DSP Project

Empirical mode Decomposition of Signal for Instantaneous Frequency

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INTRODUCTION

When analyzing precipitation charts, we should bear in mind that they represent interaction between a lot of various processes such as seasonal changes, global warming/cooling processes, ocean current changes, dynamics of cyclones and anticyclones, the amount of carbon dioxide emitted into the atmosphere, solar activity cycles, etc. All real processes we have to deal with in practice are complex, as a rule, consisting of a great number of components. The list could go on forever.
This gives rise to a rightful desire to break down the process under consideration into individual components and analyze each of the components separately. Analysis of individual components and consideration of the contribution they make into the process at hand helps us better understand the process in progress, as well as, e.g. increase the forecast reliability.

And there is no exception when it comes to various information on trading, including currency quotes that are also formed based on a great number of different factors. That is why it is quite natural to expect that an upfront breakdown into individual components can greatly facilitate their further analysis.

The vast majority of methods used in market analysis can explicitly or implicitly be attributed to methods that single out certain components from the analyzed process, i.e. decomposition methods. Let us briefly review some of them.

Empirical Mode Decomposition :

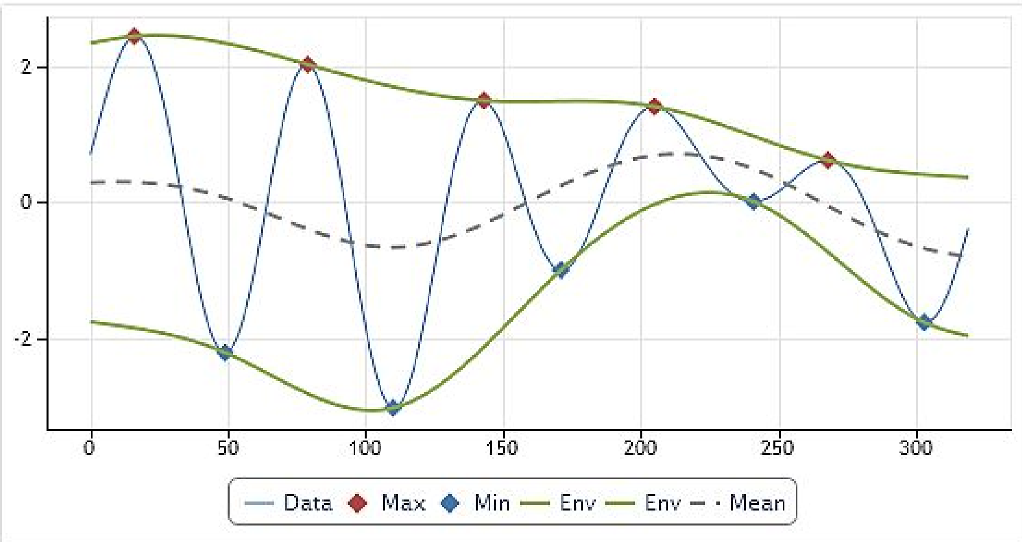
The Empirical mode decomposition (EMD) was proposed as the fundamental part of the Hilbert-huang transform. The Hilbert Huang transform is carried out, so to speak, in 2 stages. First, using the EMD algorithm, we obtain intrinsic mode functions (IMF).
Then, at the second stage, the instantaneous frequency spectrum of the initial sequence is obtained by applying the Hilbert transform to the results of the above step. The HHT allows to obtain the instantaneous frequency spectrum of nonlinear and nonstationary sequences. These sequences can consequently also be dealt with using the empirical mode decomposition.
However, this article is not going to cover the plotting of the instantaneous frequency spectrum using the Hilbert transform. We will focus only on the EMD algorithm.
In contrast to the previously mentioned Fourier transform and wavelet transform, the EMD decomposes any given data into intrinsic mode functions (IMF) that are not set analytically and are instead determined by an analyzed sequence alone. The basis functions are in this case derived adaptively directly from input data. An IMF resulting from the EMD shall satisfy only the following requirements:

1. The number of IMF extrema (the sum of the maxima and minima) and the number of zero-crossings must either be equal or differ at most by one;

