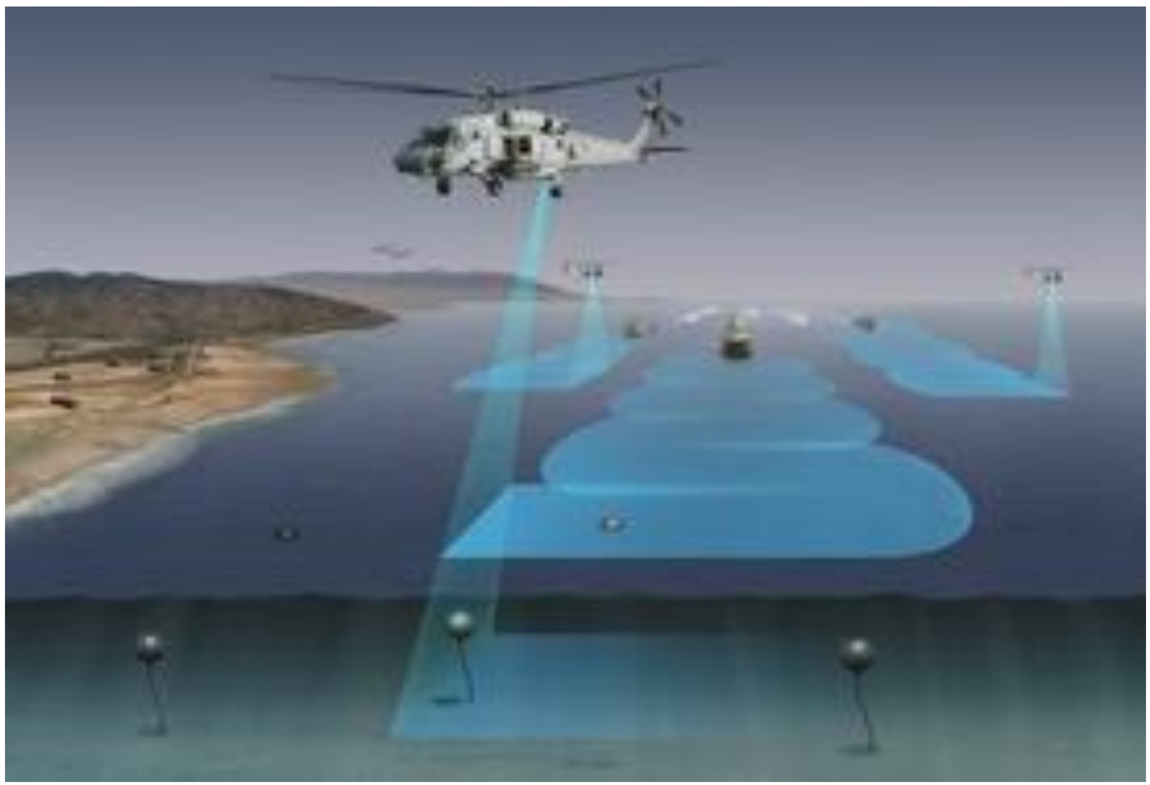
Empirical Mode Decomposition for Change Detection and Mine Detection

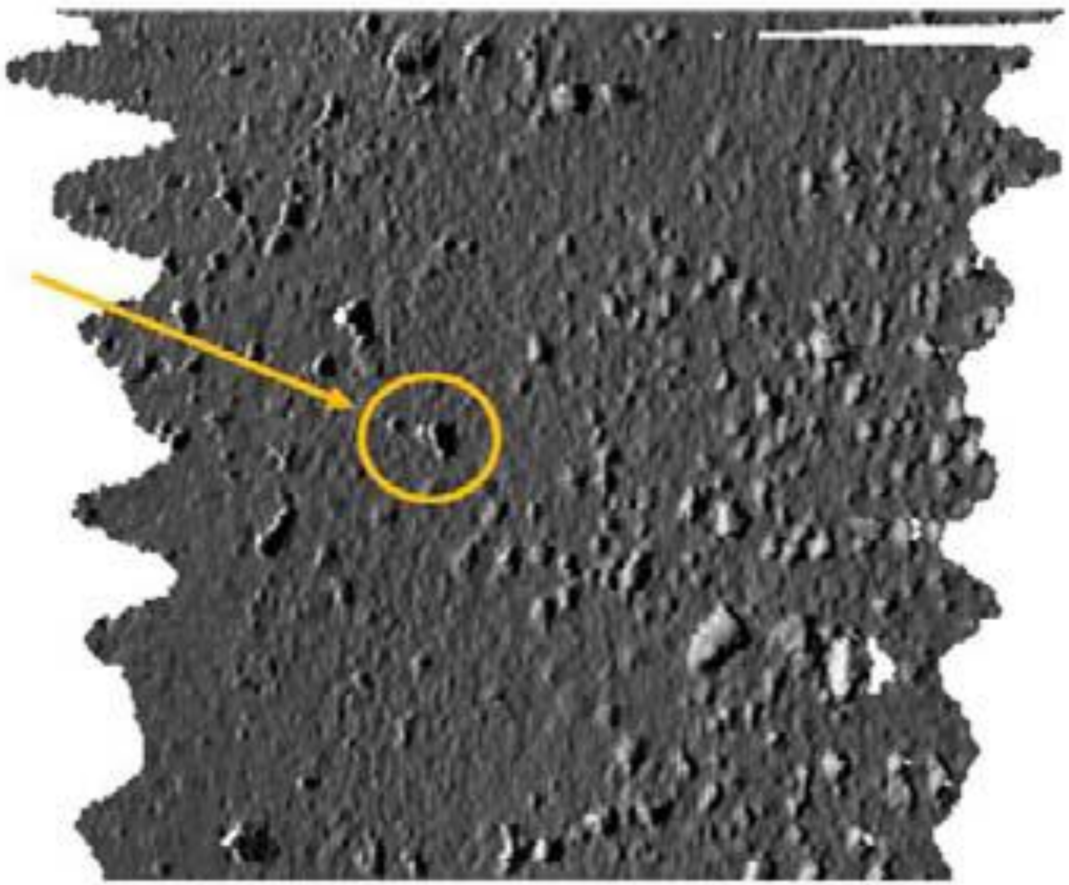
Peter Chu
Naval Postgraduate School
Monterey, California
5/18/2010

Airborne Laser Mine Detection System (ALMDS)



L3-Klein 5500 Sidescan Sonar

Image → detecting mine



How can we detect mine from image such as sidescan sonar?

