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Methods to Reveal Hidden Structures of Signals and their Applications

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As the result of the application of the maximum entropy method for reveal the structure of blurred spectra new information about characteristics of materials had been obtained. The methods based on the account of the signal entropy and the wavelet transformation had been developed to seismic signals treatment and to determ the processes bifurcation points.

Key words and phrases: entropy, wavelet, blurred spectra, seismic waves, georadar, bifurcation points.

1. Introduction

It is difficult to analyse the signals that have no distinct structure because there are no indicators of structural elements and mode change moments. In present paper the methods used to reveal the hidden structure of such signals by their processing are discribed.The approaches used in the methods proposed are connected with a posterior increase of data resolution and search for signal instability and spectrum variation domains in various modes. Relevant algorithms are based on the maximum entropy method, calculation of amplitude and time signal entropy and wavelet signals transformation.

In the maximum entropy method, the hidden structure of blurred spectra manifests itself owing to the band width decrease procedure [1]. A change in the mode of the process is characterized by high signal entropy values that reflect the chaotic pattern and instability of transition moments. A change in the mode of the process is also marked by variations in spectral characteristics. A change in the mode of the process is clearly indicated by a wavelet-spectrogram fixed the disturbed continuity, frequency variations and phase jumps of signals.

Common approaches to the development of methods for revealing hidden signal structure lead to various applications.

2. Maximum Entropy Method Applications to Material Study

The IR spectrum structures revealed have provided new data on the isomorphic replacements and structural characteristics of silicates. A high-resolution estimate of the NGR spectrum of amorphous diadochite has shown that diadochite corresponds to destinezite. Similar estimates of the blurred NGR spectra of hydrated biotites (Fig. 1) were used to trace structural transformation dynamics in detail.

3. Account of Signal Entropy and Wavelet Transformation

In order to estimate the amplitude Sa and time St entropy of the vibrational signal in data window We did obtained the sequence of differences between the amplitudes or the positions of the neighboring extremum of the signal accordingly. Then

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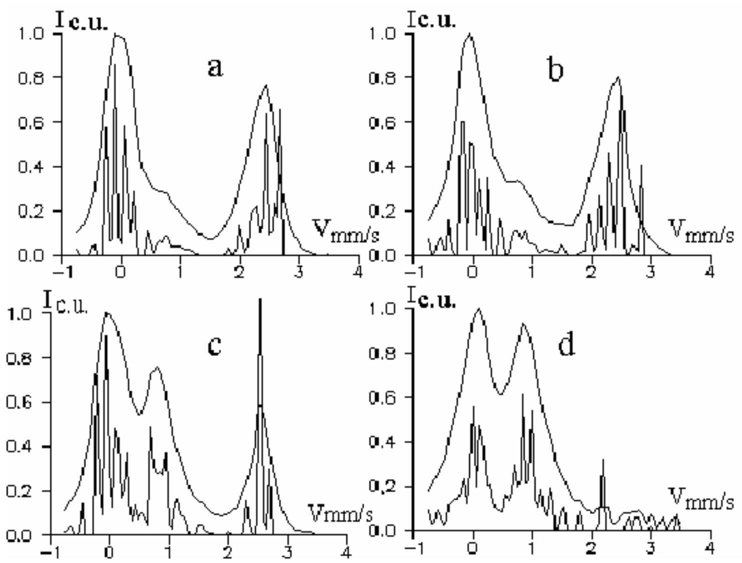

Figure 1. **The blurred NGR spectra of hydrated biotites at the various degrees of oxidation (a-d) and their maximum entropy high resolution estimations**

on the histogram of the modules of these differences we did estimated the probabilities of histogram categories $p_i, i = 1, ..., m$ and put them in formula of entropy $S = -\sum_{i=1}^{m} p_i ln p_i$. These types of signal entropy are considered as independent and may used separately (Fig. 2A) or together as $S = \sqrt{Sa^2 + St^2}$. The Fig. 2B shows that the continuous wavelet transformation allows to indicate the ranges corresponded the various harmonics components.