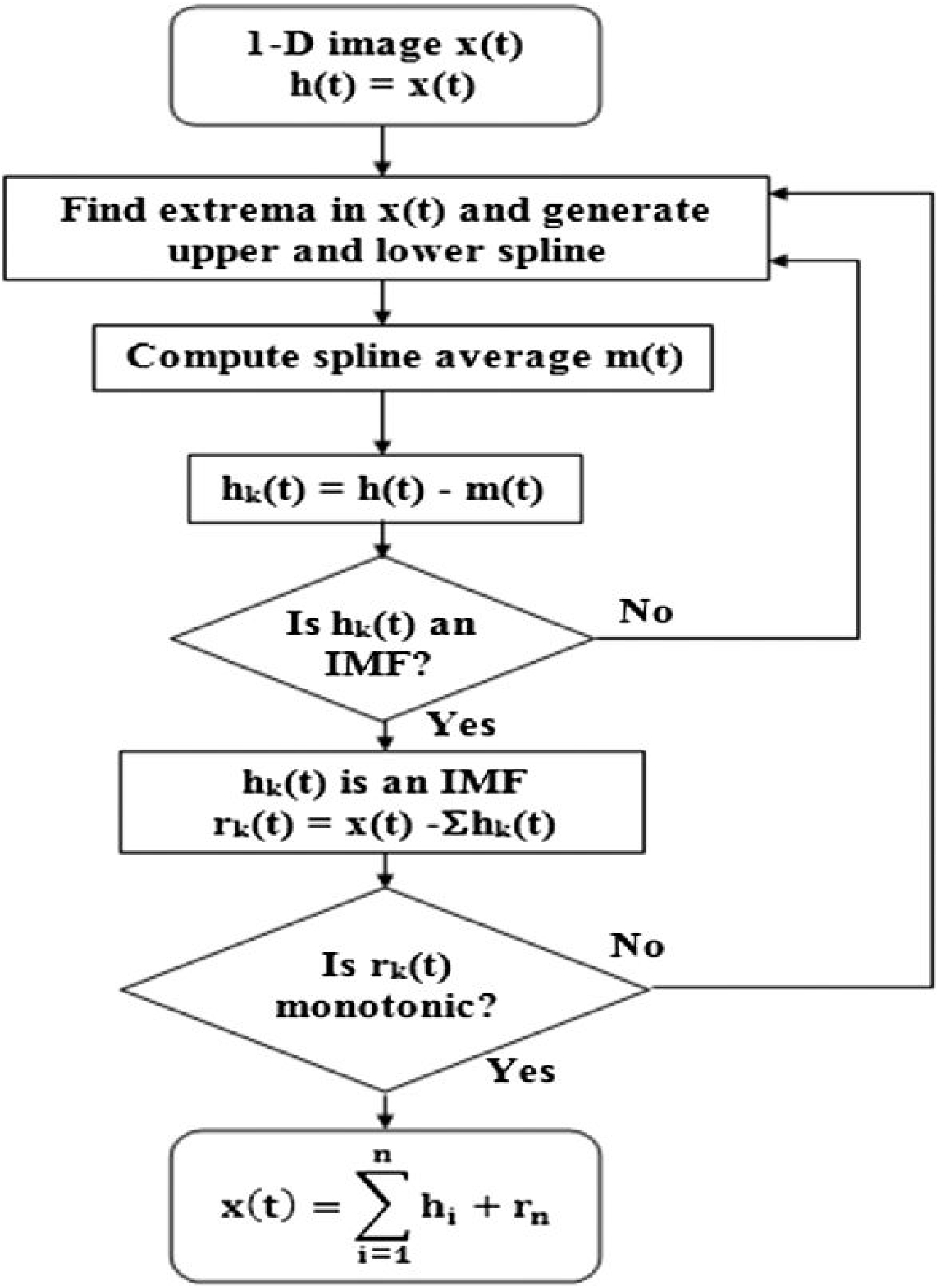
2. At any point of an IMF the mean value of the envelope defined by the local maxima and the envelope defined by the local minima shall be zero.

Decomposition results in a family of frequency ordered IMF components. Each successive IMF contains lower frequency oscillations than the preceding one. And although the term "frequency" is not quite correct when used in relation to IMFs, it is probably best suited to define their nature. The thing is that even though an IMF is of oscillatory nature, it can have variable amplitude and frequency along the time axis.

It is quite difficult to visualize the EMD algorithm performance results based on the description alone so let us proceed to its software implementation that will give us an opportunity to get to know the algorithm peculiarities.



