УДК 615.471:616.3-71

ЦИФРОВАЯ ОБРАБОТКА НЕСТАЦИОНАРНЫХ СИГНАЛОВ В ЖЕЛУДОЧНО-КИШЕЧНОМ ТРАКТЕ

♦♦♦♦♦

DIGITAL PROCESSING OF NON-STATIONARY SIGNALS IN THE GASTROINTESTINAL TRACT

Керимова Мая Исахан кызы
доктор технических наук по философии,
ассистент кафедры приборостроительная инженерия,
Азербайджанский государственный университет
нефти и промышленности
mkerimova1971@rambler.ru

Kerimova Maya Isakhan gizi
Doctor of Technical Sciences in Philosophy,
Assistant of Department of
Instrumentation Engineering,
Azerbaijan State University
Oil and Industry
mkerimova1971@rambler.ru

Аннотация. Предложена оптимальная декомпозиционная структура сигнала с учетом максимальной пропускной способности при выборе более правильного посадочного разветвления. Был использован классический критерий, основанный на минимальной энтропии, для того, чтобы сигнал имел оптимальное количество пропускных способностей.
Для дифференциальной диагностики заболеваний рассматриваемого типа предложены нормализованные коэффициенты вейвлет-пакета средней мощности сигналов, которые являются информативными признаками и имеют диагностический смысл.

Ключевые слова: энтропия, концентрация, локарифм «энергии», электрогастроэнтерограмма, вейвлет-анализ, желудочно-кишечный тракт.

Annotation. The optimal decomposition structure of the signal is proposed, taking into account the maximum throughput when choosing a more correct landing branch. The classical criterion based on the minimum entropy was used to ensure that the signal had the optimal amount of bandwidth.
For the differential diagnosis of diseases of this type, the normalized coefficients of the wavelet packet of the average signal power are proposed, which are informative signs and have a diagnostic meaning.

Keywords: entropy, concentration,energy arithmetic, electrogastroenterogram, wavelet analisis, gastrointestional tract.

EGEG (electrogastroenterogram) – these are non-stationary signals. Their spectral composition and the amplitude of the dances can change significantly even in a single measurement session.

A more modern method of analyzing the EGEG signal is the wavelet analysis.

Wavelet analysis is a more promising method of digital signal processing and provides better resolution in both frequency and time. The method is designed for the analysis of complex non-stationary signals with local properties, which, in particular, include EGEG signals [1, 2].

Batch wavelet-in the case of a distribution, it is possible to obtain estimates of the numerical characteristic-the entropy of the coefficients in the nodes of the distribution tree. To determine the optimal number of distribution levels, classical criteria based on the minimum entropy are used [3].

The entropy of the signal S for signals defined as an orthogonal distribution according to the interpreted entropy properties:

$$E(S) = \sum_i E(s_i), \tag{1}$$

where s_i – is the distribution coefficient of the signal S in the orthogonal basis.

Taking into account the signal distribution coefficient on the orthonormal basis for the four types of entropies, the following expressions are given:

– Unnormalized Shannon entropy

$$E(S) = \sum_i s_i^2 \log_2\left(s_i^2\right), \tag{2}$$

– concentration in the case of 1≤ p ≤ 2 according to the norm p:

$$E(S) = |s_i|^p = \|s_i\|_p^p \tag{3}$$

or

$$E(S) = \sqrt[1/p]{\sum_i s_i^p}$$

– logarithm of the «energy» of entropy

$$E(S) = \sum_i \log_2\left(s_i^2\right) \tag{4}$$

– entropy «SURE»

$$E(S) = \sqrt{2\ln\left(N\log_2(N)\right)}, \tag{5}$$

where N – is the number of accounts.

The normalized entropy of the packed wavelet coefficients is calculated using formulas (1–5), and the results are shown in table 1. The dependence of the entropy of these coefficients on the level of the wavelet distribution is shown in figure 3.

The calculations were repeated for every 10 patients with the specified diagnostic results in order to determine how the parameters of diagnostic significance behave [4]. For the remaining patients, the obtained dependences confirmed the nature of changes in the studied parameters in diagnostic situations indicated at the level of the wavelet distribution. Consequently, VPS performs efficient compression and smoothing of EGEG signals, creating its own wavelet spectrogram, which is visually more informative than the primary electrogastrogram, and adds fundamentally new numerical characteristics of the EGEG signal [5].

Figures 1 and 2 show the levels of normal gastric dissolution and its distribution in gastric ulcer disease.

