*electrogastrogram, EGG, stomach,*
*wavelet, signal processing,*

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# CONTINUOUS WAVELET TRANSFORM AS EFFECTIVE TOOLS FOR DETECTING MOTION ARTEFACTS IN ELECTROGASTROGRAPHICAL SIGNALS

The cutaneous recording of gastric myoelectrical activity of the stomach known as electrogastrography (EGG) seems to be the promising tool for the non-invasive assessment of gastric motility. Unfortunately the EGG recording is usually severely contaminated both by motion artefacts and endogenous biological noise source. In order to use EGG signals as reliable diagnostic tool it is necessity to look for the effective artefacts removal methods. In this paper Continuous Wavelet Transform (CWT) was applied for detection motion artefacts from the EGG data. The set of own mother wavelets extracted directly from EGG signal was created and applied for detecting motion artefacts from one channel EGG recording. The results was compared with the effects obtained by using standard mother wavelets. The proposed method based on CWT with own mother wavelet presents very good performance for detecting motion artefacts from the EGG data.

## 1. INTRODUCTION

Electrogastrogram (EGG) reflects the myoelectrical activity of stomach picked up by the electrodes placed cutaneously on the abdominal skin over the stomach. As a non-invasive test, easy to perform and relatively inexpensive EGG has been an attractive tool for physiological and pathophysiological studies of the stomach [2]. For the first time such measurement was carried out in 1922 by Walter Alvarez [1], unfortunately the lack of both high technology of registration signals and advanced method of signal processing was the main causes that delayed medical application of EGG in gastrointestinal diseases treatment. Clinical benefits from information encoded in the EGG recording highly depend on the quality of extracted signal. The main component of gastric myoelectrical activity, called gastric slow waves, has a frequency about 3 cycle per minute (0.05 Hz). Similar to the other biological signals, EGG apart from mentioned normal physiological rhythm 2-4 cpm (0.033-0.066 Hz) called normogastric rhythm, includes some additional pathological rhythms covering frequencies from 0.5 cpm up to 9 cpm (0.008-0.015~Hz). Due to the leading rhythm in the EGG signal it is possible to distinguish: bradygastric rhythm [0.5,~2) cpm ([0.01,~0.033)~ Hz) normogastric rhythm [2,4] cpm ([0.033,~0.066]~Hz) and finally tachygastric rhythm (4,~9] cpm ([0.066,~0.15)~Hz) [5]. Compared with the other electrophysiological measurements, the EGG has a low signal-to-noise ratio and is usually contaminated by cardiac, respiratory signal and possible myoelectrical activity from other organs situated near the stomach such as duodenal or small intestine. As EGG signal require at least half an hour recording before stimulation and the same time after stimulation so it is almost impossible to avoid motion artefacts which are a specially strong as far as children are concerned. Artefacts damage the recorded data and make interpretation of EGG very difficult or even impossible. Advanced signal processing methods are needed for studying the gastric electrical behavior. In order to use EGG as a diagnostic tool the artefacts have to be detected and automatically eliminated before analysis.

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## 2. MATERIALS AND METHOD

The multiresolution signal decomposition methods analyze signals at different scales or resolution and thus ideally suit for studying the non-stationary signal such as EGG [2,3,7]. Multiresolution representation is computed by decomposing original signal using wavelet orthogonal basis and could be treated as decomposition using set of independent frequency channels [6]. The wavelet transform has varying window size that provide optimal time-resolution in all the frequency ranges. As the Continuous Wavelet Transform (CWT) exhibits the property of 'zooming' in the sharp temporal variation in a signal the object of this study is to examine the applicability of CWT for detecting motion artefacts in the EGG signals.

The CWT of one-dimensional signal $f(t) \in L^2(R)$ with respect to a mother wavelet $\psi(t)$ is defined as :

$$W_\psi\{f(t)\}(a,b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{+\infty} f(t)(\frac{t-b}{a})dt \tag{1}$$

where $a,b$ $(a,b \in R \wedge a \neq 0)$ are the scale and translation parameters, respectively.

The idea of using wavelets for detection motion artefacts in the one-channel EGG recording, based on cutting the part of original signal, which after visual inspection was decided to be an artefact, and create an appropriate wavelet $\psi$ which the best 'matches' the waveshape of extracting artefact.

## 3. MOTHER WAVELET FOR EGG ANALYSIS

After visual inspection of various motion artefacts shapes, raw one-dimensional EGG signal recording from four different persons were taken under consideration. From the parts of different original signals, which were qualified by the physician, as the motion artefacts, four (similar in the shape with distinguished artefacts) mother wavelets were created and named adequately: egg1, egg2, egg3, egg4.

Fig. 1 displays two hours recording of one-channel EGG (Mal 61), 30 minutes in fasting state and 90 minutes after stimulation with 300 ml of 237 kcal yoghurt. Ten seconds lasting motion artefact which appeared between 89 minutes 55 seconds and 90 minutes 05 seconds pointed out with an arrow in the graph Fig. 1 was the source for constructing the mother wavelet egg3. It is shown in the Fig. 2 that constructed wavelet egg3 is the same in the shape as the indicated artefact.