Efficient Method →

Empirical Mode Decomposition

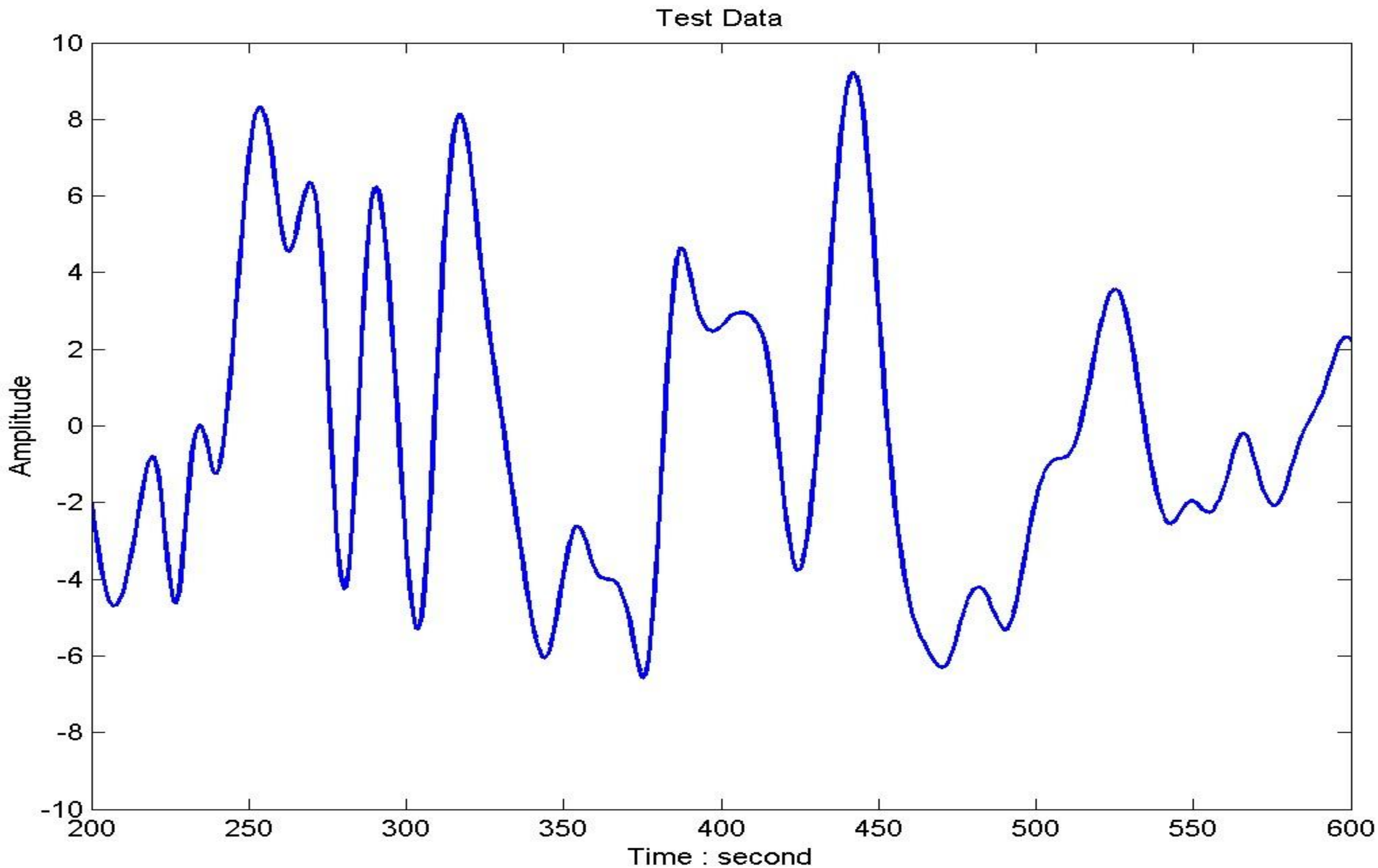
(Huang et al., 1998)

One Dimensional EMD →

Time Series Analysis

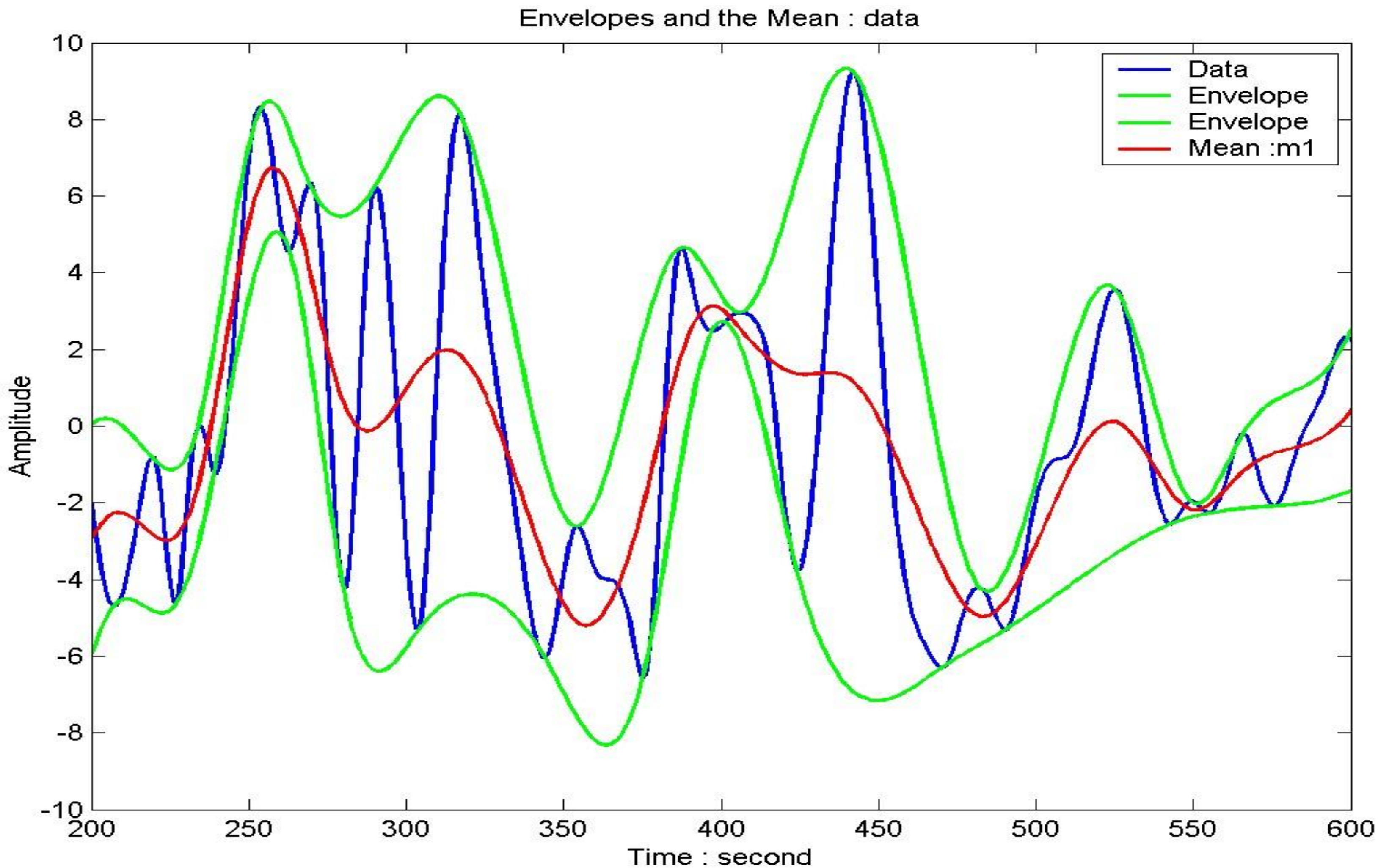
Empirical Mode Decomposition:

Methodology : Test Data



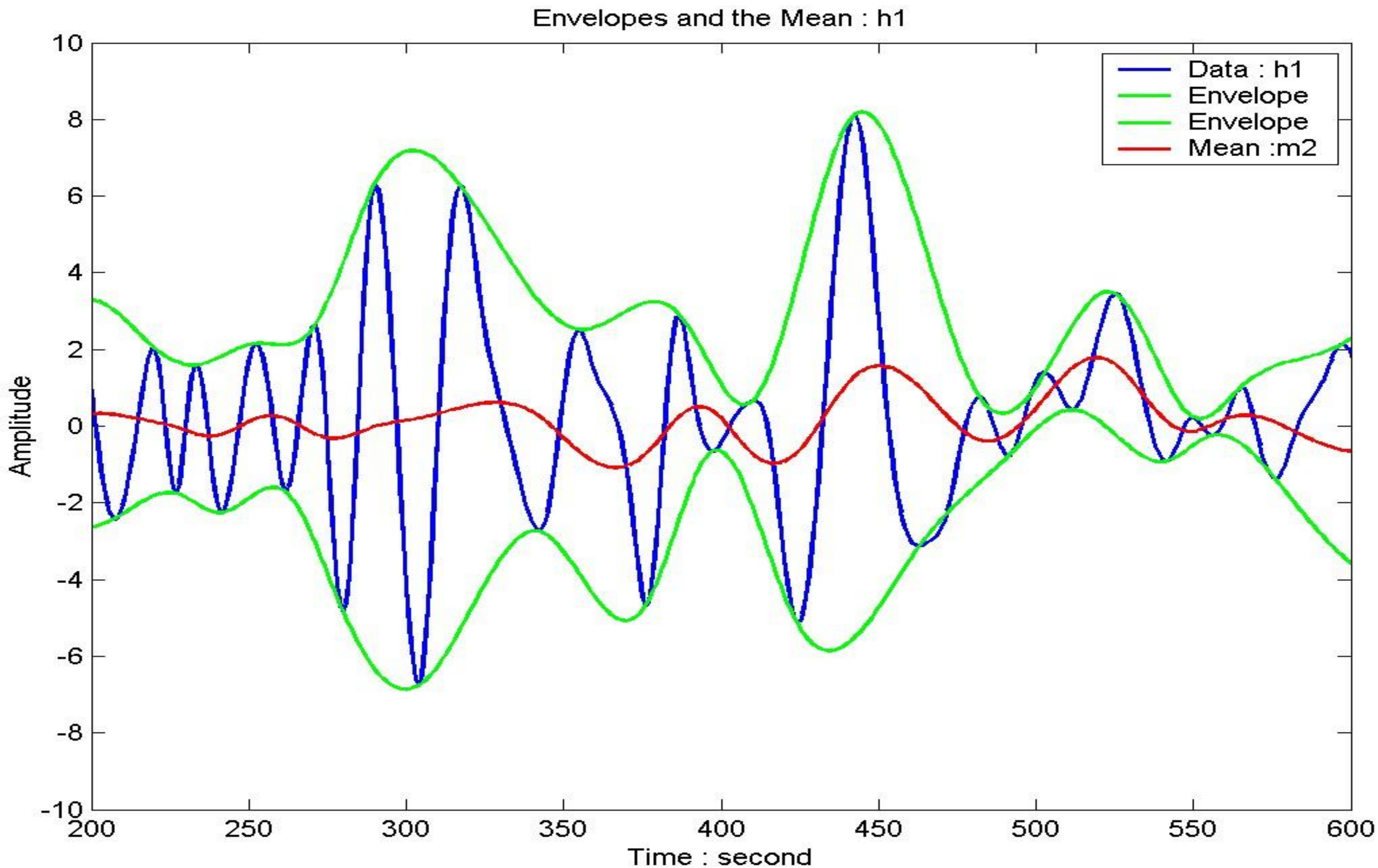
Empirical Mode Decomposition:

Methodology : data and m1



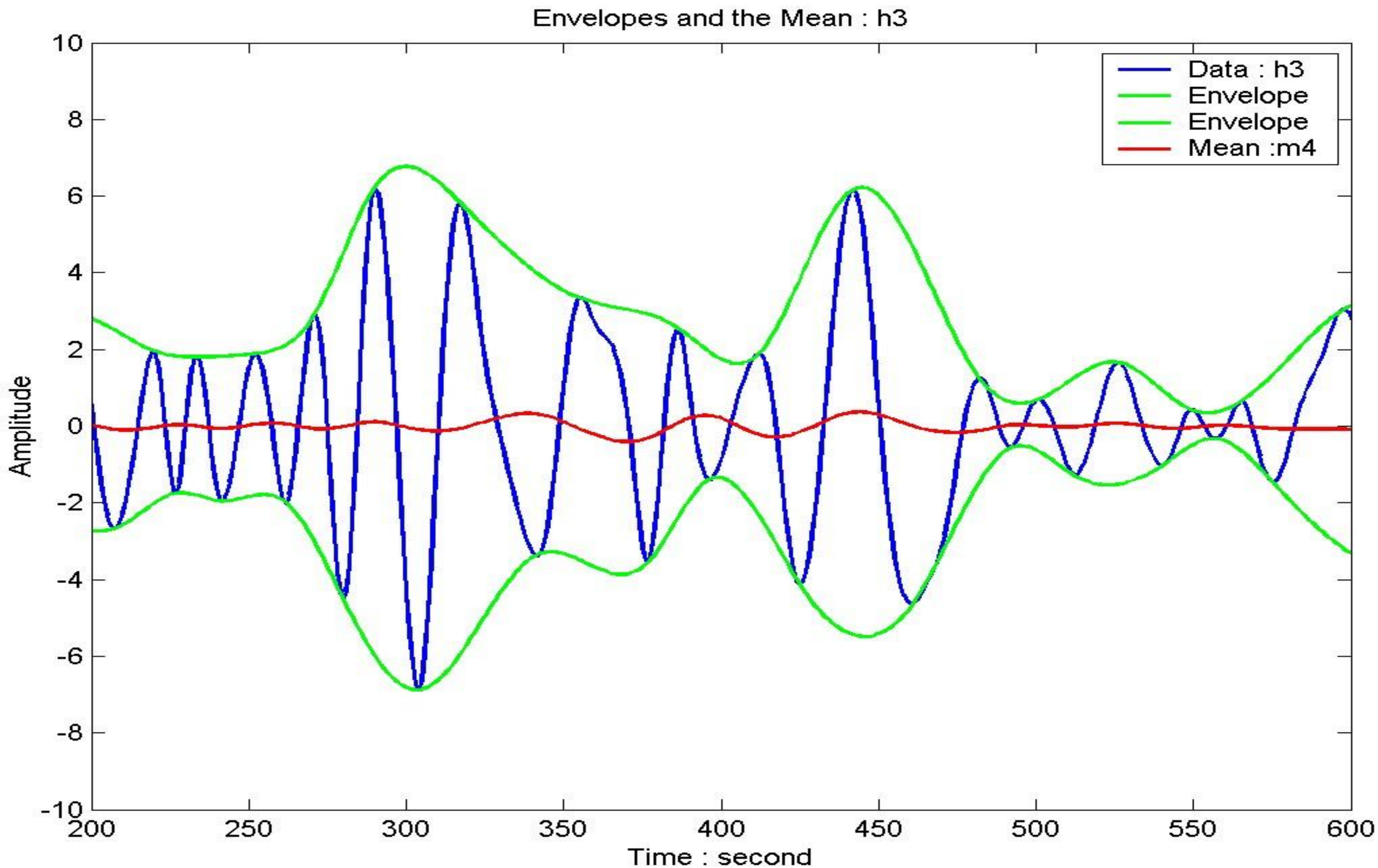
Empirical Mode Decomposition:

Methodology : h1 & m2



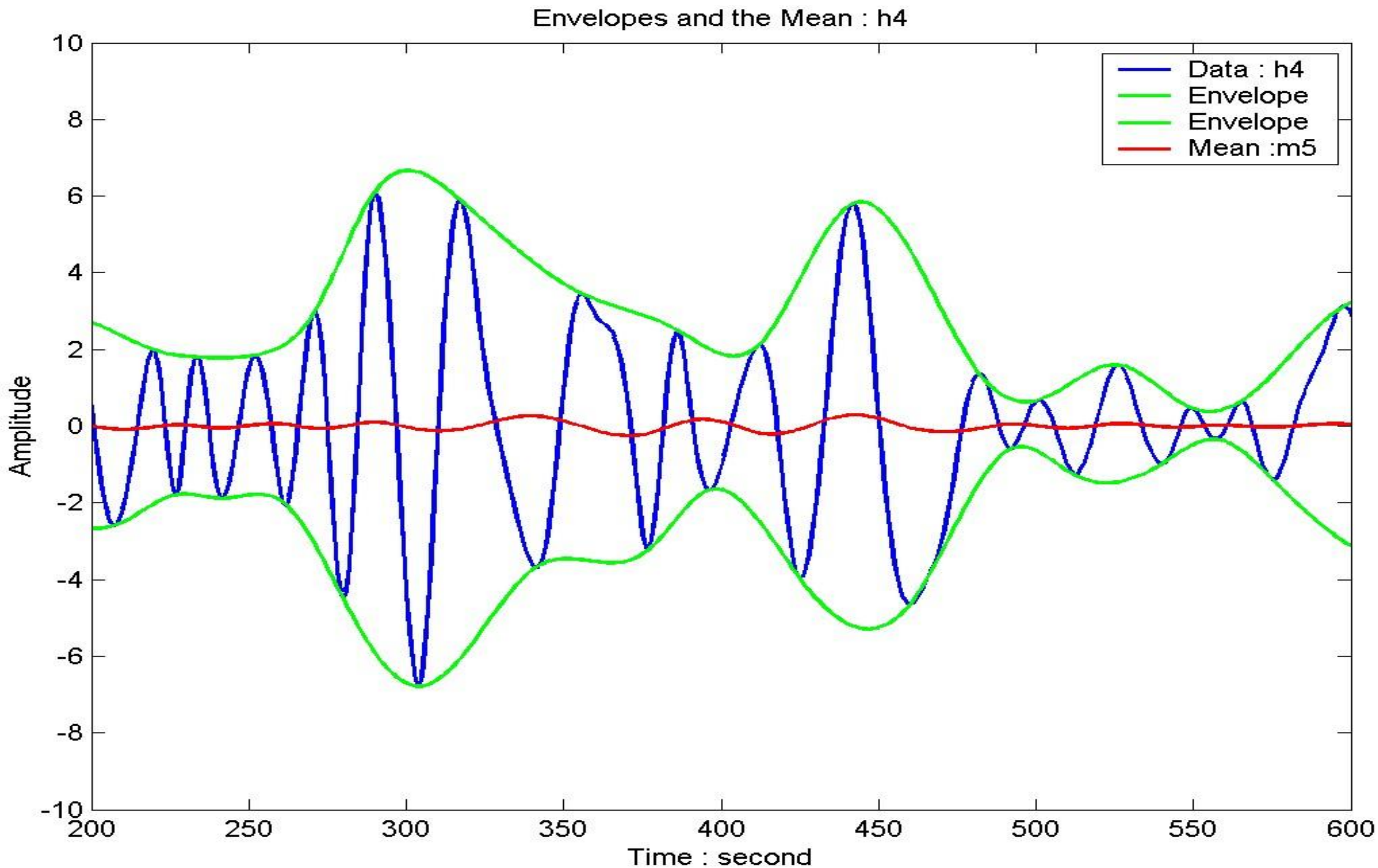
Empirical Mode Decomposition:

