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Polycardiosignals Coherence Evaluation Results for Patients with Cardiopulmonary Diseases

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Introduction

The spectral estimation plays a major role in signal processing. It has numerous applications in diversified fields such as radar, sonar, speech, communications, biomedical, etc [1,2,3]. One of the most well-known non-parametric spectral estimation algorithms is the Capon's approach, which is also known as minimum variance distortion less response (MVDR) [4,5]. This technique was extensively studied and is considered as a high-resolution method. The MVDR spectrum can be viewed as the output of a bank of filters, with each filter centered at one of the analysis frequencies. Its band pass filters are both data and frequency dependent which is the main difference with a periodogram-based approach where its band pass filters are a discrete Fourier matrix, which is both data and frequency independent [3,6].

The objective of this paper is to adapt Fourier transformation to assessing and comparing the characteristics of hereinbefore signals and coherence between each of signal.

Theoretical Background

There were analyzed 3 different information carrying cardiosignals: electrocardiogram (ECG), impedance cardiogram (ICG) and seismocardiogram (SCG). All these cardio signals origin are different: ECG shows electric heart activity, ICG – hemodynamic activity disturbance and SCG - mechanic activity changing. These three signals were recorded at the same time, so they describe the activity of person heart from three different sides.

The magnitude squared coherence (MSC) function is as an alternative to the popular Welch's method [7,8]. We define the magnitude squared coherence (MSC) function between two signals $x_1(n)$ and $x_2(n)$ as

$$\gamma^2_{x_1x_2}(w_k)=\frac{\left|S_{x_1x_2}(w_k)\right|^2}{S_{x_1x_1}(w_k)S_{x_2x_2}(w_k)}, \quad (1)$$

$$S_{x_1x_2}(w_k)=\frac{f_k^H R^{-1}_{x_1x_1} R_{x_1x_2} R^{-1}_{x_2x_2} f_k}{\left[f_k^H R^{-1}_{x_1x_1} f_k\right]\cdot\left[f_k^H R^{-1}_{x_2x_2} f_k\right]}. \quad (2)$$

We deduce the magnitude-squared cross spectrum:

$$S_{x_1x_2}(w_k)=\frac{\left[f_k^H R^{-1}_{x_1x_1} R_{x_1x_2} R^{-1}_{x_2x_2} f_k\right]^2}{\left[f_k^H R^{-1}_{x_1x_1} f_k\right]^2\cdot\left[f_k^H R^{-1}_{x_2x_2} f_k\right]^2}. \quad (3)$$

using expressions

$$S_{x_px_p}(w_k)=\frac{1}{f_k^H R^{-1}_{x_px_p} f_k}, p=1,2, \quad (4)$$

where $R_{x_px_p}=E\left\{x_p(n)x_p^H(n)\right\}$ is the covariance matrix of the signal $x_p(n)$ and

$$x_p(n)=\left[x_p(n) \quad x_p(n-1) \quad \dots \quad x_p(n-L+1)\right]^T. \quad (5)$$

Consider the (LxK) matrix

$$F=\left[f_0 \quad f_1 \quad \cdots \quad f_{K-1}\right], \quad (6)$$

where

$$f_k=\frac{1}{\sqrt{L}}\left[1 \quad \exp(jw_k) \quad \dots \quad \exp(jw_k(L-1))\right]^T, \quad (7)$$

where $w_k=2\pi k/K; k=0,1,\dots,K-1$. For K=L, F is called the Fourier matrix and is unitary, i.e. $F^HF=FF^H=I$ and (2) in (1), the MSC becomes

$$\gamma_{x_1x_2}^2(w_k) = \frac{\left[f_k^H R_{x_1x_1}^{-1} R_{x_1x_2} R_{x_2x_2}^{-1} f_k\right]^2}{\left[f_k^H R_{x_1x_1}^{-1} f_k\right] \cdot \left[f_k^H R_{x_2x_2}^{-1} f_k\right]}. \qquad (8)$$

Results

The training and testing sets were received from the data base, accumulated in the Institute of Cardiology and in the Clinic of Internal Diseases of Kaunas University of Medicine. This data base contains five groups of persons: 35pts with cardiovascular diseases and hypertension in pulmonary artery; 74pts with cardiovascular diseases but without hypertension in pulmonary artery; 15pts with pulmonary diseases but without hypertension in pulmonary artery; 20pts with pulmonary diseases and hypertension in pulmonary artery; 10 persons without cardiopulmonary diseases.