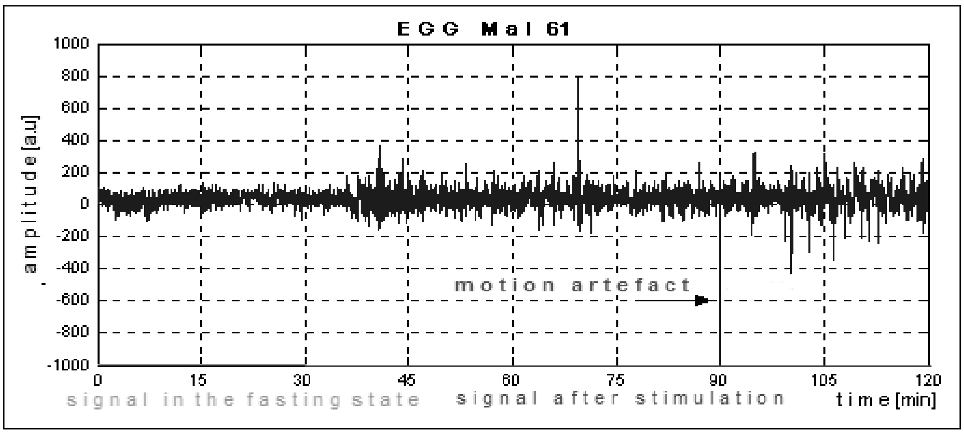


Fig. 1. Two hours recording of one channel EGG signal Mal61 with motion artefacts.

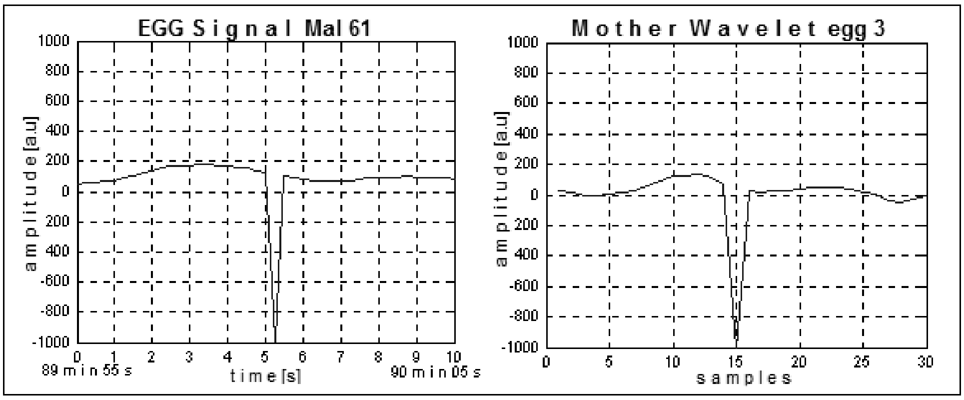


Fig. 2. The zoom of 10 seconds motion artefact in signal Mal61 pointed out by an arrow in Fig. 1 next to created mother wavelet egg3.

For detecting motion artefacts in the EGG signal four mother wavelets (egg1, egg2, egg3, egg4) has been constructed (Fig. 3). Each of them was created on the basis of part of the one channel EGG signal recorded from different persons (egg1-signal Mal57, egg2-signal Mal60, egg3-signal Mal61 and egg4-signal Mal63). Two of created mother wavelets (egg1, egg2) after interpolation consist of 20 samples and the others include 30 samples.

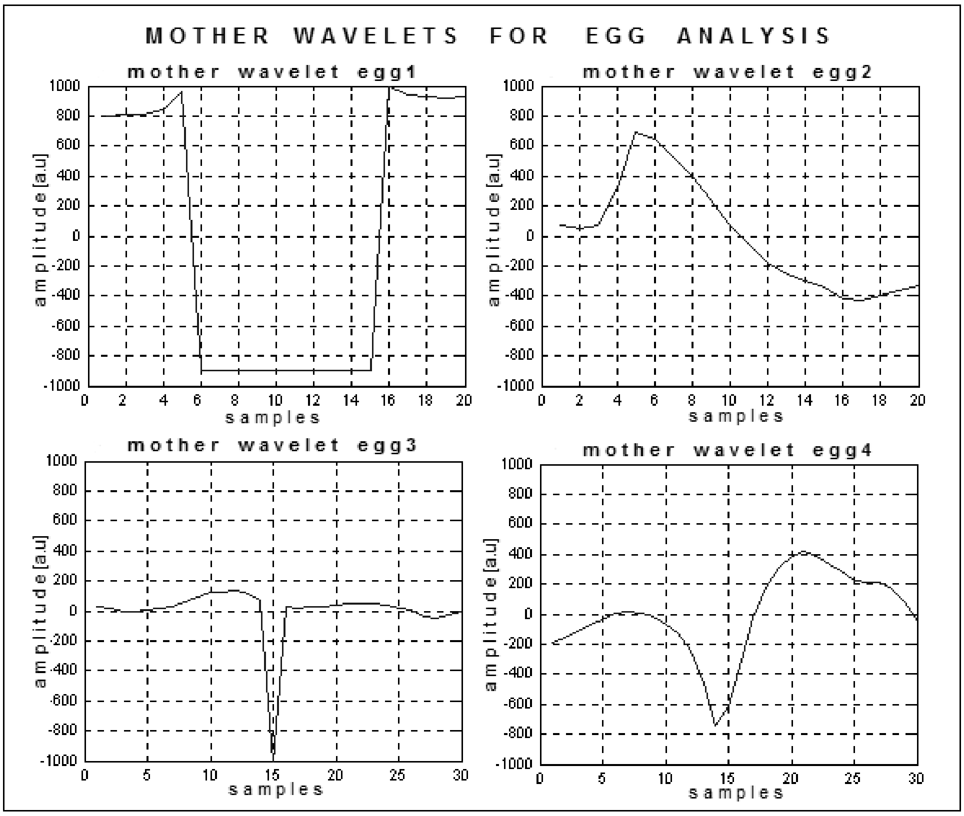


Fig. 3. Set of constructed mother wavelets : egg1, egg2, egg3, egg4 for EGG analysis.