Methodology : h3 & m4



Empirical Mode Decomposition:

Methodology : h4 & m5



Empirical Mode Decomposition

Sifting : to get one IMF component

$$x(t) - m_1(t) = h_1(t),$$

$$m_1(t) - m_2(t) = h_2(t),$$

$$\cdots\cdots$$

$$m_{k-1}(t) - m_k(t) = h_k(t).$$

$$\Rightarrow \quad x(t) = m_k(t) + \sum_{i=1}^{k} h_i(t).$$

$h_i(t)$ → Intrinsic Mode Function (IMF)

$m_k(t)$ → Trend

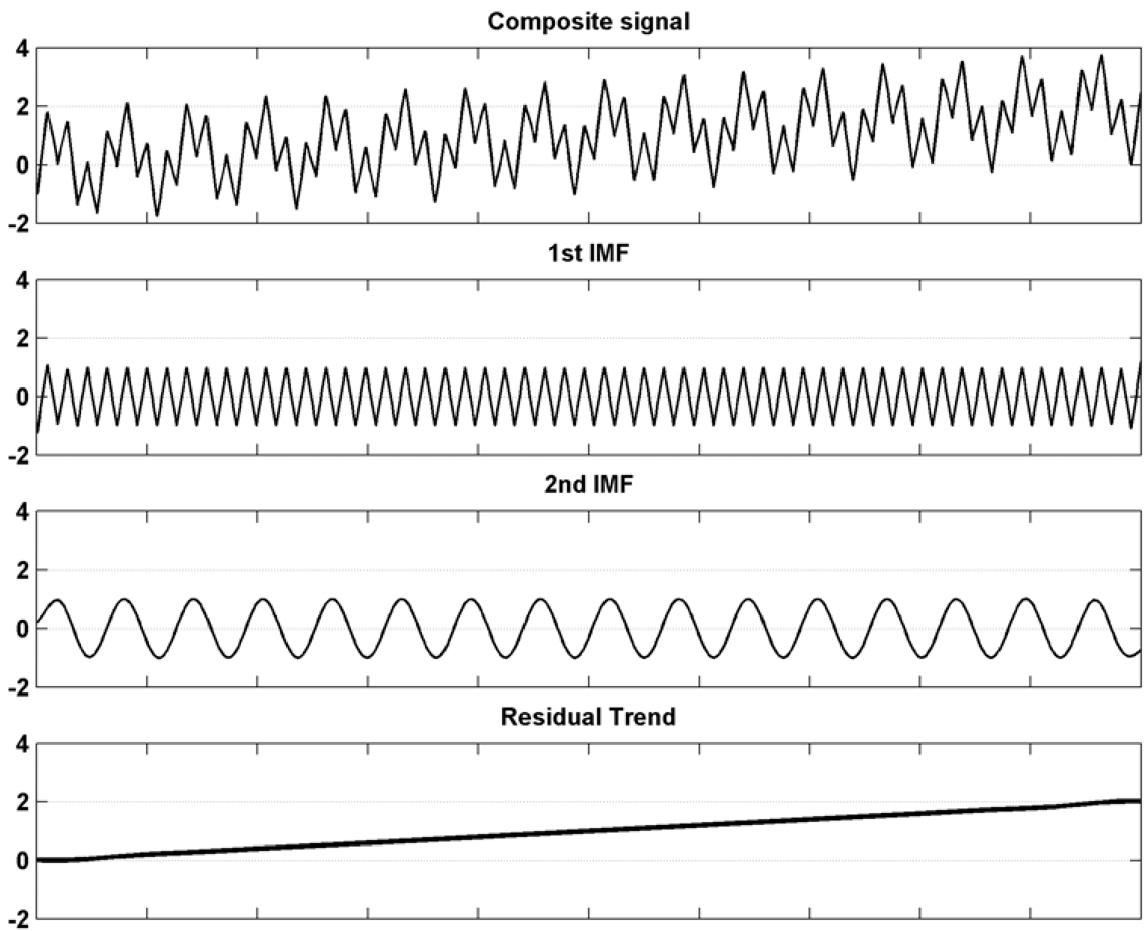
The Stoppage Criteria

The Cauchy type criterion:

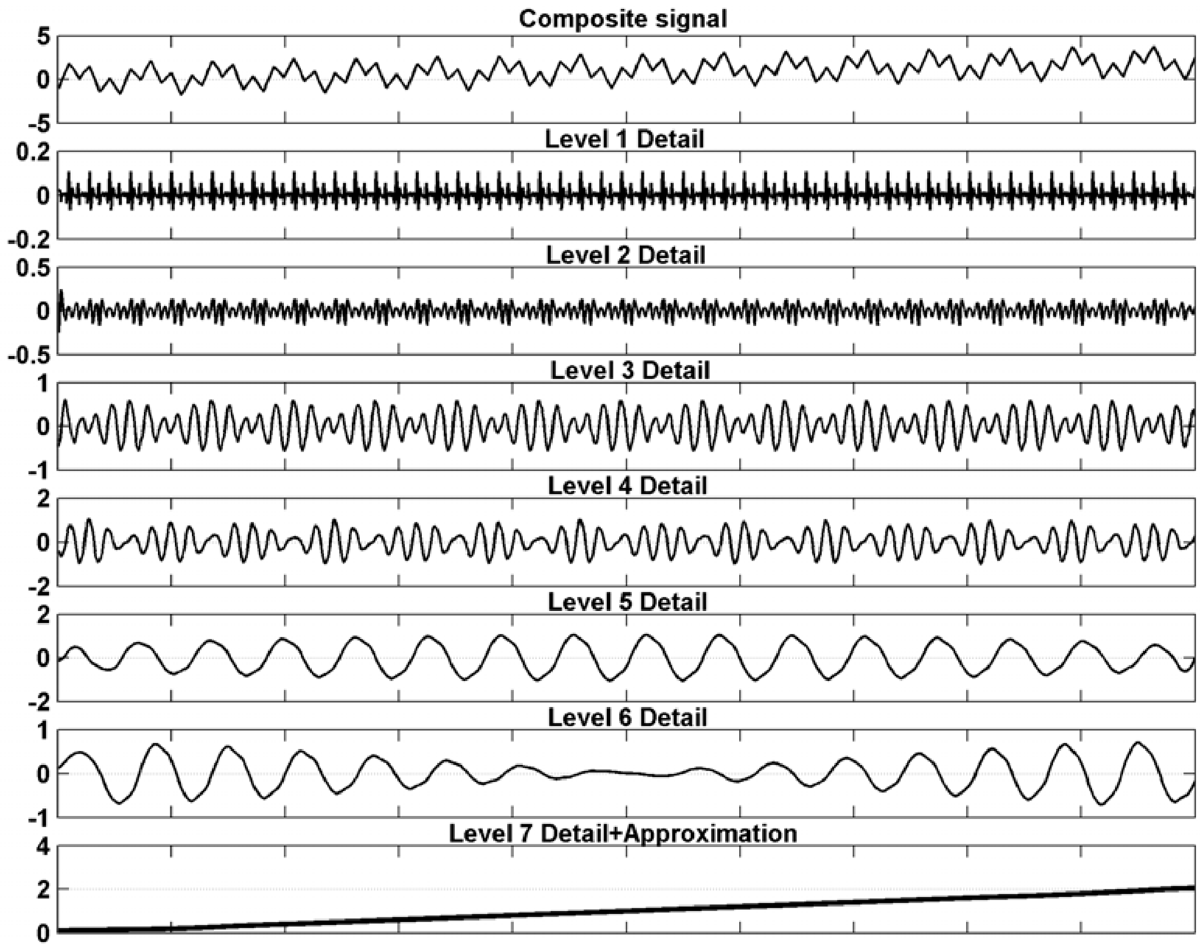
when SD is small than a pre-set value, where