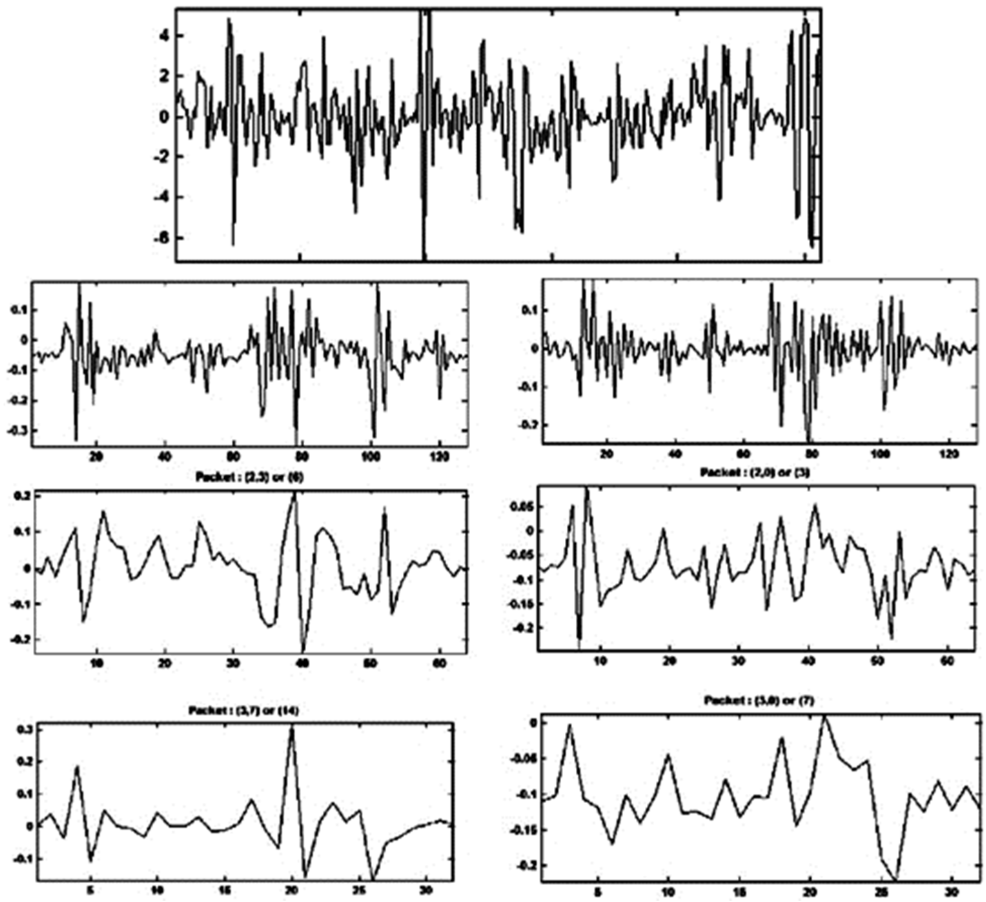

Figure 1 – Signal distribution levels for normal gastric solutions

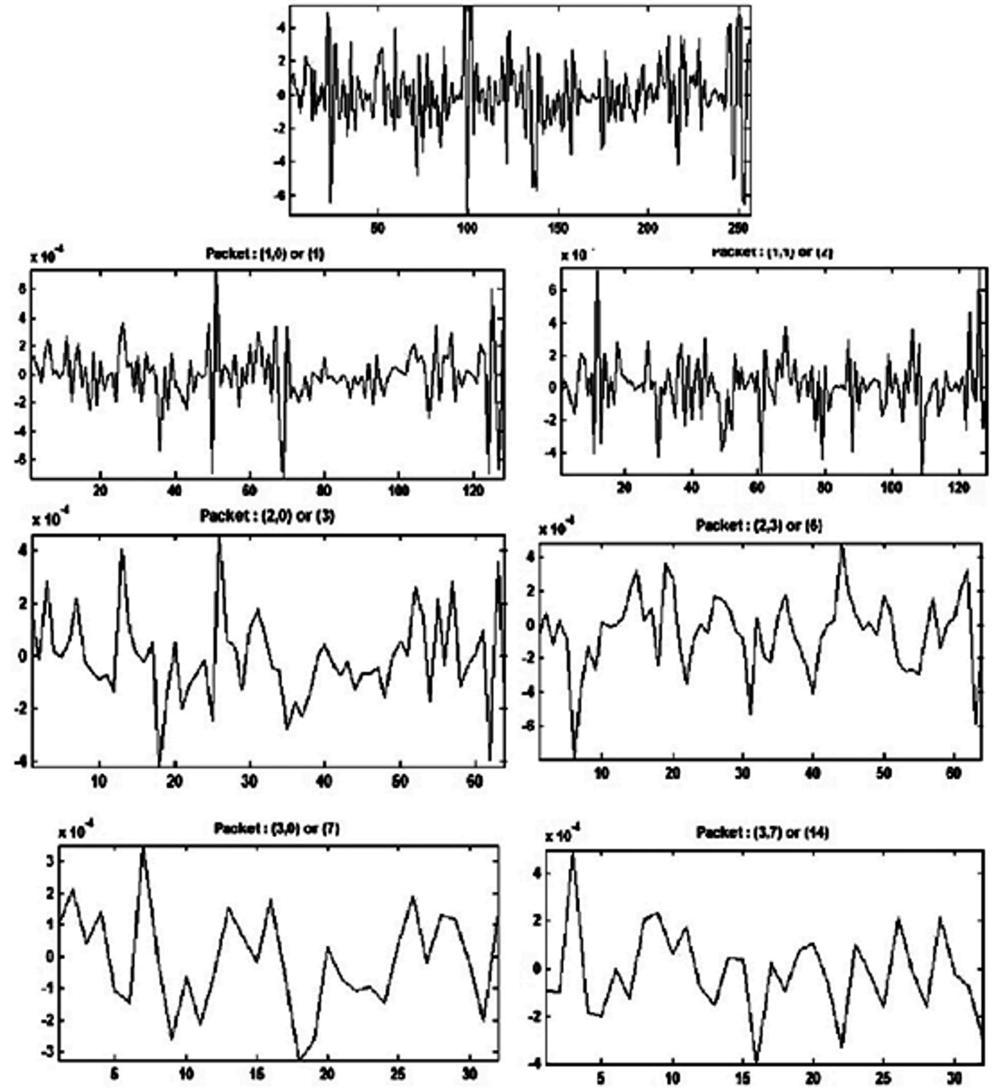

Figure 2 – Signal distribution levels in gastric ulcer disease

For the considered gastrointestinal tract diseases, the optimal number of decomposition levels of the orthogonal wavelet transform was selected, the ability of the studied signal to decompose was taken into account, and the entropy minimum of the decomposition level was determined (tab. 1).

Table 1 – Signal entropy values for different distribution levels

Normal stomach condition				
m	Shannon	Norm (p = 1)	Log energy	SURE
1	1,40211	1,803698145	–2,49306	1,850099
2	1,34061	1,837845206	–1,97997	1,886925
3	1,54229	1,801391962	–2,44146	1,84754
Stomach ulcer condition				
m	Shannon	Norm (p = 1)	Log energy	SURE
1	0,60730	1,934917569	–0,78839	1,982106
2	0,78556	1,913962382	–1,04463	1,962631
3	0,90596	1,901491783	–1,18756	1,950777