The CWT stated mathematically by the formula (1) was applied for one channel EGG signal. In this case function $f$ is the raw EGG signal which should be cleaned from motion artefacts, and the function $\psi = egg \wedge i \in \{1,2,3,4\}$ for $a = b = 1$ is one of created or standard mother wavelets translated by $b$ and scaled by $a$. Both parameters in this study have been set to one.

Using CWT as a tool for inspecting the EGG signal, totally control correlation process was obtained, it means that CWT coefficients reach the maximum value for this part of original signal that, is the most similar to the wavelet used for analysis. CWT coefficients are the key for localization motion artefacts in the examining signal.

The EGG analysis was conducted by the aid of 'wavemngr' library of *Wavelet Toolbox in Matlab*. The results obtained by applying CWT with constructed four mother wavelets were compared with the results obtained for some standard mother wavelets such as: Morlet, Daubechies-3, Discrete Meyer and Gauss-2. At the first step for each one-channel EGG signal examination, the length (in samples) of motion artefact in the EGG signal was estimated manually by the aid of *Signal Processing Toolbox of Matlab*, as reference data. Afterwards by applying CWT both with created and standard mother wavelets for 8 scales, each of studding signal were represented by 8xN matrix of wavelet coefficient (N - number of samples) for each used mother wavelet. Each row of wavelet coefficients matrix consist of N wavelet coefficients for each scale. The maximum value of CWT coefficient point out the localization (first sample) for detected motion artefact (Fig. 4).

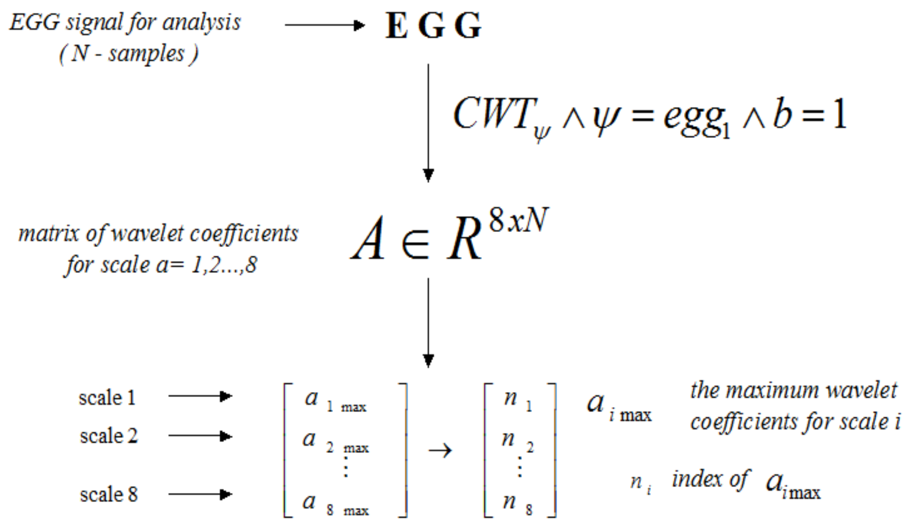


Fig. 4. The scheme of CWT analysis for EGG signal.

The index $n_i$ of the maximum value of CWT coefficient point out the localization (first sample) for detected motion artefact. The analysis was perform for 4 constructed mother wavelets: egg1, egg2, egg3, egg4 and compared with the results obtained for some standard mother wavelets such as: db3, morlet, dmey, gauss2

## 4. RESULT

Table 1. Below table presents the samples number for automatically detected motion artefacts by the aid of CWT. The first sample number for two detected motion artefact was underline.

*EGG signal Mal 64*

| | Created Mother Wavelets | | | | Standard Mother Wavelets | | | |
|---|---|---|---|---|---|---|---|---|
| | Sample number of detecting artefact | | | | | | | |
| scale nb. | egg1 | egg2 | egg3 | egg4 | morl | db3 | dmey | gauss2 |
| 1. | 3901 | 11890 | 3868 | <u>3870</u> | 2 | 1 | 1 | 2 |
| 2. | <u>11900</u> | 3869 | 3863 | 3871 | 3 | 2 | 2 | 2 |
| 3. | <u>3885</u> | 3869 | 3864 | 3874 | 2 | 1 | 2 | 12098 |
| 4. | 3887 | 3870 | 3864 | 3875 | 2 | 2 | 2 | 11884 |
| 5. | 3892 | <u>3867</u> | 3864 | 3887 | 2 | 3876 | 3878 | 126 |
| 6. | 3895 | 11876 | 3861 | 11893 | 3876 | 3879 | 3878 | 127 |
| 7. | 3898 | 11876 | <u>3860</u> | <u>11891</u> | 3878 | <u>3873</u> | 3878 | <u>11900</u> |
| 8. | 3901 | <u>11873</u> | 3861 | 11895 | <u>3873</u> | 3873 | <u>3873</u> | <u>3873</u> |

The results from the Table 1 was shown on the time representation of EGG Mal64 (Fig. 5) where the markers indicate the beginning and the end of motion artefacts. The first marker was set according the smallest samples number underline in the Table 1.