Algorithm :



Instantaneous Frequency :

In order to calculate the IF, a complex signal has to be obtained from each IMF for which envelope and phase signals can be defined. From a practical point of view, the analytic signal defined by Gabor is the appropriate
method for generating a unique complex signal from a real one.Given equation is the time expression for an analytic signal, z(t):

$z(t) = s(t) + j*H[s(t)] = a(t)*e^{j*\phi(t)}$

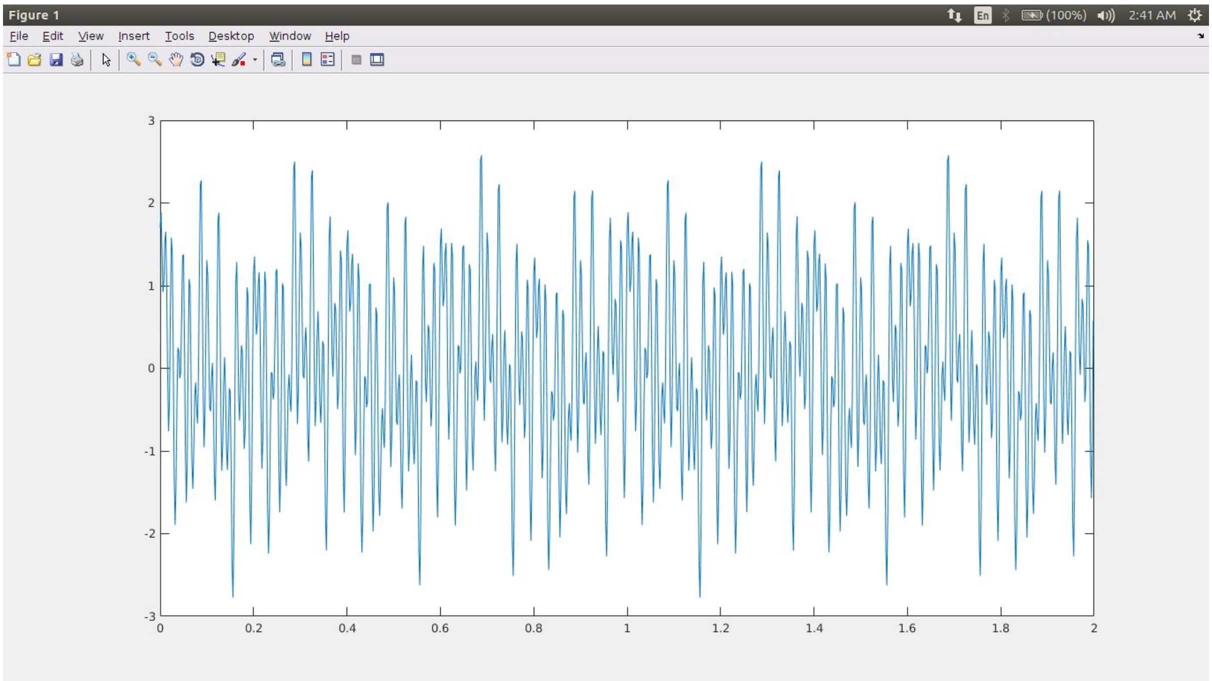
where s(t) is the real signal (an IMF in the present work),
H[*] is the Hilbert transform, a(t) is the absolute value of z(t), and Φ(t) is the phase of z(t).Then, an instantaneous frequency (f_i) and envelope (e_i) can be defined as the phase derivative and envelope of the analytic signal,respectively:

$f_i(t) = (1/(2*\pi))*(d\phi/dt)$
$e_i(t) = |z(t)| = a(t)$

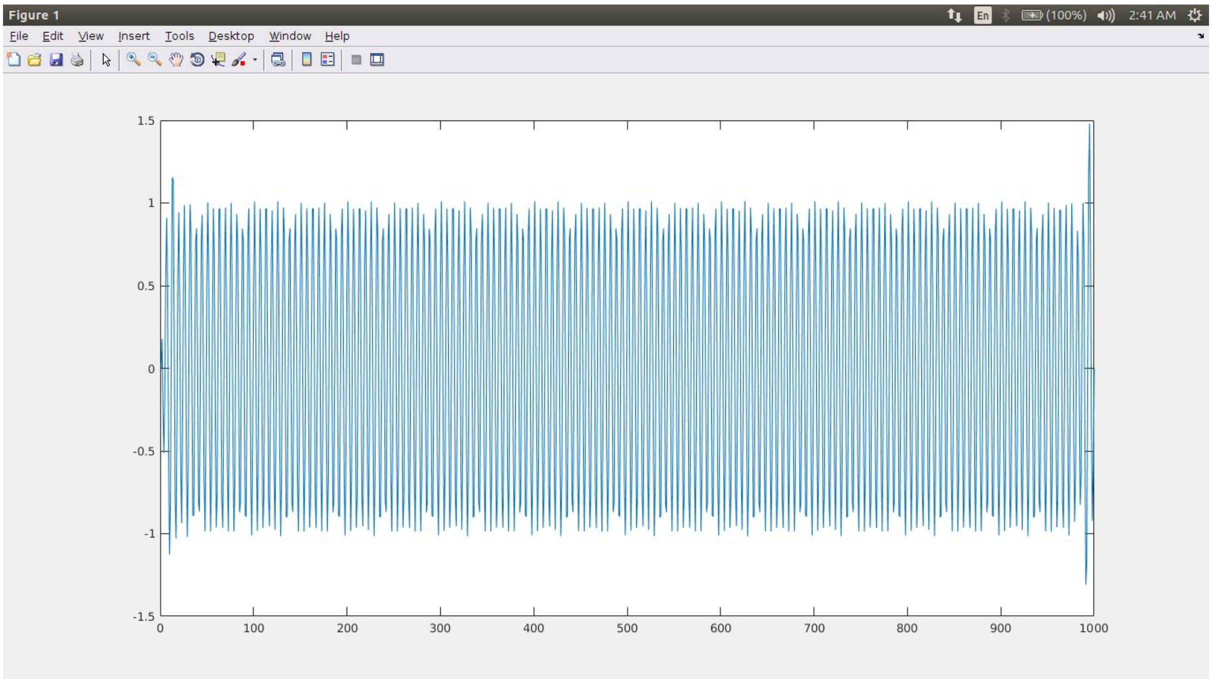
According to the definition, positive IF values will only result if the phase of the analytic signal is monotonically increasing.

Results :

Input Signal = 0.8*sin(2*π*50*t) + cos(2*π*80*t)+ 0.6*sin(2*π*25*t) + 0.4*cos(2*π*10*t) +0.3*cos(2*π*3*t)



IMF 1 :



IMF 2 :