$$SD = \frac{\sum_{t=0}^{T} \left| h_{k-1}(t) - h_k(t) \right|^2}{\sum_{t=0}^{T} h_{k-1}^{\ 2}(t)}$$

EMD → two modes



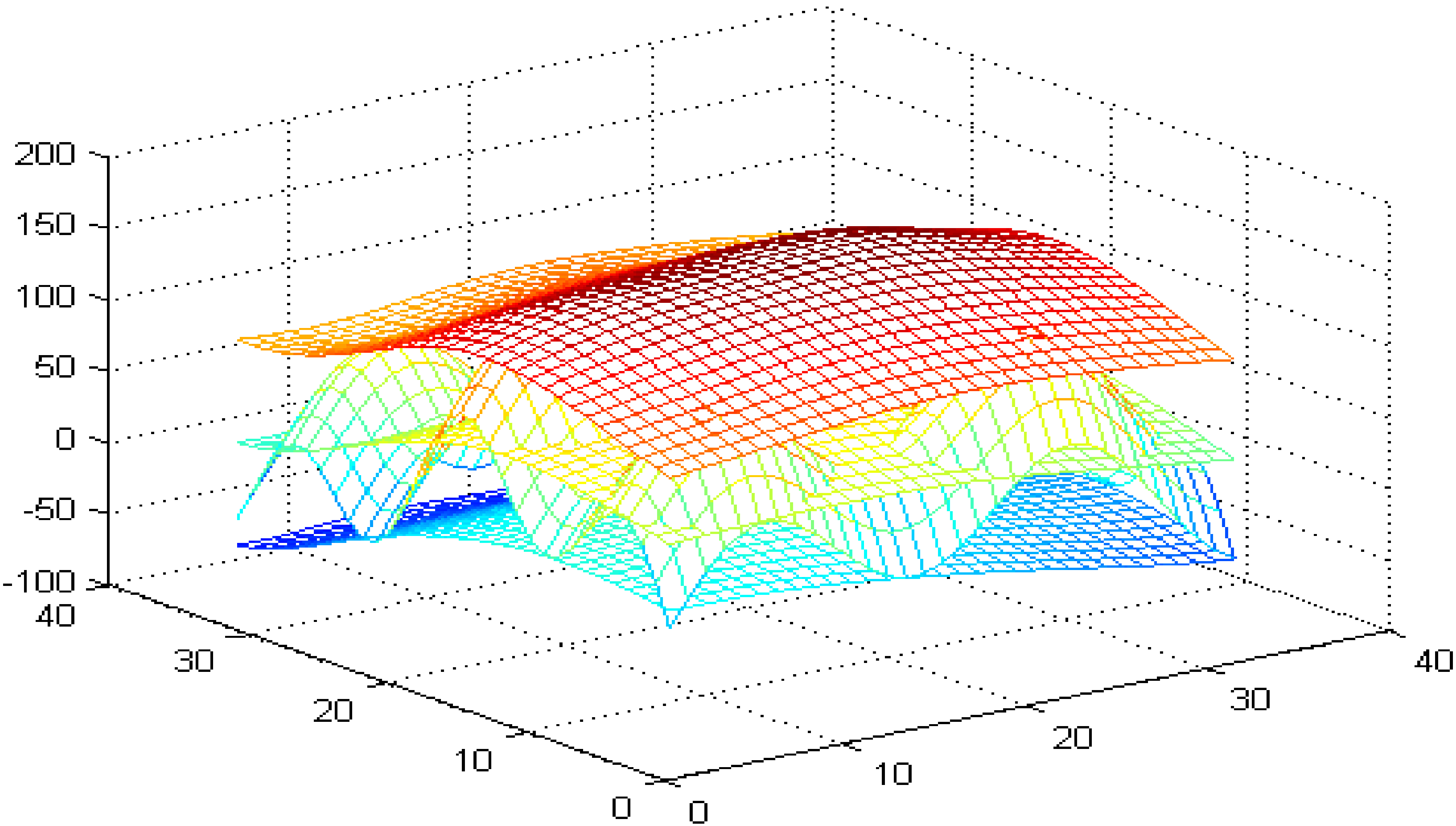
Wavelet-based signal separation → 6 modes



Bi-dimensional EMD (BEMD)→

Image Data Analysis

“2D Spline”



Methods for Spline in BEMD

- Radial Based Function
- Thin Plate Interpretation
- Delaunay Triangulation
- By Slicing
- NURBS : NonUniform Rational B-Spline

Radial Based Function

Linear	$\phi(r) = r$
Cubic splines	$\phi(r) = r^3$
Thin plate splines	$\phi(r) = r^2 \log(r)$
Hardy's multiquadrics	$\phi(r) = \left(r^2 + c^2\right)^{1/2}$
Inverse multiquadrics	$\phi(r) = \left(r^2 + c^2\right)^{-1/2}$
Exponential splines	$\phi(r) = \exp(-cr)$
Gaussian splines	$\phi(r) = \exp(-cr^2)$
Compactly supported spline	$\phi(r) = (1-r)^m + p(r)$

Thin Plate Smoothing

Thin plate smoothing spline calculates the function f(x,y) so that it minimizes the integral bending norm, I_f, over the entire image

