Hilbert-Huang transform and its applications

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NASA

Featured IP Assets:
US 5,983,162; US 6,311,130; US 6,381,559; US 6,631,325; US 6,738,734; US 6,782,124; US 6,862,558; US 6,990,436; US 6,901,353; US 7,346,461

Related IP:
US 10/963,470

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Lot Summary:

Ocean Tomo Federal Services, LLC, is offering exclusive licenses to NASA Goddard Space Flight Center inventions. Offered in this Lot are ten U.S. patents and one domestic application directed to a method and system for analyzing signals, specifically to analyzing nonlinear physical signals. These advanced techniques have broad applications for measuring, calibrating and testing physical signals, as well as processing, simulating and modeling data. The breadth of these assets allows the inventions to be used in fields requiring acoustical analysis, simulating geophysical events, or modeling dynamic systems.

Conventional methods for processing acoustic and vibration data emanating from physical phenomenon have not yielded entirely accurate results. These prior solutions found limited success because the recorded signals were nonlinear, non-stationary, and of finite duration. One technique typically employed to overcome these drawbacks relies on Fourier transforms. The results, however, are based on extremely generalized approximations and are incapable of providing accurate physical interpretations.

The techniques disclosed within the present invention address the limitations associated with modeling physical phenomena by first decomposing the physical signals to indicate intrinsic oscillatory modes and then by applying a Hilbert transform to construct an energy-frequency-time distribution to preserve the occurrence of physical events at corresponding times. The inventions overcome time scale and linearity issues and are not restricted by imperfect sensors and numerical schemes that contaminate data.

The proprietary rights bundled within this Lot would be valuable to any company interested in dynamic vibrations and acoustic technologies. Market examples include controls and automations, seismic exploration, reservoir imaging, geographical development, and industrial manufacturing. The inventions enable the analysis of dynamic, non-linear systems and provide accurate interpretations of the underlying physics of the data signals. This data processing system will present new opportunities for analyzing dynamic non-linear signals, providing an advantage to any company who integrates this technology into their products and services.

Sample Forward Citation Analysis:

- Flint Hills Scientific, LLC
- Goodrich Corp.
- International Business Machines Corp.
- Kenwood Corp.
- Rohde & Schwarz GmbH & Co. KG
- Siemens AG
- Sony Corporation
- STMicroelectronics Inc.
- Texas Instruments Inc.

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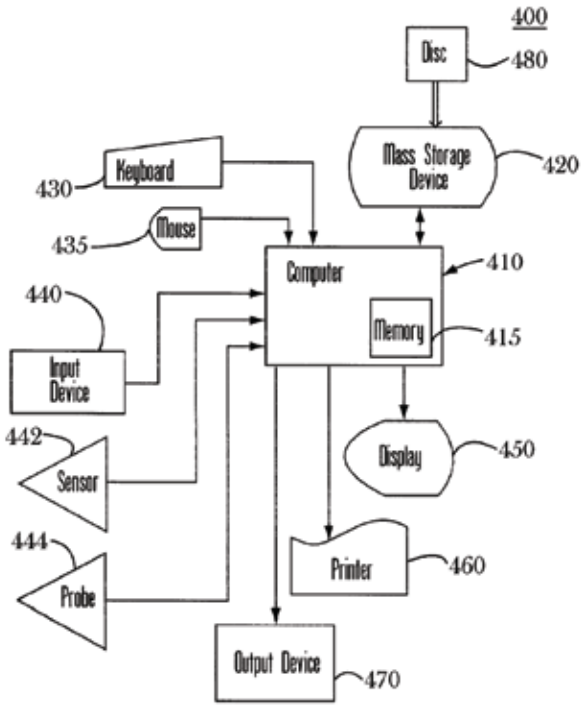
- U.S. Navy, The
- University of Chicago, The
- Vanguard Technologies, LLC

Potential Licensees:

- Engineering Firms
- Scientific Modeling Companies
- Data Analysis Companies



Patent Number:

US 5,983,162

Title:

Computer implemented empirical mode decomposition method, apparatus and article of manufacture

Inventor:

Norden E. Huang

Issue Date:

November 9, 1999

Earliest Filing Date:

August 12, 1996

Representative Independent Claim:

A computer implemented method of analyzing a physical signal representative of a physical phenomenon, comprising the computer implemented steps of: inputting the physical signal representative of the physical phenomenon; recursively sifting the physical signal via Empirical Mode Decomposition to extract an intrinsic mode function indicative of an intrinsic oscillatory mode in the physical phenomenon; and displaying the intrinsic mode function.