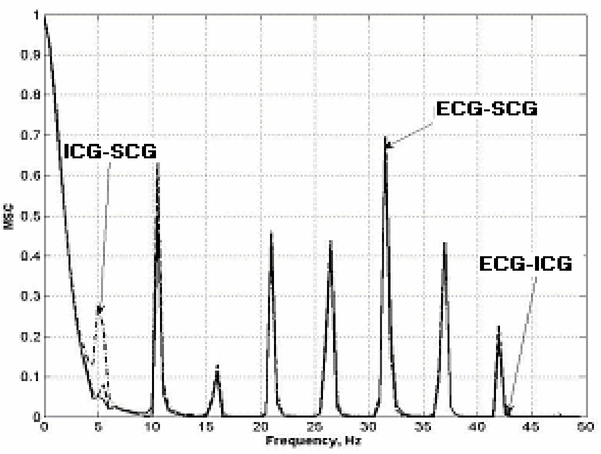

Fig. 1. Coherence of “healthy” persons

From this database 30 persons were recruited for experimental testing. These persons were divided into 2 groups: 20 of them had cardiovascular diseases and hypertension in pulmonary artery, 10 others – hadn’t any big gripe about the health.

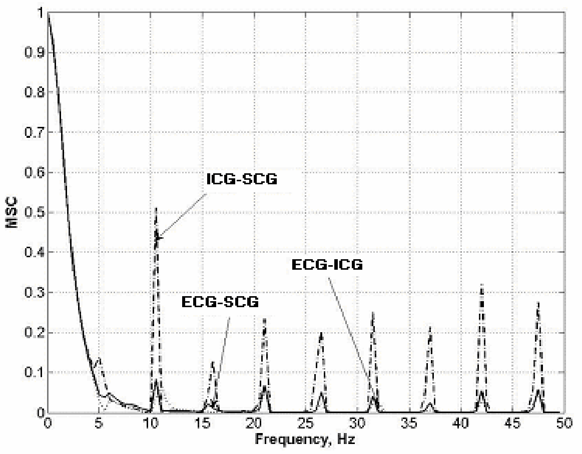

Fig. 2. Coherence of “sick” persons

Three cardiosignals were recorded at the same time. Results show, that coherence curves are different between recruited groups. All coherences of “healthy” persons are similar: they have the same number of peaks and coherence between all thee signals are big and almost the same (Fig.1). Mean value of coherence curve varies around 0.4-0.5 in the peaks. The second maximum value of coherence curve is around 0.68-0.72 at frequency 11 Hz or 32 Hz.

Conversely, the coherence of all cardiosignals of patient is low (Fig.2) and has very different meaning in the same peak (Fig.3). Mean value of “sick” coherence curve varies around 0.30-0.38 in the peaks. The second maximum value of coherence curve is around 0.72-0.42 at frequency 11 Hz or 32 Hz.

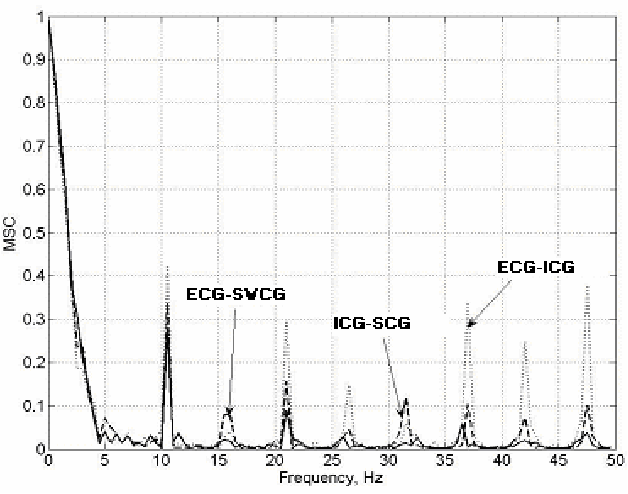

Fig. 3. Coherence of “sick” persons

Using method of Simpson the areas of each coherence curve were calculated. The areas of three different coherence curves of each person are shown in the figure 4. The results shows that a certain hyper plane can be drown which divides a space in two parts. Moreover, a classification can be done from estimated coherence parameters.