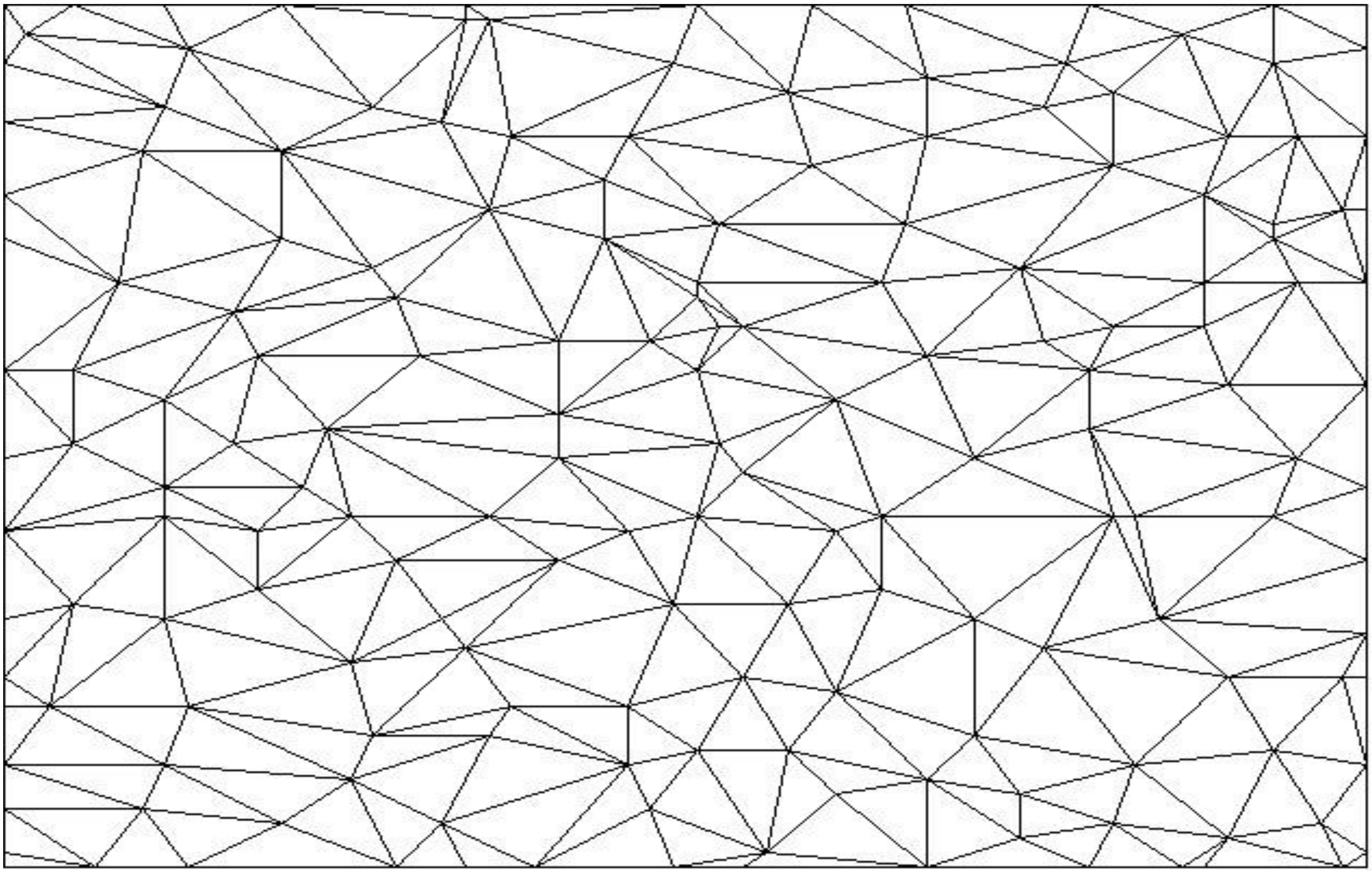
$$I_f = \iint_R \left[\left(\frac{\partial^2 f}{\partial x^2} \right)^2 + 2 \left(\frac{\partial^2 f}{\partial x \partial y} \right)^2 + \left(\frac{\partial^2 f}{\partial y^2} \right)^2 \right] dxdy$$

This means the solution of a linear system with as many unknown as there are data points.

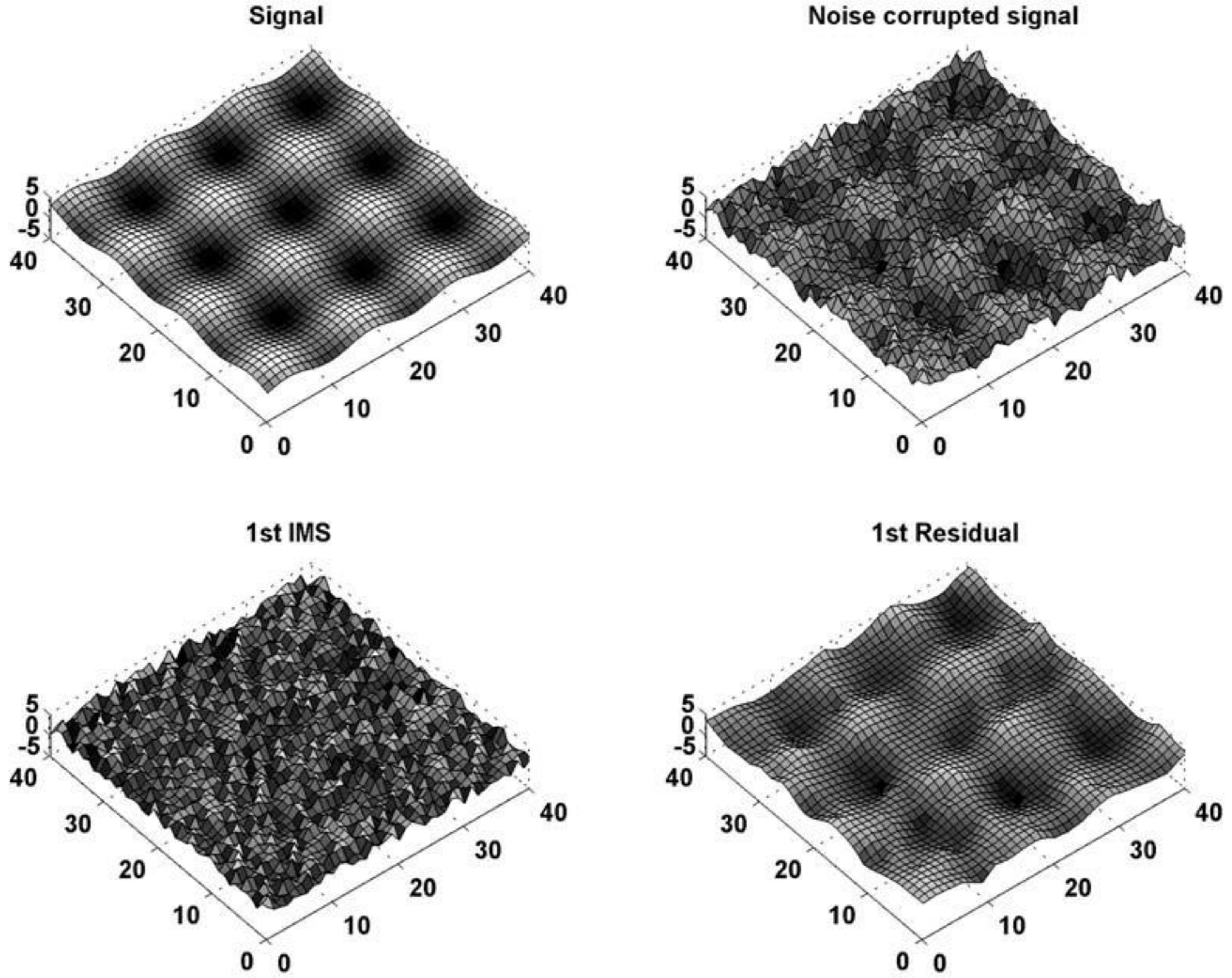
Delaunay Triangulations

- On the basis of Delaunay triangulation we will calculate maximum envelop using the Bernstein-Bezier fitting and interpolation The Bernstein-Bezier calculation includes an optimal fitting around any maximum point and first order smooth connecting along each adjacent edge of Delaunay triangles.