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Patent Number:
US 6,311,130

Title:
Computer implemented empirical mode decomposition method, apparatus, and article of manufacture for two-dimensional signals

Inventor:
Norden E. Huang

Issue Date:
October 30, 2001

Earliest Filing Date:
August 12, 1996

Representative Independent Claim:
A computer implemented method of processing a two-dimensional physical signal representative of a physical phenomenon, comprising the computer implemented steps of: inputting the two-dimensional physical signal representative of the physical phenomenon; decomposing the two-dimensional physical signal into one dimensional profiles; and recursively sifting the profiles via Empirical Mode Decomposition to extract an intrinsic mode function for each of the profiles indicative of an intrinsic oscillatory mode in the physical phenomenon.

Patent Number:
US 6,381,559

Title:
Empirical mode decomposition apparatus, method and article of manufacture for analyzing biological signals and performing curve fitting

Inventor:
Norden E. Huang

Issue Date:
April 30, 2002

Earliest Filing Date:
August 12, 1996

Representative Independent Claim:
A computer implemented method of analyzing a signal, comprising: inputting the signal; recursively sifting the signal via Empirical Mode Decomposition to extract an intrinsic mode function indicative of an intrinsic oscillatory mode; generating a residual signal by subtracting the intrinsic mode function from the signal; treating the residual signal as the signal during a next iteration of said recursive sifting step iterating to perform said recursive sifting to generate an n-th intrinsic mode function indicative of an n-th intrinsic oscillatory mode until a stopping condition is met; and constructing a filtered signal from a subset of the intrinsic mode functions.

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Patent Number:
US 6,631,325

Title:
Computer implemented empirical mode decomposition method apparatus, and article of manufacture utilizing curvature extrema

Inventors:
Norden Eh Huang; Zheng Shen

Issue Date:
October 7, 2003

Earliest Filing Date:
August 12, 1996

Representative Independent Claim:
An article of manufacture, comprising: a computer-usable medium including computer-readable program code means, embodied therein, for causing a computer to analyze a physical signal representative of a physical phenomenon, the computer-readable program code means comprising: computer-readable program code means for inputting the physical signal; computer-readable program code means for recursively sifting said signal via Empirical Mode Decomposition to extract an intrinsic mode function indicative of an intrinsic oscillatory mode in a physical phenomenon; and computer-readable program code means for displaying the intrinsic mode function on a display, said recursive sifting means identifying extrema in said signal from curvature extrema.

Patent Number:
US 6,738,734

Title:
Empirical mode decomposition apparatus, method and article of manufacture for analyzing biological signals and performing curve fitting

Inventor:
Norden E. Huang

Issue Date:
May 18, 2004

Earliest Filing Date:
August 12, 1996

Representative Independent Claim:
A computer implemented method of analyzing a signal, comprising: inputting the signal; recursively sifting the signal via Empirical Mode Decomposition to extract an intrinsic mode function indicative of an intrinsic oscillatory mode; and using the intrinsic mode function as a basis to interpret the signal.

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Patent Number:
US 6,782,124

Title:
Three dimensional empirical mode decomposition analysis apparatus, method and article manufacture

Inventor:
Per Gloersen

Issue Date:
August 24, 2004

Earliest Filing Date:
August 12, 1996

Representative Independent Claim:
A computer implemented method of analyzing three-dimensional (3D) phenomena, said method comprising the steps of: inputting a representation of a 3D phenomenon; creating a complex representation of said 3D phenomenon; recursively sifting said complex representation using Empirical Mode Decomposition to extract an intrinsic mode function indicative of an intrinsic oscillatory mode; and processing the intrinsic mode function.

Patent Number:
US 6,862,558

Title:
Empirical mode decomposition for analyzing acoustical signals

Inventor:
Norden E. Huang

Issue Date:
March 1, 2005

Earliest Filing Date:
February 14, 2001

Representative Independent Claim:
A computer implemented method of analyzing an acoustical signal, comprising: inputting the acoustical signal; extracting a set of intrinsic mode functions from the acoustical signal; and storing said set of intrinsic mode functions of the acoustical signal; and identifying a specific acoustical signal; wherein said specific acoustic signal is identified in said set of intrinsic mode functions.

