Technická univerzita v Košiciach, Fakulta BERG

HODNOTENIE HABILITAČNEJ PRÁCE

POSUDOK OPONENTA PRÁCE

Názov práce: **Spracovanie signálov použitím modelov neceločíselného rádu**

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Odbor habilitačného konania a inauguračného konania: ***automatizácia*** Akad. rok: ***2020/2021***

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Pracovisko oponenta: ***Rzeszow University of Technology***

KOMENTÁR OPONENTA HABILITAČNEJ PRÁCE
AKTUÁLNOSŤ ZVOLENEJ TÉMY HABILITAČNEJ PRÁCE:

The topic of the thesis is very important because the ability to reduce the signal redundancy and enable signal compression plays an important role in signal processing and pattern recognition. There are many signals and patterns, which contain information that is already present in previous instances of ones (speech samples, images of different formats, data of medical measuring, etc) which no need to transmit the redundant information in telecommunication or can be successfully reconstructed in the case of damaged signals or patterns.
In recent years, the interest in studying mathematical models with fractional derivatives has been increasing. This interest is mainly determined by the attempts to understand phenomena in fractal, irregular and hereditary media. The idea of using the signal history is fundamentally rooted in fractional calculus. That means that an important advantage of the fractional-order operators is that they have implicitly inner hereditary nature ("memory" of all past events). In other words, fractional order mathematical models allow using the key-advantage, the history of the signal. Therefore, studying this topic is very interesting and should generate the increasing attention of scientists and engineers.

METÓDY SPRACOVANIA HABILITAČNEJ PRÁCE:

The dissertation is written with a good presentation of the object of research and methods of its investigation. The thesis consists of 2 introductory chapters, which include the main objective, mathematical theory for linear prediction method (LPM) for different cases (one-dimensional (1D) and two-dimensional (2D) standard LPM, 1D and 2D fractional LPM), and of a set of attached published works in which different applications to one-dimensional (1D) and two-dimensional (2D) signals are described (standard test signals, as well as the real-data signals, such as speech, electrocardiogram and electroencephalogram, greyscale images are used for the numerical experiments. Habilitation work also includes the implementation of MATLAB toolbox to show the practical application of the developed approach. A good list of the bibliography, programming code snippets for the examples provided in the work that are part of the created toolbox, also demonstrate that the level of the dissertation is very high.

DOSIAHNUTÉ VÝSLEDKY HABILITAČNEJ PRÁCE A NOVÉ POZNATKY:

The essence of the dissertation is a description of a new approach to the standard linear prediction and its generalization to fractional linear prediction with the possible applications to 1D and 2D signals. The basic properties and algorithms for the calculation, and MATLAB codes, which enable visualization and application of the possible applications to 1D and 2D signals for modeling different applications of signal processing, are presented.

In my opinion, the following results are the most important and original:

(1) Generalization of standard linear prediction to fractional linear prediction case and demonstration its applications to 1D and 2D signals;
(2) The numerical experiments in 1D using different type test signals as well as using the real-data signals, such as speech, ECG and EEG signals;
(3) The scheme for the optimal predictor coefficients computation of the FLP model;
(4) Generalization of the one-dimensional FLP model to two-dimensional case using the linear combination of the fractional derivatives with fractional orders α and β, having four parameters in total (two coefficients and two fractional orders);
(5) a new methodology based on which the order of fractional derivative can be estimated as the inverse of the memory length of the proposed fractional linear predictor.
(6) The closed form expressions of the optimal fractional linear predictor with restricted memory are derived
(7) MATLAB Toolbox implementation of Fractional Linear Prediction (FLP) with a supporting livescript interface that offers a user-friendly environment for the prediction of one-dimensional signals.
(8) Creating and implementation in the toolbox of two versions of the FLP using the "full" memory (the whole history of the signal) and the "restricted" memory (two, three or four previous samples), and their comparation with the standard linear prediction.

PRÍNOS PRE ĎALŠÍ ROZVOJ VEDY A TECHNIKY (UMENIA):

First of all, a new general approach on the basis of fractional derivatives for linear prediction method (LPM) is proposed. I would say that this is a pioneering set of works on fractional-order based signal prediction. The numerical experiments undertaken in habilitation work prove that Fractional LPM can be successfully applied in processing of both 1D and 2D signals, giving comparable or better performance using the same and even a smaller number of parameters. This is important in any parametric coding scheme, where the parameters have to be quantized and transmitted to the receiver. The proposed fractional linear prediction approach can be applied in different areas of signal processing including biomedical signal coding (e. g. EEG or ECG).

PRIPOMIENKY A POZNÁMKY K HABILITAČNEJ PRÁCI:

My understanding of the Slovak language, due to my stay in Slovakia years ago as a visiting professor within the National Scholarship Program of the Slovak Republic, allows me to easily read the content of the introductory chapters, which are written in Slovak. However, I would like to note that the articles attached to the dissertation are in English, and they are very well written and published in prestigious scientific journals and presented at good international scientific conferences.

OTÁZKY K RIEŠENEJ PROBLEMATIKE:

Questions:
(1) Please explain all various meanings of the word “order”, that appear throughout your works.
(2) Can your FLP methods be interpreted as “fractional-order based” or “fractional-order inspired”?
(3) Please characterize the improvements provided by your FLP methods compared to the existing approaches.

SPLNENIE SLEDOVANÝCH CIEĽOV HABILITAČNEJ PRÁCE:

The objectives of this habilitation dissertation have been fulfilled completely.

CELKOVÉ ZHODNOTENIE HABILITAČNEJ PRÁCE A ZÁVER:

Overall, I evaluate the dissertation as a very well-written work that summarizes the author’s new knowledge and approaches to solving the problem of signal prediction in complex engineering systems. The work is interesting and highly original. The main results of the dissertation are published in prestigious journals and presented at international scientific conferences. The Toolbox for MATLAB written by the author for performing computations, visualizations and applications of FLP also underline the significant value of this work.

I suggest that after minimal modification this habilitation dissertation, which is almost perfectly self-contained, can be published as a book in Springer Briefs series, or elsewhere.

Predloženú habilitačnú prácu na základe predchádzajúceho hodnotenia

ODPORÚČAM prijať k obhajobe

a po jej obhájení navrhujem udeliť vedecko-pedagogický titul "docent (doc.)"

Podpisom na tomto posudku zároveň súhlasím s licenčnými podmienkami obsiahnutými v licenčnej zmluve na použitie posudku záverečnej práce, ktorá je súčasťou tohto posudku.

Dátum: 26.10.2020 .....

podpis autora posudku