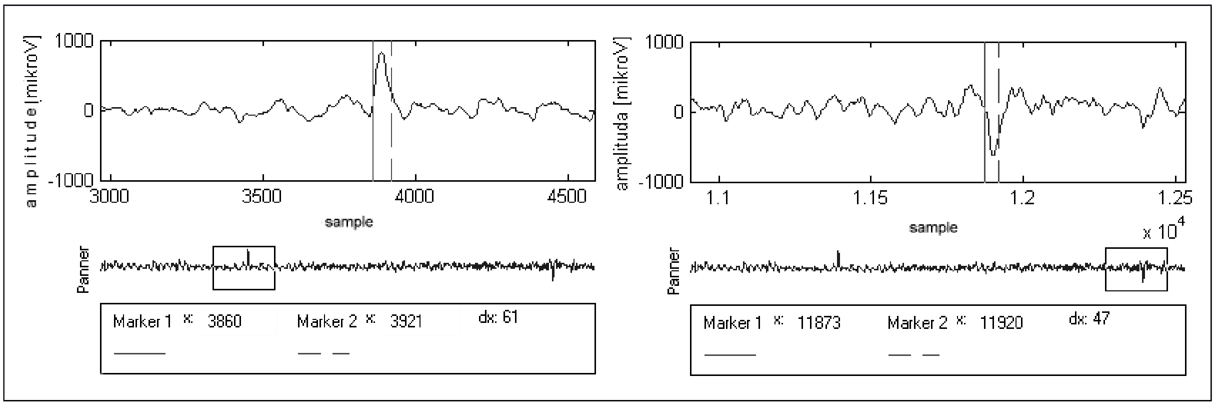


Fig. 5. Signal Mal 64 with two motion artefacts detected by CWT.

In the Fig. 6 and Fig. 7 there are shown the obtained results after CWT applied for signal Mal 64 in the graphical mode. The created mother wavelet clearly pointed out both two artefacts.

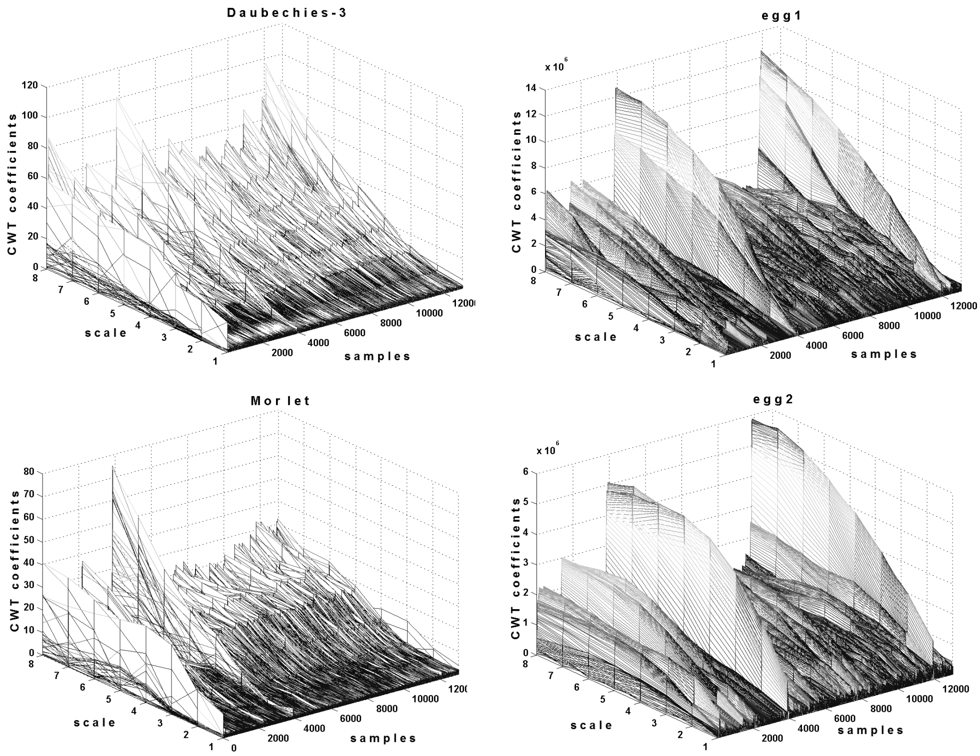


Fig. 6. Motion artefacts localization in EGG signal Mal64. Results obtained after applying CWT, on the left side with the standard mother wavelets: Daubechies-3 & Morlet, on the right side with created mother wavelets: egg1, egg2.