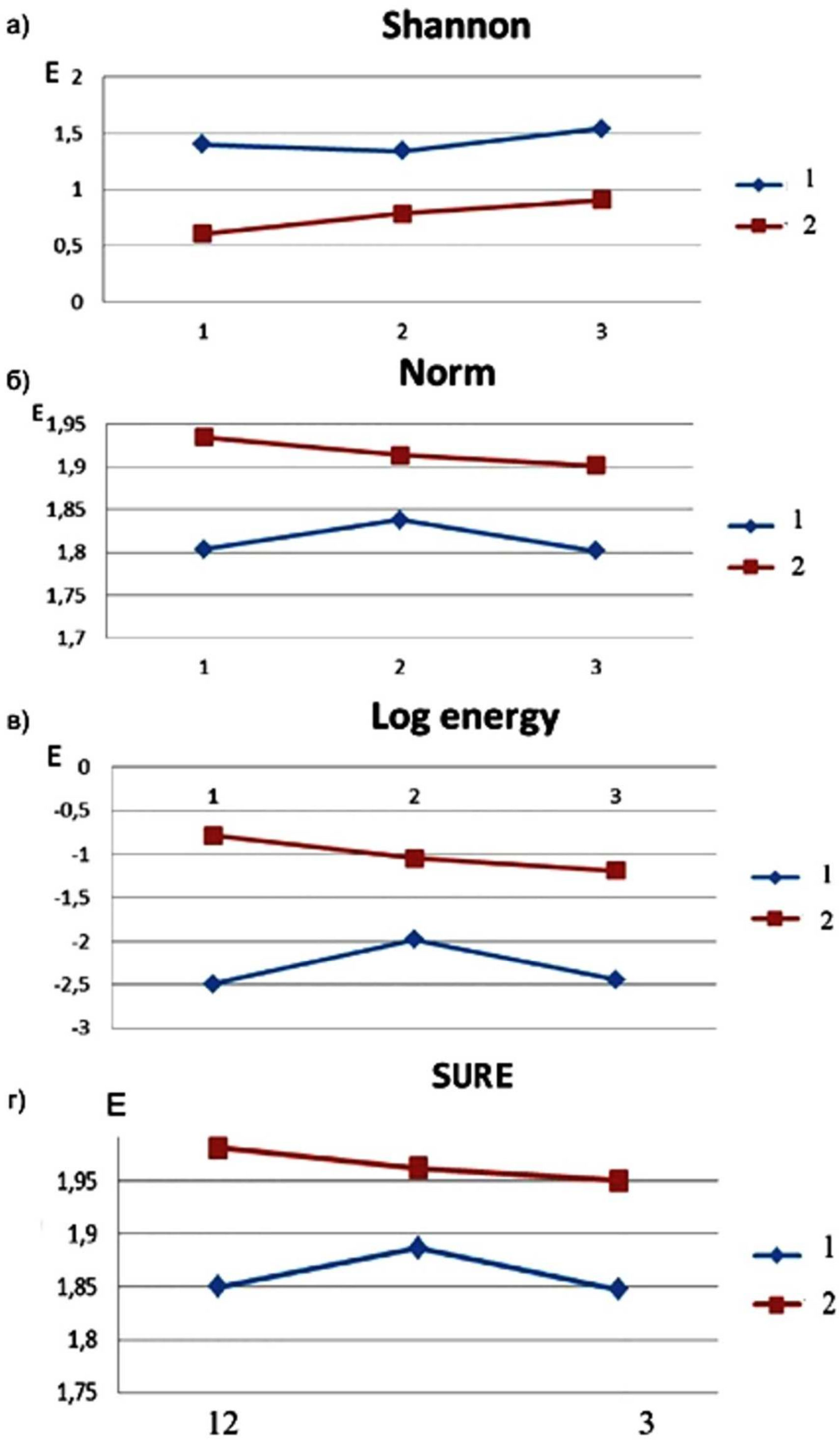

Figure 3 – Estimates of gastric entropy in normal (1) and peptic ulcer disease (2)

Conclusion: Thus, a more acceptable method compared to the classical wavelet distribution scheme is that the signal processing is performed on the basis of a wavelet packet, so that the high-frequency aggregates of the pyramid of the analyzed signal are processed, resulting in a «complete» (balanced) wavelet decomposition tree. The optimal structure of the signal decomposition during the processing of the wavelet packet is selected taking into account the additional criterion of the signal throughput according to the minimum entropy criterion.

For the recognition of EGEG signals, the normalized average power of the wavelet packet coefficients is used, which are informative features, sensitive to changes in the average power, and have a diagnostic value.

Литература

1. Заруцкий И.В., Манойлов В.В. Предварительная очистка масс- спектрометрических сигналов от шумов с помощью вейвлет-фильтров // Научное приборостроение. – 2007. – Т. 17. – № 1. – С. 115–120.
2. Малла С. Вейвлеты в обработке сигналов. – М. : Мир, 2005. – С. 671.
3. Попов А.И., Рудалев А.В. Особенности применения вейвлета Морле при анализе гастрограмм // Сайт семинара «Прикладные информационные технологии». – URL : itprojects.narfu.ru/pit/?q=node/63
4. Свиньин С.Ф., Попов А.И., Рудалев А.В. Вейвлет-анализ и информационные технологии в задачах обработки электрогастроэнтерограмм. – М. :Труды СПИРАН, 2013. – Вып. 4 (27). – С. 129–143.
5. Смоленцев Н.К. Основы теории вейвлетов // Вейвлеты в Matlab. – М. : ДМК Пресс, 2005. – С. 304.

References

1. Zarutsky I.V., Manoilov V.V. Preliminary purification of mass-spectrometric signals from noise by means of wavelet filters // Nauchnoe priborostroenie. – 2007. – Vol. 17. – № 1. – P. 115–120.
2. Malla S. Wavelets in signal processing. – M. : Mir, 2005. – P. 671.
3. Popov A.I., Rudalev A.V. Features of application of Morlet wavelet at the analysis of gastro-grams // Site of seminar «Applied information technologies». – URL : itprojects.narfu.ru/pit/?q=node/63
4. Svinin S.F., Popov A.I., Rudalev A.V. Wavelet analysis and information technologies in problems of processing electrogastroenterograms. – M. : SPIRAN Proceedings, 2013. – Vol. 4 (27). – P. 129–143.
5. Smolentsev N.K. Fundamentals of wavelet theory // Wavelets in Matlab. – M. : DMK Press, 2005. – P. 304.