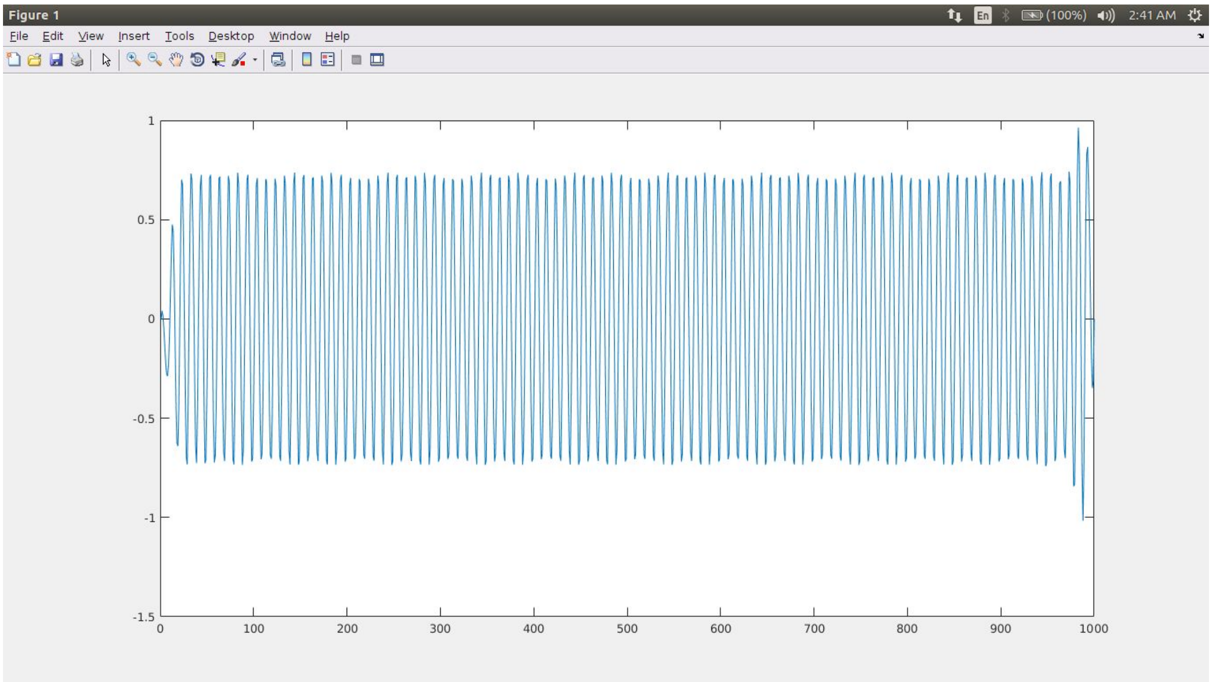


Figure 1
File Edit View Insert Tools Desktop Window Help
(100%) 2:41 AM
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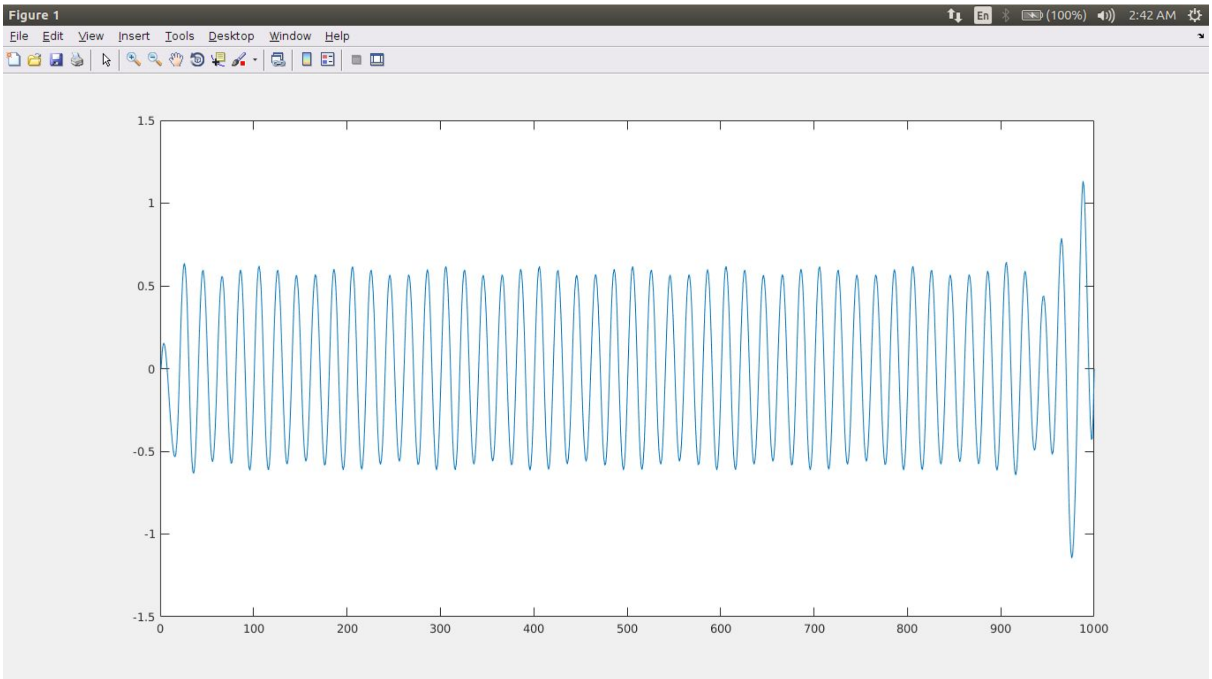
