT

	FFT	DTFT
Definition	The combination of multiple computing techniques including DFT and DTFT	Mathematical Technique that transforms time to frequency domains by dividing the signal into samples.
Work	Very Fast Analysis	Providing the relation between time and frequency domain
Applications	Solving partial differential equations, JPEG compression, etc....	Spectrum estimation, conviction, etc...
Version	Fast Version	Discrete Version

As we can see in Table 1, the difference between FFT and DTFT can be divided to many categories. The DTFT requires a big amount of time with a high number of samples N , whereas, FFT is an algorithm to make DTFT computations faster. The FFT hold one good assumption: that N is an integer multiple of two. This allows certain symmetries to occur, and hence reducing the number of calculations with less time. FFT has an advantage over DFT and DTFT because we have a decrease in the complexity from $O(N^2)$ to $O(N \log N)$ where N is representing the data points or number of samples. So, for example if $N = 1024 = 2^{10}$, $N \log N = 10240$.

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