The basis of Delaunay triangulation

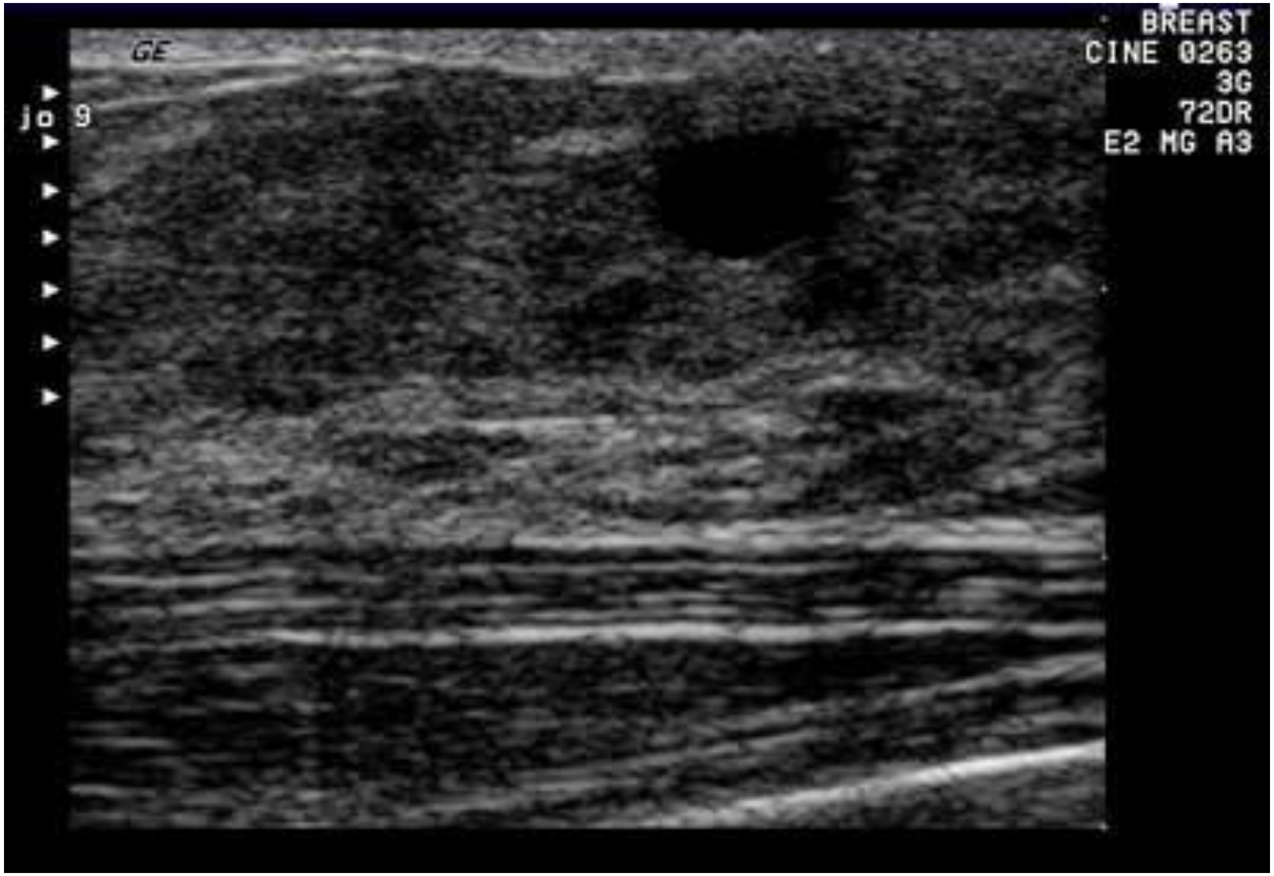


Examples of BEMD


Signal
Noise corrupted signal
1st IMS
1st Residual
5
0
-5
40
30
20
10
0
0
10
20
30
40

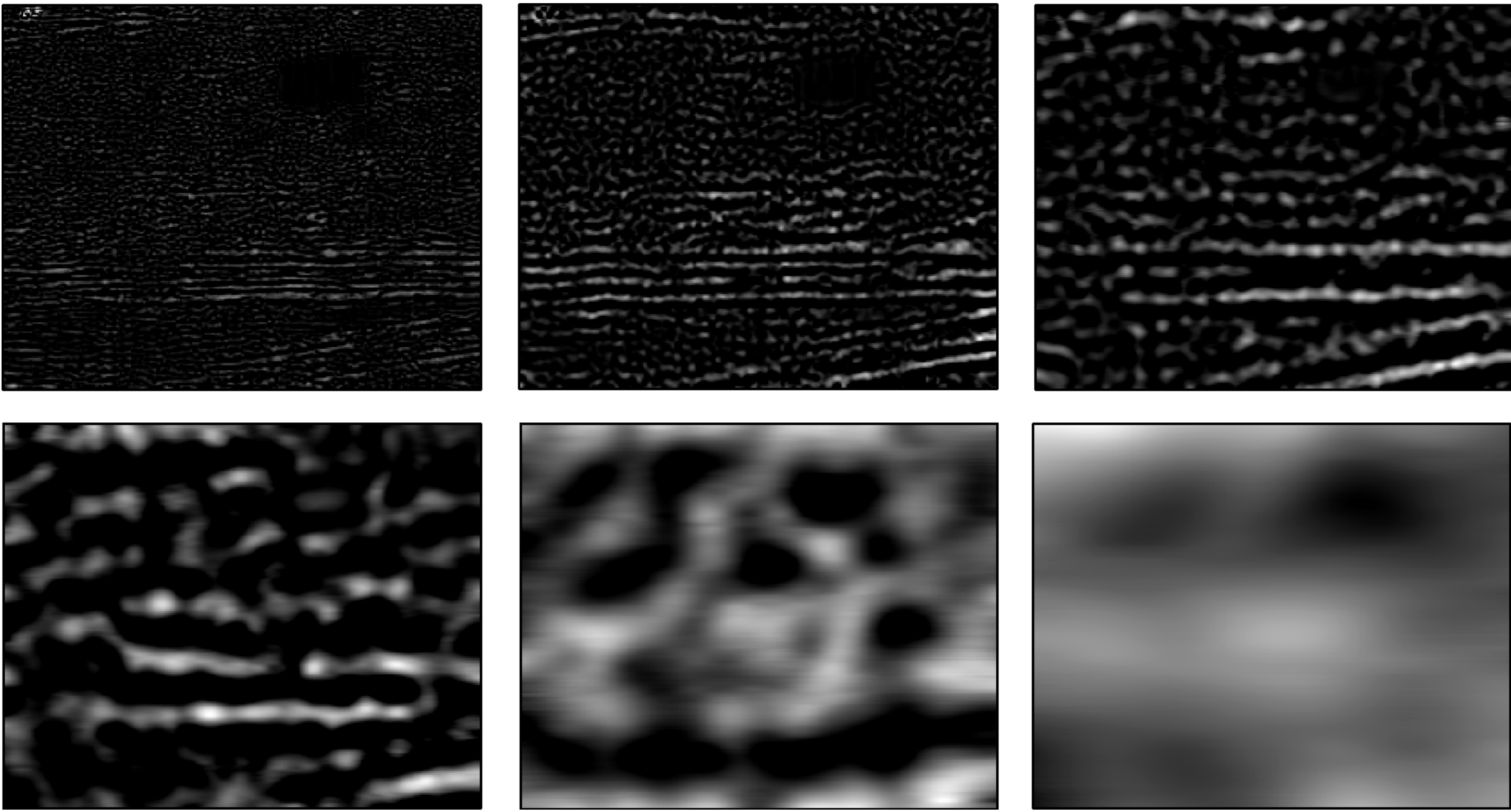
Original image:

http://www.sonoworld.com/Sonoworld/Galleries/ShowCategoryImages.aspx?CategoryID=30#