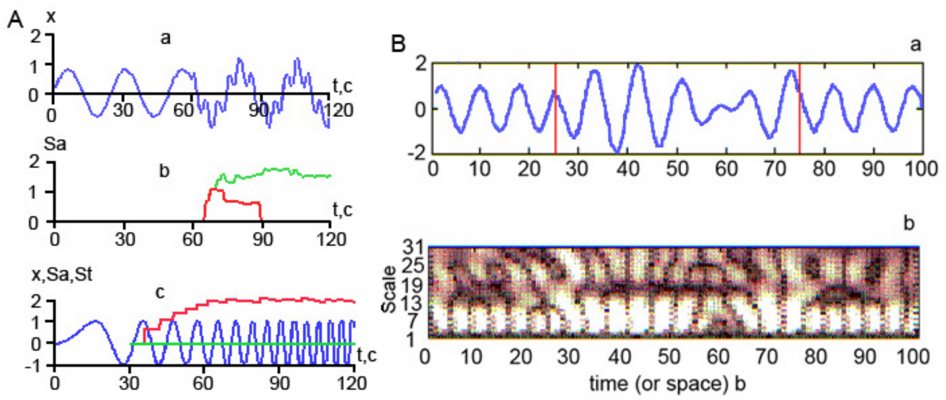

Figure 2. **A. Simulating signal (a), it's Sa, St entropies (b) in sliding window; c — simulating signal (curve 1) and it's Sa, St entropies (curves 2,3) accounted in spreading window. B. Analyzed signal and it's continuous wavelet transformations**

4. Seismological Application of Wavelet Algorithms

Application of wavelet algorithm to the seismic diagrams processing allows to estimate the coordinates of the hypocenters and epicenters of the seismic events [2]. Such processing of seismograms has automatically revealed the moments of arrival of various types of seismic waves (Fig. 3A). The determination of the coordinates of the sources of seismic events with wavelet algorithm help and by conventional WGS program processing gave similar results (Fig. 3C). The wavelet algorithms can be used in modified form to increase the resolution of georadar profiling and radon survey data [2, 3].

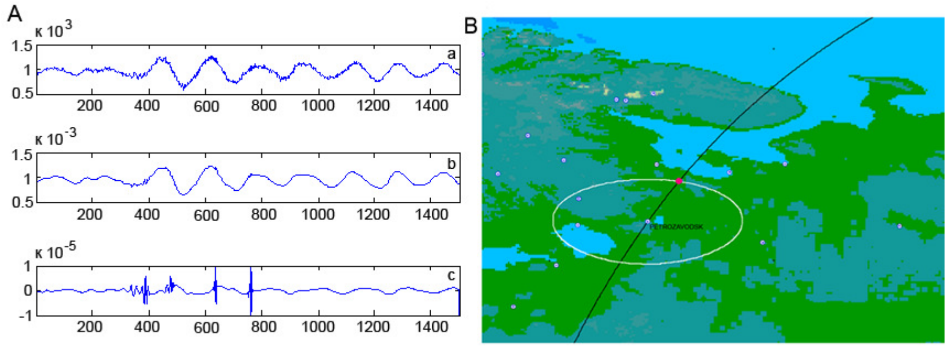

Figure 3. **Wavelet reconstruction of place of rocket parts falling: A. Seismic diagram part corresponded a longitudinal seismic waves (a), the first approximated (b) detailed (c) coefficient dependencies and wavelet diagram (d); B – the determination of the place of the event**

5. Bifurcations of Non-Steady-State Processes

Wavelet and entropy algorithms were employed to reveal the bifurcation points of non-steady-state processes of river runoff and solar activity As Fig. 4 shows on the example of Suna runoff these methods give the similar results.