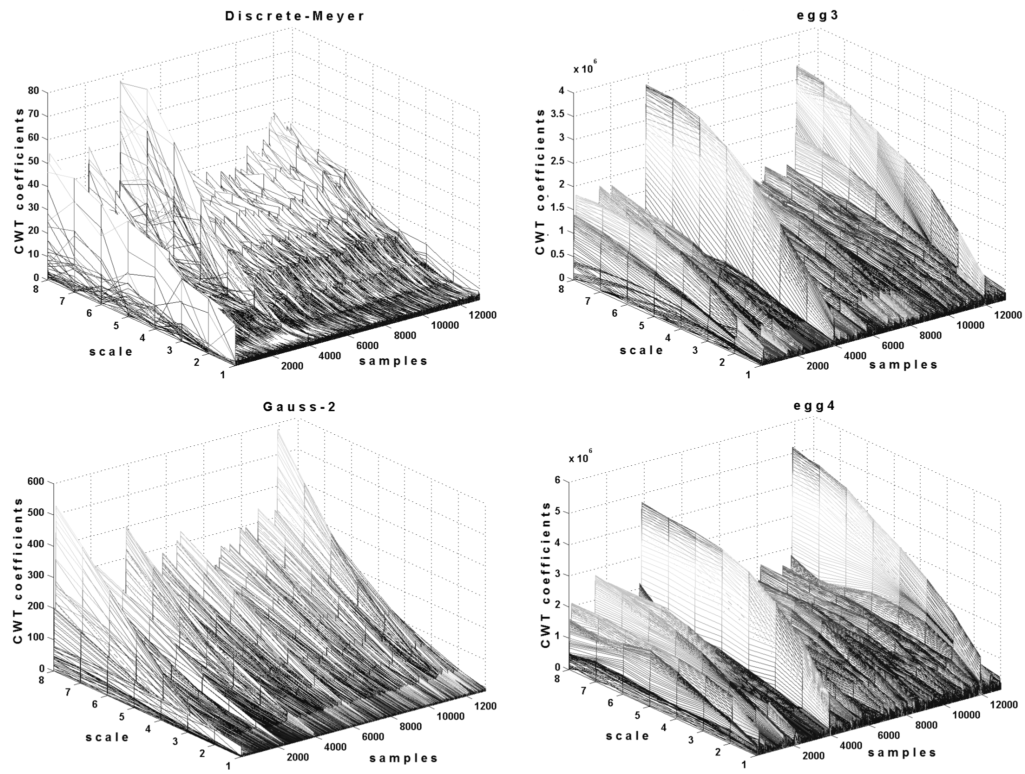


Fig. 7. Motion artefacts localization in EGG signal Mal64. Results obtained after applying CWT, on the left side with the standard mother wavelets: Discrete Meyer & Gauss-2, on the right side with created mother wavelets: egg3, egg4.

Below there are presented results for some other EGG signals named Mal 76 and Mal 78.

Table 2. Contain the samples number for automatically detected motion artefacts by the aid of CWT for signal Mal 76. The first sample number for two detected motion artefact was underline. The first artefact was identify at about 2741 sample the second one at 16526.

*EGG signal Mal 76*

| | Created Mother Wavelets | | | | Standard Mother Wavelets | | | |
|---|---|---|---|---|---|---|---|---|
| | Sample number of detecting artefact | | | | | | | |
| scale nb. | egg1 | egg2 | egg3 | egg4 | morl | db3 | dmey | gauss2 |
| 1. | 16257 | 2753 | 16518 | 2755 | 2 | 1 | 1 | 2 |
| 2. | 2745 | 2757 | 2745 | 2760 | 3 | 2 | 2 | 16519 |
| 3. | 2744 | 2762 | 2744 | 2762 | 2 | 1 | 2 | 16527 |
| 4. | 16562 | 2765 | 2743 | 2766 | 2 | 16519 | 2 | 16527 |
| 5. | 16563 | 2768 | 2742 | 16554 | 16519 | 16524 | 2733 | 16527 |
| 6. | 2787 | 16500 | 2742 | 16556 | 16519 | 16525 | 16520 | 16528 |
| 7. | 2790 | 16491 | 2741 | 2776 | 16520 | 16526 | 16519 | 16528 |
| 8. | 2797 | 16487 | 2741 | 2781 | 16520 | 16527 | 16520 | 2744 |

The next figure presents the time representation of EGG signal Mal 76 with indicated two artefacts. The first one started at about 2741 sample the second one at 16526 sample.