IMF 3 :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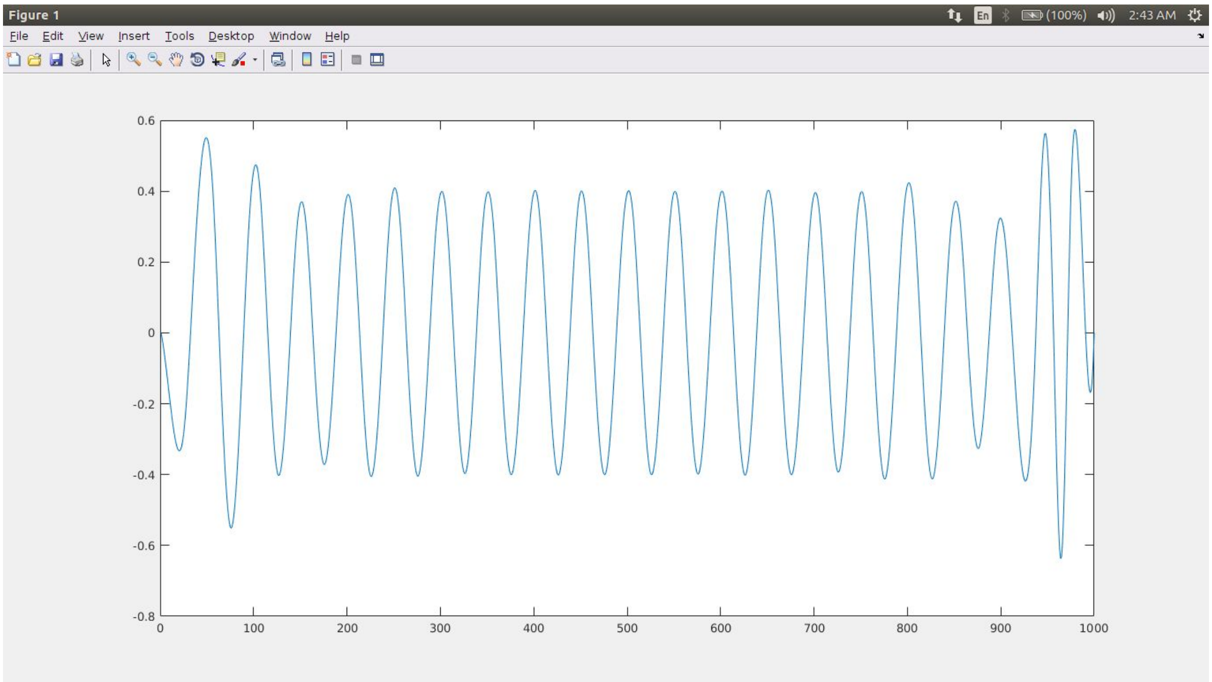
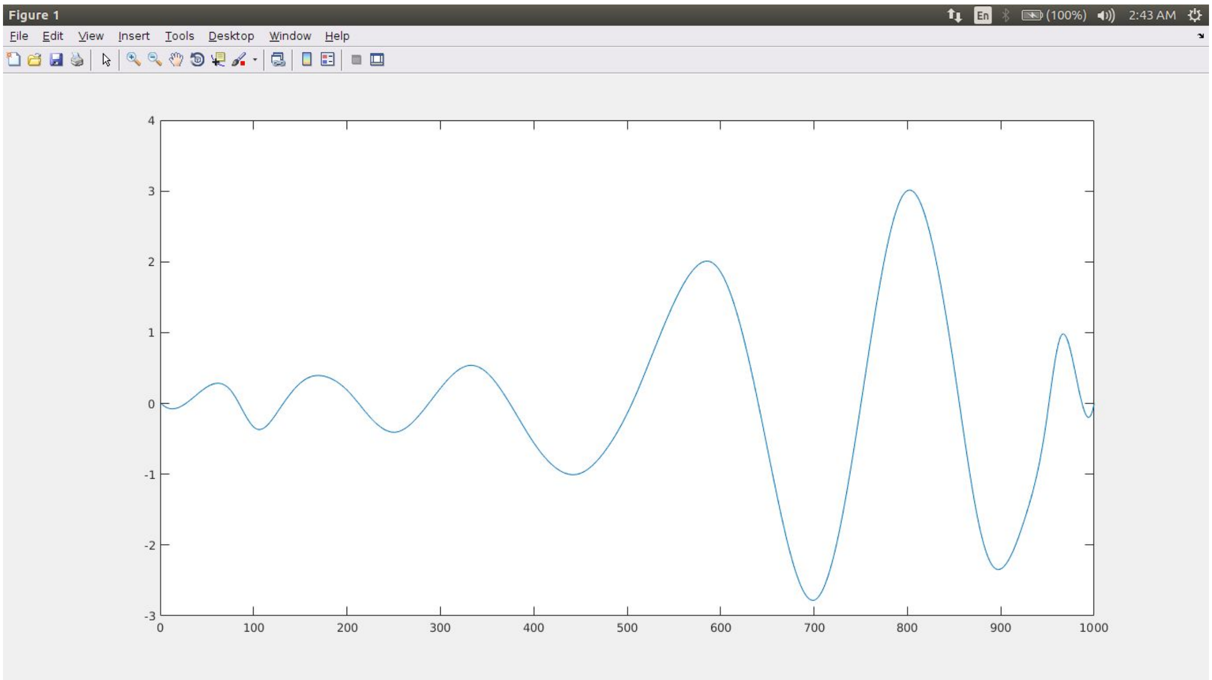
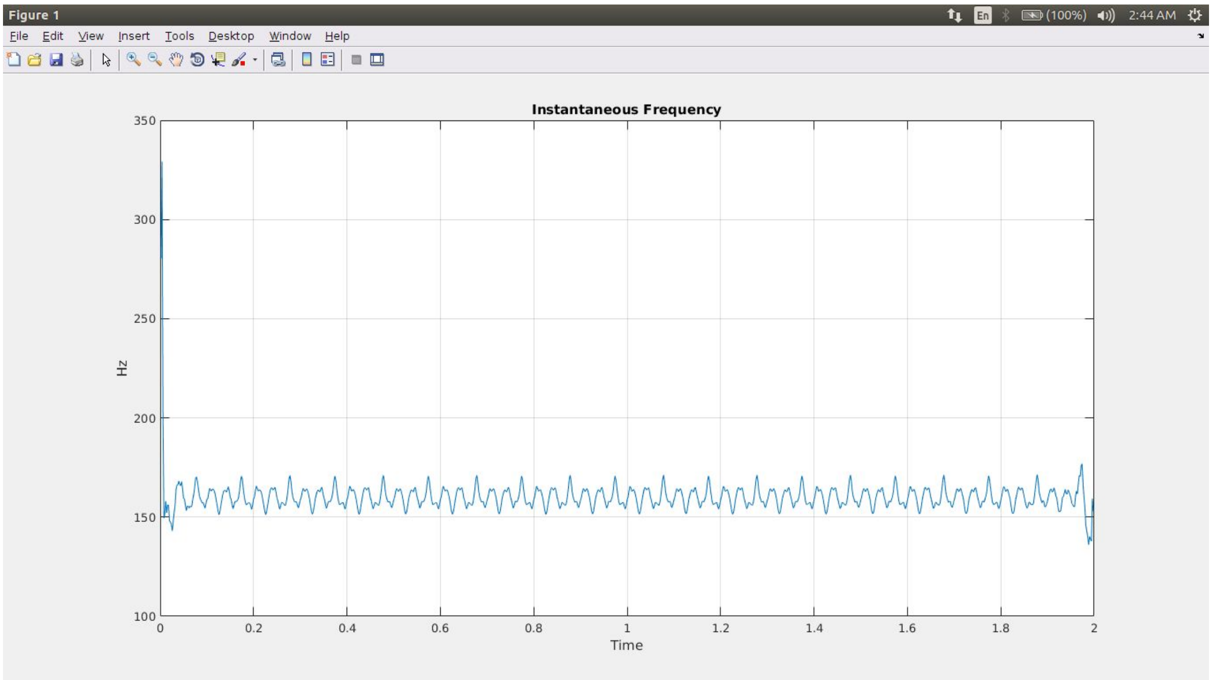
IMF 4 :