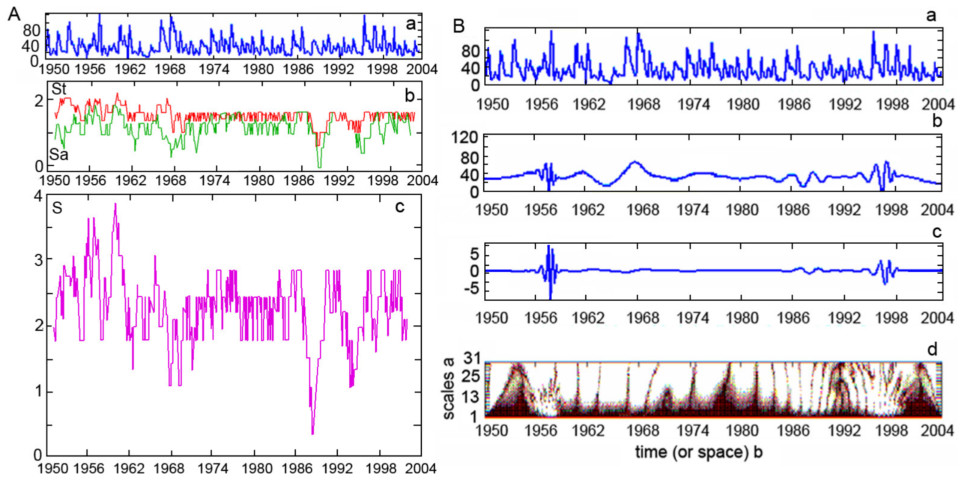

Figure 4. **The Suna runoff (a) by entropy (A)and wavelet (B) treatment A. Sa and St entropies (b),** $S = \sqrt{Sa^2 + St^2}$ **(c); B. The first approximated (b) and detailed (c) coefficients dependencies and wavelet diagram (d)**

When studying these processes, blurred bifurcations with transition domains, comparable in duration to steady process development domains, were observed. Bifurcation nuclei were identified by filtration procedures (Fig. 5).

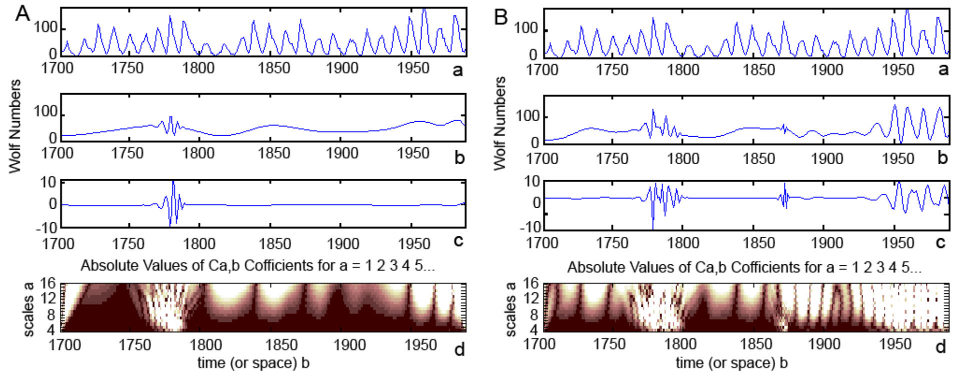

Figure 5. **The bifurcations in data of solar activity at the threshold 2(A) and 1.0001(B) of wavelet filtration, analyzed data (a), the first approximated (b) and detailed (c) coefficients dependencies, wavelet diagram (d)**

6. Conclusion

The study has corroborated the efficiency of the methods developed to reveal a hidden structures of signals and the informative value of the results obtained. The characteristic feature of the methods is the minimum use of a priori information. The methods proposed are more general-purpose, simple and economical than instrumental measurement improvement methods and exhibit a wide application range. Examples of application of the algorithms also show that they can be used in various fields.

References

1. *Belashev B. Z.* Methods for Reconstruction of a Blurred Spectrum // Journal of Applied Spectroscopy. — 2001. — Vol. 68, No 5. — Pp. 838–846.
2. *Belashev B. Z., Ekimova I. A., Nilov I. I.* Increasing the Resolution of Geophysical Data with Wavelets // Proceedings of the 14th International conference "Connection between the surface and deep structures of the Earth's crust", 27-31 October, 2008, Petrozavodsk, Part 1. — 2008. — P. 54. — In russian.
3. *Kozhukhov S. A., Belashev B. Z., Savitsky A. I.* Methodical Aspects of Radon Monitoring of Karelia // Proceedings of the 14th International Conference "Connection between the surface and deep structures of the Earth's crust", 27-31 October, 2008, Petrozavodsk, Part 1. — 2008. — Pp. 272–274. — In russian.

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Методы выявления структуры скрытых сигналов и их применение

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В результате применения метода максимума энтропии для выявления структуры размытых спектров была получена новая информация о свойствах материалов. Методы, основанные на учете энтропии сигналов и вейвлет-преобразовании, применены для обработки сейсмических сигналов и определения точек бифуркации сигналов.

Ключевые слова: энтропия, вейвлет, стертые спектры, сейсмические волны, георадар, точки бифуркации.