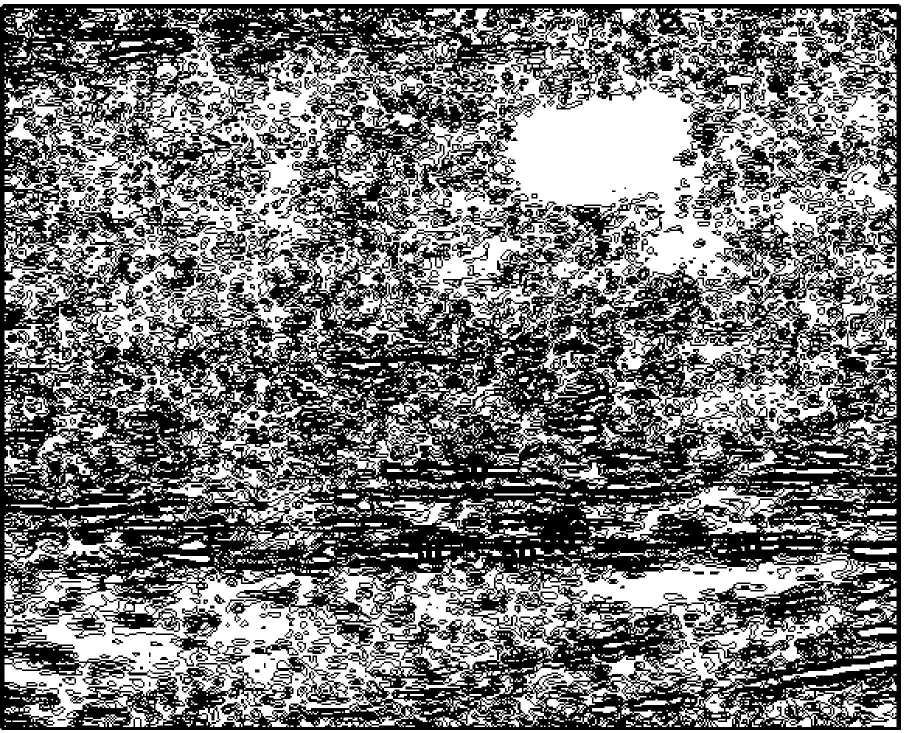


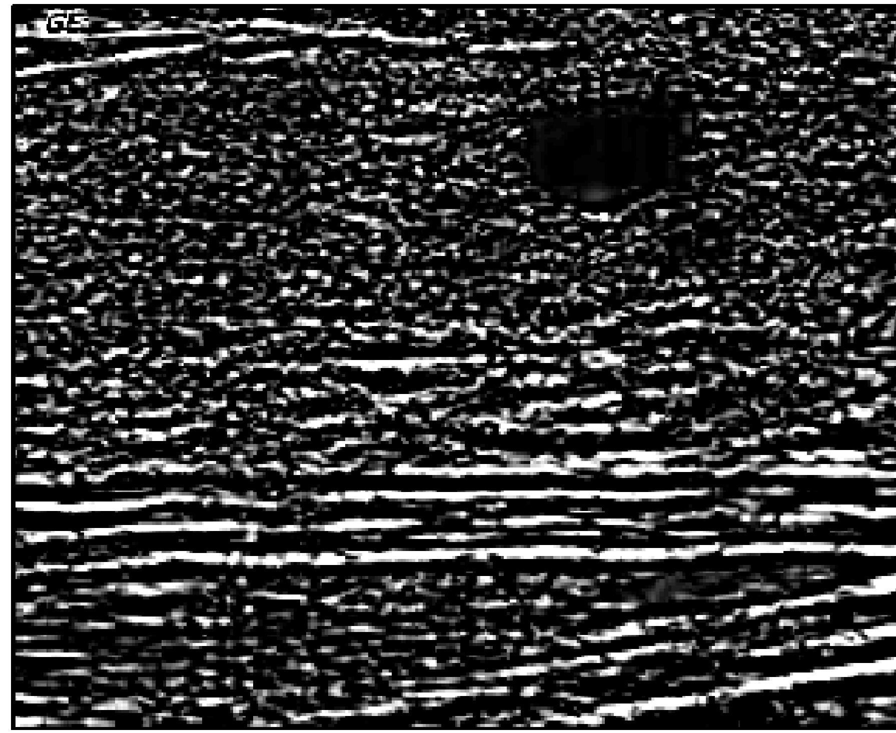
Transverse sonogram, left breast palpable mass.
Small, well defined anechoic cyst.

IMFs: 1 2 3
4 5 6



Combination of IMF 1 and IMF 2 gives the obvious uniform region.
Left is the contour figure and right is the Image.

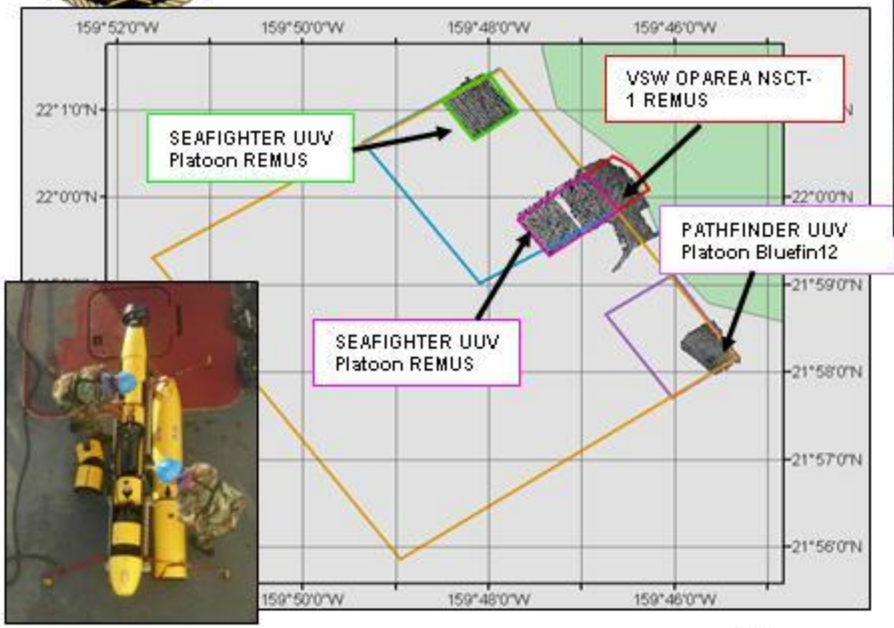


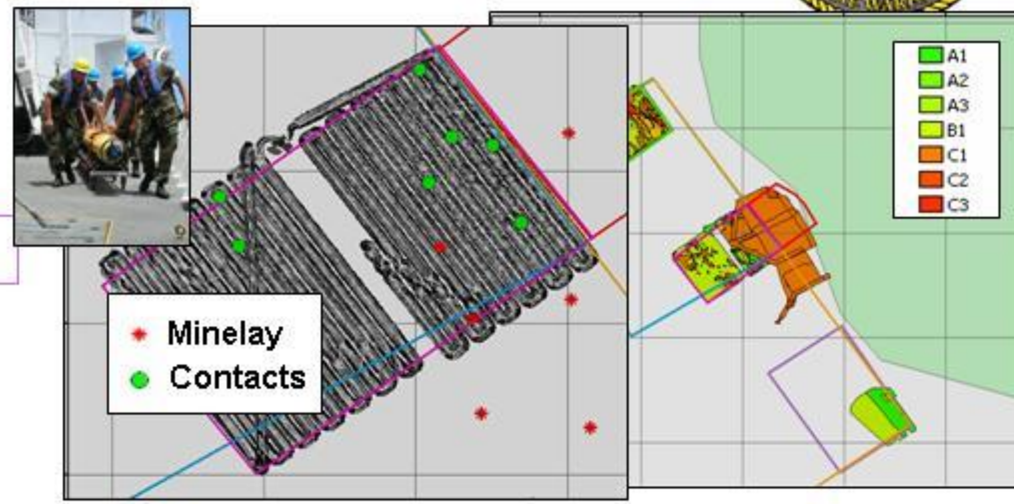


EMD → Effective Method for Identifying Change Detection

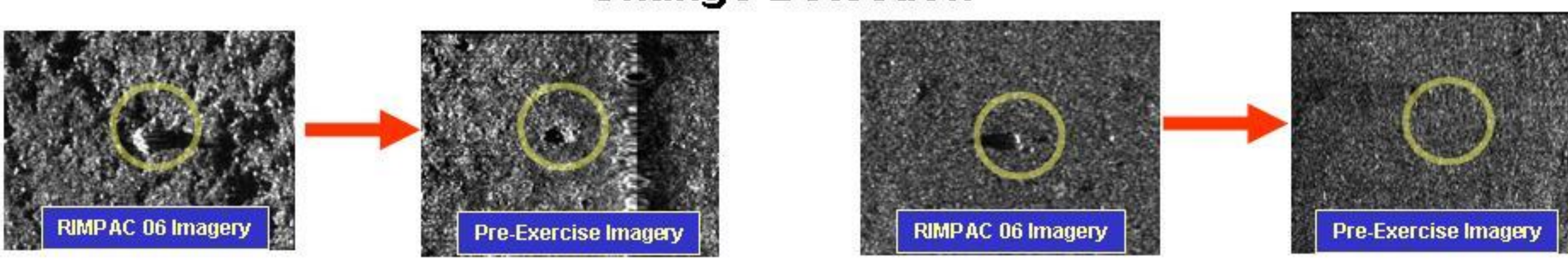
Intelligence Preparation of the Environment

INTEGRATION: Mine Detection and Classification





Change Detection



Contact eliminated as prior ID'd non-Mine

Contact not in pre-exercise imagery. Confirmed as Mk25 Bottom Mine.

IPE Objective: To gain efficiency in the detection of mine like objects for further prosecution

Unclassified

After Image Coregistration

Baseline Image

Repeat Image

My Plan

EMD →
Difference of the Two Images

→ Change Detection

Proposed Work

- (1) Development of efficient EMD software for analyzing 2D images
- (2) Analysis of NSWC-PC image data (sidescan sonar, laser, radar, …) for software validation and verification
- (3) Implementation of the software into Navy mine detection platforms such as sidescan sonar, ALMDS, …
- (4) Development of simple and efficient method for identifying change detection