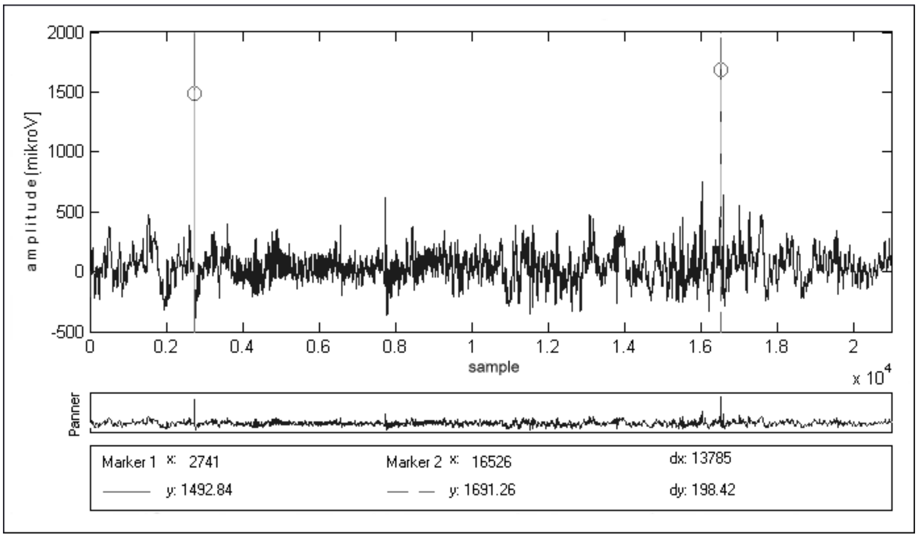


Fig. 8. Time representation of EGG signal Mal 76 with two distinguish*ed* artefacts.

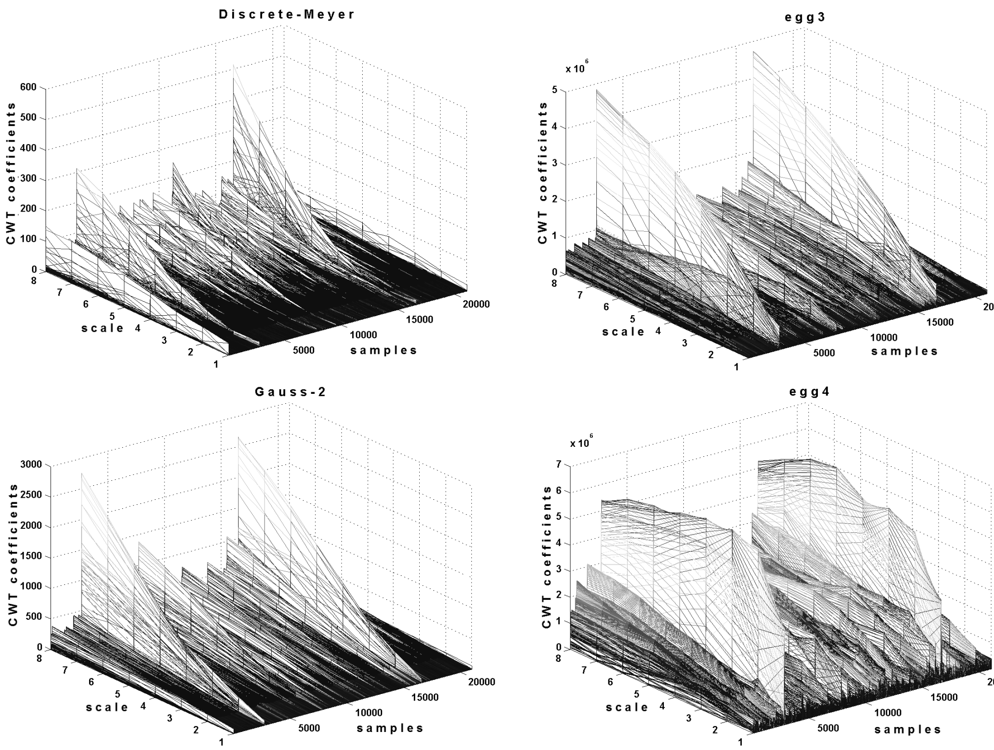


Fig. 9. Motion artefacts localization in EGG signal Mal 76. Results obtained after applying CWT, on the left side with the standard mother wavelets: Discrete Meyer, Gauss-2 on the right side with created mother wavelets: egg3, egg4.

Table 3. The samples number for automatically detected motion artefacts by the aid of CWT for signal Mal 78.

*EGG signal Mal 78*

| | Created Mother Wavelets | | | | Standard Mother Wavelets | | | |
|---|---|---|---|---|---|---|---|---|
| | Sample number of detecting artefact | | | | | | | |
| scale nb. | egg1 | egg2 | egg3 | egg4 | morl | db3 | dmey | gauss2 |
| 1. | 2112 | <u>2106</u> | 2114 | 2119 | 2116 | 2115 | 2107 | 2116 |
| 2. | <u>2110</u> | 2104 | 2114 | <u>2108</u> | 2155 | 2108 | 2155 | 2116 |
| 3. | 2119 | 2137 | 2113 | 2107 | 2108 | <u>2108</u> | <u>2108</u> | 2121 |
| 4. | 2125 | 2141 | 2113 | 2153 | 2116 | 2120 | 2106 | 2114 |
| 5. | 2126 | 2143 | 2112 | 2174 | <u>2109</u> | 2120 | 2116 | 2113 |
| 6. | 2104 | 2082 | 2112 | 2152 | 2116 | 2120 | 2116 | 2113 |
| 7. | 2105 | 2168 | 2109 | 2154 | 2121 | 2120 | 2120 | 2113 |
| 8. | 2112 | 2160 | <u>2110</u> | 2160 | 2121 | 2121 | 2121 | 2112 |

Both the standard and created mother wavelets well detect second artefact starting at 2110 sample. The first artefact (at 776 sample) is better indicated by all created mother wavelets then the standard ones. From the standard mother wavelets the best performance presets the wavelet gauss 2.