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Patent Number:
US 6,990,436

Title:
Computing frequency by using generalized zero-crossing applied to intrinsic mode functions

Inventor:
Norden E. Huang

Issue Date:
January 24, 2006

Earliest Filing Date:
November 28, 2003

Representative Independent Claim:
The computer implemented method of analyzing a physical signal from a physical device comprising the steps of; a. inputting the physical signal; b. extracting a set of Intrinsic Mode Functions from the physical signal; c. generating a set of mean frequency functions from the Intrinsic Mode Functions, wherein the step of generating a set of mean frequency functions includes computing the mean frequency at a point along the time scale for one of the Intrinsic Mode Functions and continuing to perform the computing step for all of the Intrinsic Mode Functions; and, d. displaying said set of mean frequency functions.

Patent Number:
US 6,901,353

Title:
Computing instantaneous frequency by normalizing Hilbert transform

Inventor:
Norden E. Huang

Issue Date:
May 31, 2005

Earliest Filing Date:
July 8, 2003

Representative Independent Claim:
A computer implemented method of analyzing a signal comprising: inputting the signal; extracting a collection of Intrinsic Mode Functions from the signal via Empirical Mode Decomposition; normalizing the Intrinsic Mode Functions; and transforming the normalized Intrinsic Mode Functions with a Hilbert Transform.

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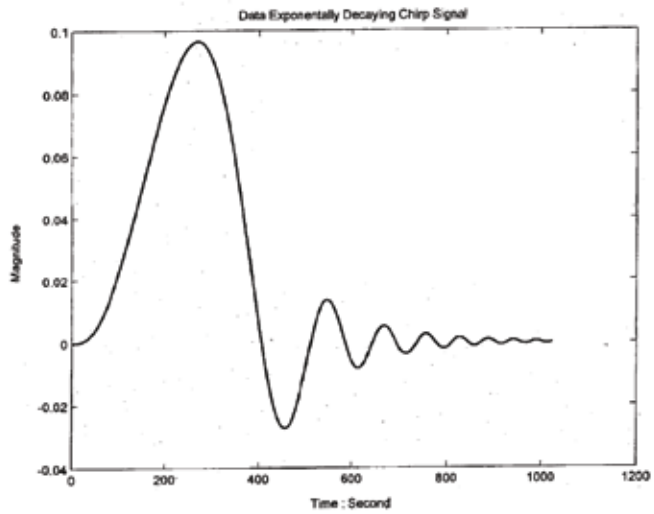
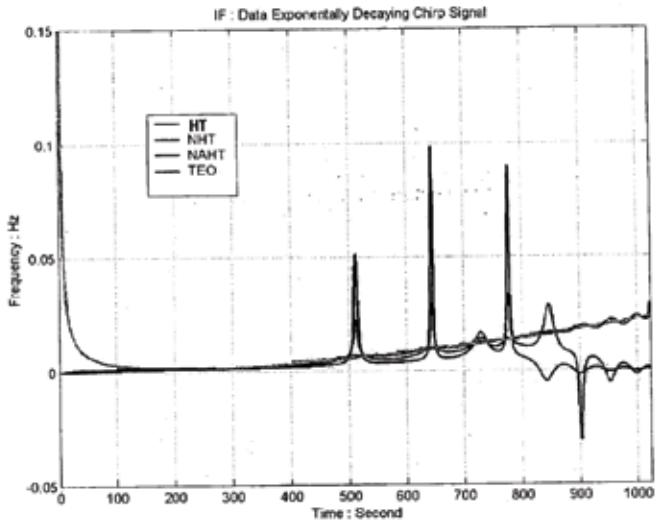
Patent Number:
US 7,346,461

Title:
System and method of analyzing vibrations and identifying failure signatures in the vibrations

Inventors:
Norden E. Huang; Liming W. Salvino

Issue Date:
March 18, 2008

Earliest Filing Date:
September 30, 2005

Representative Independent Claim:
A method of analyzing vibrations, said method comprising the steps of: collecting vibration data; extracting intrinsic mode functions (IMFs) indicative of intrinsic oscillatory modes in said collected vibration data satisfying at least one of the conditions: a) the number of extrema and number of minima crossings differ by at most a first predetermined value and b) the mean value of an upper envelope maxima and lower envelope minima approaches a second predetermined value; generating a stability spectrum for said vibration data from said IMFs by classifying said vibration data into positive and negative results and separating said positive and negative results; generating a non-linearity indicator for said stability spectrum; and, displaying non-linearity indicator in said stability spectrum, said non-linearity indicator indicating a transition from stability to instability.