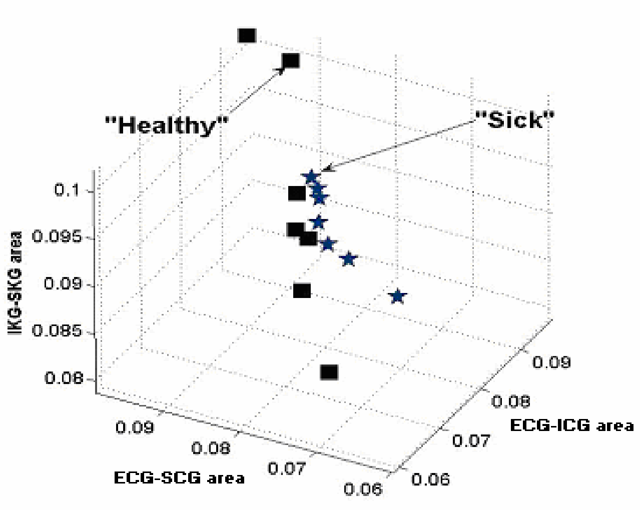

Fig. 4. Coherence areas

Finally, all coherence curves were splitted into three different size zones: 0-10 Hz, 11-35 Hz and 36-50 Hz.

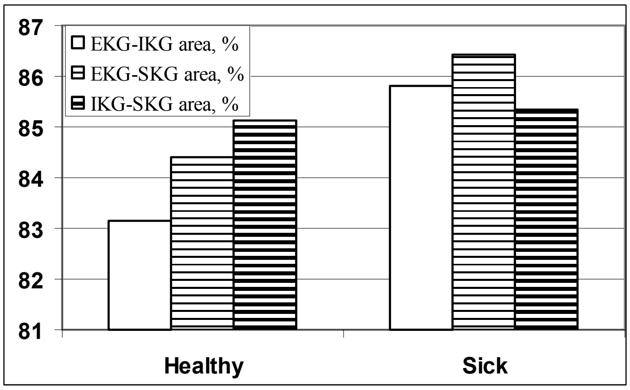

Fig. 5. Relative area of coherence curve, 0-10 Hz

Comparing relative areas of coherence curves of the first part was mentioned, that the biggest area of "healthy" people took ICG-SCG coherence and of "sick" people – ECG-SCG coherence, accordingly about 85% and about 86,50% (Fig. 5).

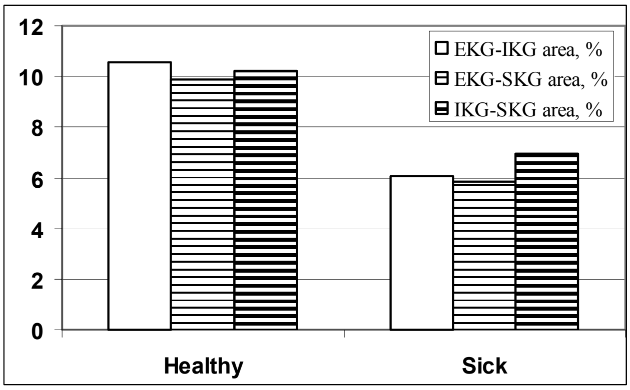

Fig. 6. Relative area of coherence curve, 11-35 Hz

In the second part (11-35 Hz) was mentioned, that relative areas of coherences curves took rather similar parts: relative area of coherence curves of "healthy" people was about 10% and relative area of coherence curves of "sick" people was about 6% only (see Fig. 6).

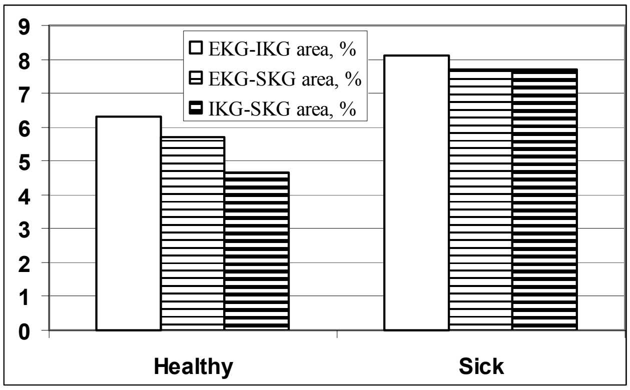

Fig. 7. Relative area of coherence curve, 36-50 Hz

Conversely, in the last part relative area of coherence curves of "sick" people was about 7.8-8 % and 5-6% of "healthy" people only (Fig. 7).

Comparing "healthy" and "sick" persons in all signals, the biggest comparative area occupied the first zone, i.e., 0-10 Hz. ICG-SCG coherence area of "healthy" people and ECG-SCG of "sick" had the biggest comparative areas. All other comparative areas approach zero by exponent.