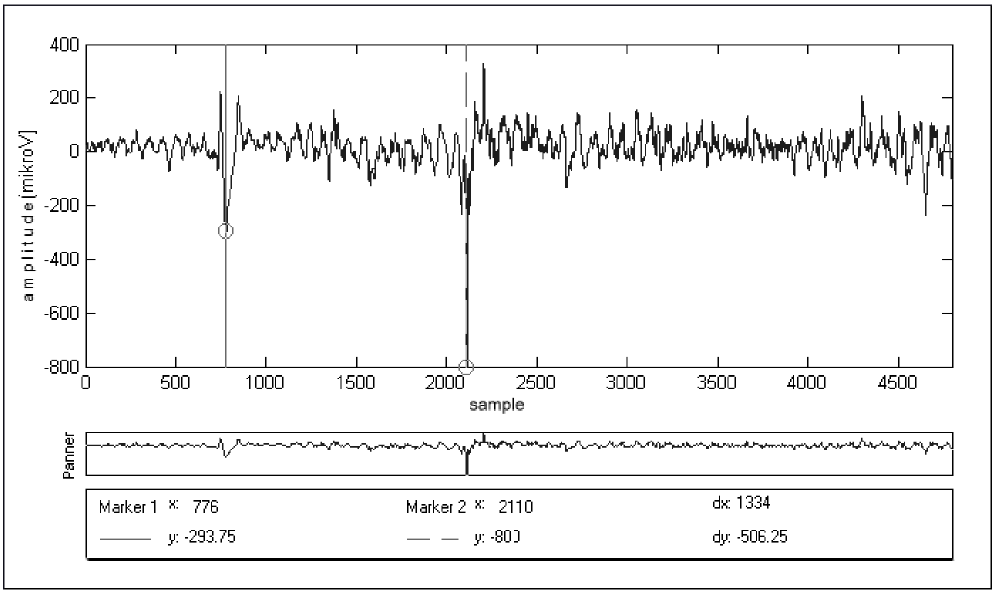


Fig. 10. Time representation of EGG signal Mal 76 with two motion artefacts the first one started at 776 sample and the second one at 2110.

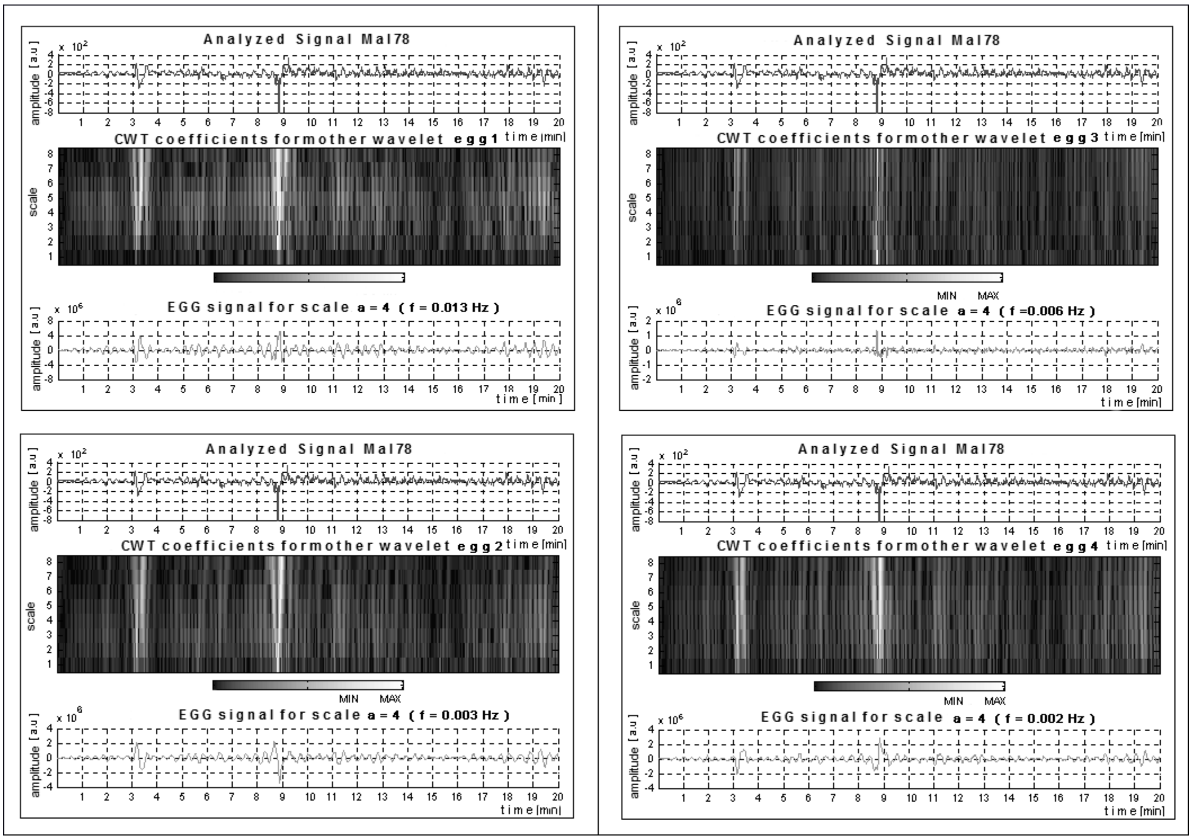


Fig. 11. The EGG Mal 78 analysis by applied CWT. The bright area represent the highest value for CWT coefficients which pointed out two motion artefacts detected by egg1, egg2, egg3,egg4.