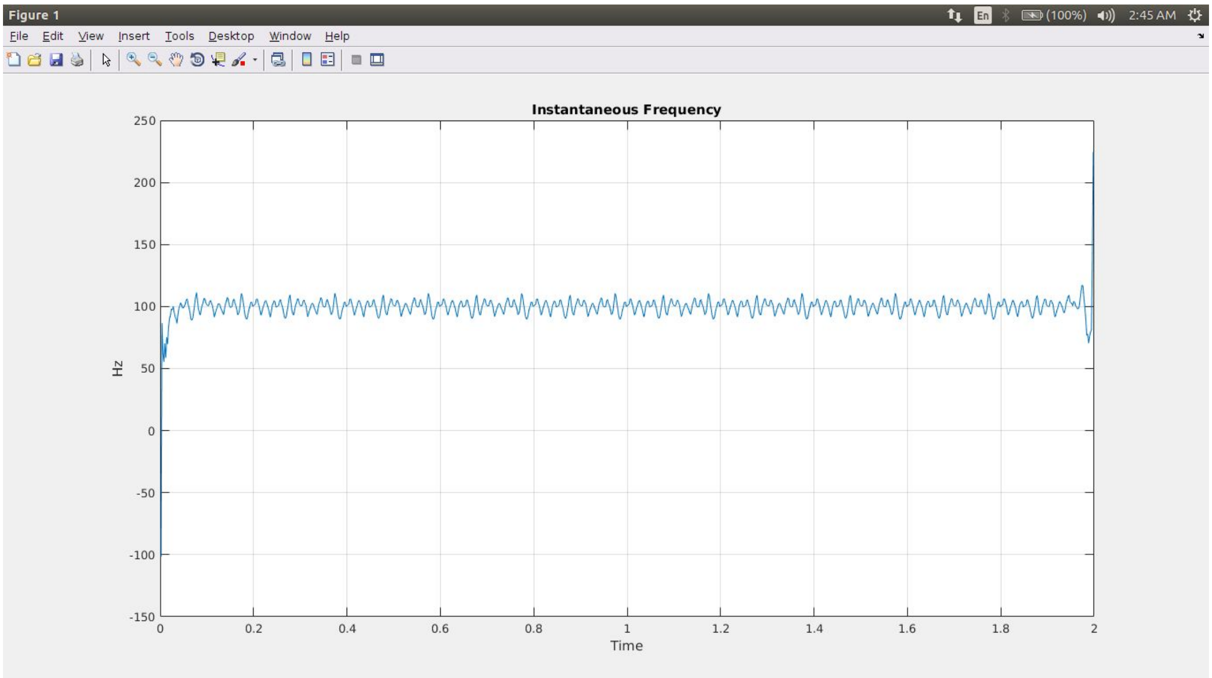
IMF 5 :