Conclusions

1. All coherences of "healthy" persons are similar – they have the same number of peaks and coherence between all thee signals are big and almost the same.
2. The coherence of all cardio signals of patient is low and has very different meaning in the same peak.
3. Comparing "healthy" and "sick" persons in all signals, the biggest comparative area occupied the first zone, i.e., 0-10 Hz.
4. Comparing "healthy" and "sick" persons in all signals, the biggest comparative area occupied the first zone, i.e., 0-10 Hz. ICG-SCG coherence area of "healthy" people and ECG-SCG of "sick" had the biggest comparative areas.

Acknowledgements

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A big part of heart disease diagnostics criteria is collected by registration and analysis of cardio signals that show electric heart activity disturbance (ECG) and hemodynamic and mechanic activity changing, as impedance cardiograms (ICG) and seismocardiograms (SCG). Therefore, a solution of problem of effective heart disease diagnostic is the creation of new cardiosignals analysis technologies. Previously Fourier series were applied to frequency analysis of ECG, but this method was not applied to estimation of ICG and SCG frequency characteristics. In this paper, the frequency analysis method was applied to three cardio signals, because they reflect the electrical and mechanical work of the human heart better as one ECG signal. The main aim of this work is to adapt Fourier transformation to assessing and comparing the characteristics of hereinbefore signals and coherence. Ill. 7, bibl. 9 (in English; summaries in English, Russian and Lithuanian).

Г. Кершулите, З. Навицкас, И. Блужас, Л. Гаргасас, А. Вайнорас, Р. Русяцкас, С. Садаускас, А. Науджюнас. Свойства когеренции поликардиосигналов // Электроника и электротехника. – Каунас: Технология, 2007. – № 5(77). – С. 41–44.

Большую часть диагностических критериев сердечных заболеваний получаем путем регистрации и анализа кардиосигналов, которые отражают как электрические нарушения работы сердца (ЭКГ), так и изменения в гемодинамической и механической работе, т. е. импеданскардиограмма (ИКГ) и сейсмокардиограмма (СКГ). Более того, эффективным решением проблем диагностики сердечных заболеваний является создание новых технологий анализа кардиосигналов. Уже несколько десятилетий трансформация Фурье применяется для частотного ЭКГ анализа, в то же время этот метод не был использован при интерпретации частотных характеристик ИКГ и СКГ. Целью работы было попытаться применить Фурье анализ при оценке и сравнении трех синхронно зарегистрированных кардиосигналов, так как они отражают электрическую работу сердца, гемодинамические и механические изменения более точно чем один ЭКГ сигнал, а также оценить и сравнить три синхронно зарегистрированные кардиосигналы – ЭКГ, ИКГ и СКГ по частотным характеристикам и когеренции. Ил. 7, библ. 9 (на английском языке; рефераты на английском, русском и литовском яз.).

G. Keršulytė, Z. Navickas, J. Blužas L. Gargasas, A. Vainoras, R. Ruseckas, S. Sadauskas, A.Naudžiūnas. Polikardiosignalų koherencijos savybės // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 5(77). – P. 41–44.

Didelė dalis širdies ligų diagnostinių kriterijų gaunama registruojant ir analizuojant kardiosignalus, kurie atspindi tiek elektrinės širdies veiklos sutrikimus (EKG), tiek hemodinaminės bei mechaninės veiklos pokyčius, t. y. impedanskardiogramą (IKG) ir seismokardiogramą (SKG). Efektyvus širdies ligų diagnostikos problemų sprendimo būdas – kurti naujas kardiosignalų analizės technologijas. Jau kelis dešimtmečius Furjė transformacija taikoma EKG dažnių analizei, o IKG ir SKG dažnio charakteristikoms vertinti šis metodas nebuvo taikomas. Darbo tikslas buvo pritaikyti Furjė analizę trims sinchroniškai užregistruotiems kardiosignalams įvertinti bei palyginti, nes jie atspindi elektrinės širdies, hemodinaminės bei mechaninės širdies veiklos pokyčius geriau nei vienas EKG signalas. Kitas darbo tikslas buvo pritaikyti Furjė analizę trijų sinchroniškai užregistruotų signalų – EKG, IKG ir SKG dažnio charakteristikoms ir koherencijai įvertinti bei palyginti. Il. 7, bibl. 9 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).