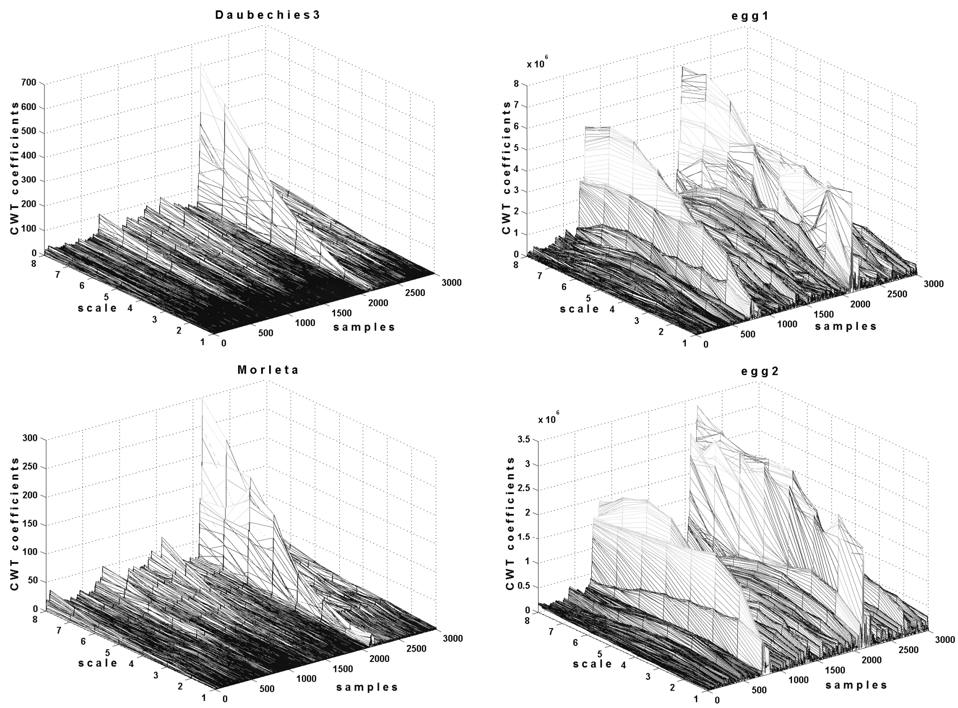


Fig. 12. Motion artefacts localization in EGG signal Mal 78. Results obtained after applying CWT, on the left side with the standard mother wavelets: Daubechies-3, Morleta, on the right side with created mother wavelets: egg1, egg2.

# 5. CONCLUSIONS

For signal Mal 64, mother wavelets egg1, egg2, egg3 and egg4 clearly pointed out two motion artefacts for each scale (the first artefact started at 3860 sample and the second one at 11873), while standard mother wavelets: db3, morlet, dmey, gauss2 detection is weaker especially for the second artefact (started at 11873 sample) (Fig. 6, Fig. 7). The same results can be observed for signal Mal 76 (Fig. 9) and Mal 78 (Fig. 11, Fig. 12). The results obtained for different EGG data, using CWT with mother wavelet, created as we depict in this paper, confirm that all constructed wavelets are more successful in recognizing and localization motion artefacts then the standard ones. The proposed procedure is also easily applicable for multichannel EGG data, where it gives the opportunity for insight in the EGG propagation. Presented method of detection motion artefacts in EGG recording seems to be very promising tool for effective application, but needs further investigation in order to increase its preciseness.

## BIBLIOGRAPHY


[1] ALVAREZ W.C., The Electrogastrogram and What It Shows, Journal of the Americal Medical Association, Vol. 78, 1992, pp. 1116-1119.

[2] KOCH K.L., STERN R.M., Handbook of Electrogastrography, Oxford University Press, 2004.

[3] LIANG H., LIN Z., Stimulus Artifact Concellation in The Serosal Recordings of Gastric Myoelectrical Activity Using Wavelet Transform, IEEE Transactions On Biomedical Engineering, Vol. 49, No.7, 2002.

[4] LIANG H., LIN Z., Multiresolution Signal Decomposition and Its Applications to Electrogastric Signals, Recent research developments in biomedical engineering, Vol. 1, 2002, pp. 15-31.

[5] PARKMAN H.P., HASLER W.L., BARNETT J.L., EAKER E.Y., Electrogastrography: a Document Prepared by The Gastric Section of The American Motility Society Clinical GI Motility Testing Task Force, Neurogastroenterol Motility, Vol. 15, 2003, pp. 89-102.

[6] MALLAT S.G., A Theory for Multiresolution Signal Decomposition: The Wavelet Representation, IEEE Transactions on Pattern Analysis Machine Intelligence, Vol. 11, No. 7, 1989.

[7] DE SOBRAL CINTRA R.J., TCHERVENSKY I.V., DIMITROV V.S., MINTCHEV M.R., Optimal Wavelets for Electrogastrography, Engineering in Medicine and Biology Society, IEMBS '04, 26th Annual International Conference of the IEEE, 2004.