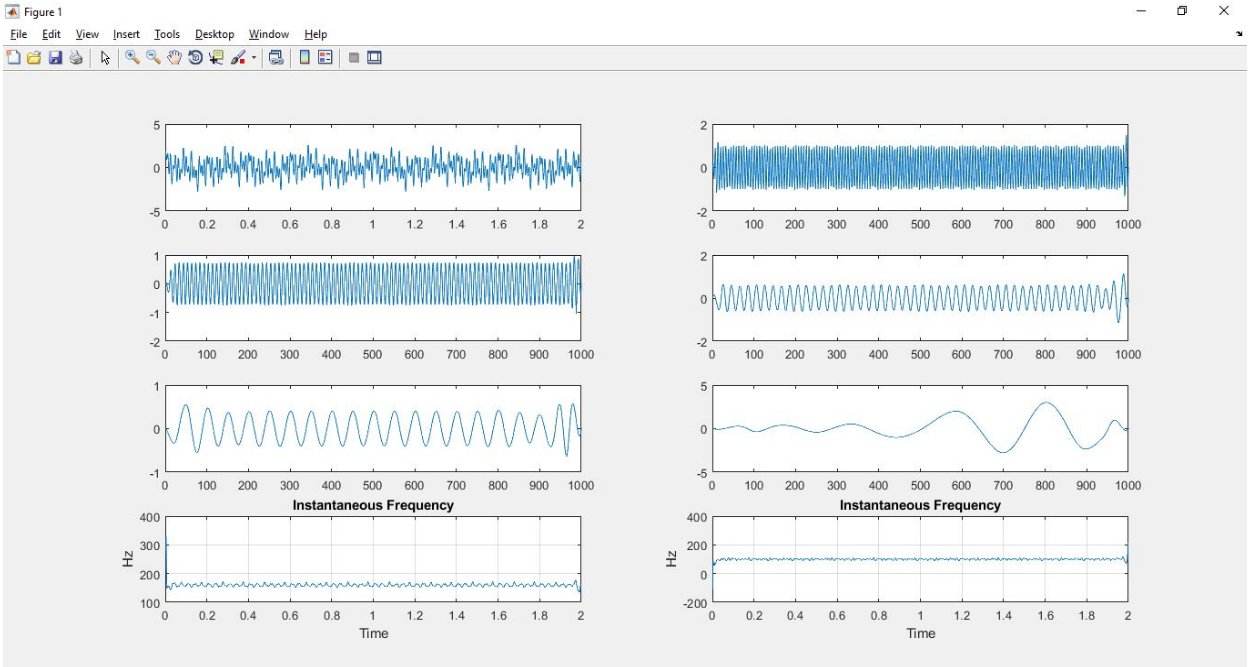
Instantaneous frequency 1 :



Instantaneous frequency 2 :



All graphs together :



Application of the EMD Algorithm :

Since the EMD algorithm was initially a part of the Hilbert-Huang transform, the calculation of the instantaneous frequency spectrum of a sequence can serve as an example demonstrating the application of this algorithm. This involves performance of the Hilbert transform on IMF components extracted using the EMD. This procedure is however not considered in this article.

Apart from calculating the spectrum, the EMD algorithm can be used to smooth sequences.