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Physica A 387 (2008) 1205–1217

PHYSICA A

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Quantitative parameters which describe speech sound distortions due to inadequate dental mounting

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Received 8 October 2006; received in revised form 1 October 2007
Available online 1 November 2007

Abstract

This paper presents a search over adequate quantitative parameters in order to reflect the speech quality alteration due to the incorrect positioning of a dental mounting. The research is based on signal analysis.

These parameters are extracted from the short time Fourier transform (STFT) and wavelet transform. The paper also investigates the possibility of using the Shannon entropy of the signal as a quantitative parameter.

For the investigation the /sh/ and /s/ sounds (phonemes) were used.

PACS: 87.80.Tq; 02.30.Nw; 43.60.-c; 43.60.Cg; 43.60.Gk; 43.64.-q; 43.80.Qf; 43.80.Ka

Keywords: Signal analysis; Speech quality; Short time Fourier transform; Wavelet transform; Shannon entropy; Hurst exponent; Autoregressive spectrum; Prosthodontic products; Quantitative analysis

1. Introduction

It is known due to dentistry practice that the quality of speech is influenced by the correct positioning of dental mountings, by the materials of prosthetic products, the geometrical shape and the accuracy of processing prosthodontic products.

A complicated relation exists between speech quality and the geometry of the oral cavity, and also the properties of the materials in the oral cavity.

On the other hand the speech sounds are irregular oscillations of the air pressure and contain an enormous quantity of information.

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0378-4371/$ - see front matter
doi:10.1016/j.physa.2007.10.066

The character of speech sounds is difficult to be analyzed and interpreted, but it is detected with accuracy by the hearing sense which is a more sensitive analysis device than well known handmade devices.

A wide literature devoted to acoustic models of speech sound production exists [1], but these models cannot be used in order to reflect these distortions, due to speech mechanisms which are not sufficiently understand and are difficult to be expressed mathematically. An important difficulty in modeling is the contribution of the volitional control and learning mechanisms.

Speech sounds can be analyzed using standard signal processing methods [2,3]. Important investigations of speech sounds are based on the Fourier spectrum [4] and on the short-time Fourier spectrum (spectrogram) [5–8]. These studies are made in order to establish the relation between quality of speech and prosthetic mount position [9–22].

Not all speech sounds are sensitive to changes of the dental system. The most sensitive sounds which are produced in the oral cavity are /s/, /sh/, /t/, /th/, and they depend on the spoken language.

Early investigations had a qualitative nature [9,11,16,17]. Ritchie et al. [6] reported speech defects caused by incorrect incisor positions in maxillary dentures. It was found that a displacement of the maxillary incisors to the labial direction was most sensitive in producing speech problems. Speech alterations were also found after the insertion of a fixed partial denture.

Jindra et al. [8] analyzed the syllables of a patient using different dentures with the help of spectrogram images. The syllables most sensitive to speech alternation were established.

Ögütcen Toller [2] also used a spectrogram for temporomandibular joint disfunction. Spectrogram studies were also published in Ref. [7,17,19].

Investigations using the sound represented in the time domain were published by [4,12].

Seifert, Runte et al. [13–15] studied the influence of maxillary central incisor the position from complete dentures on /s/ sound. The authors investigated with accuracy the relation between spectrum amplitude and spectrogram on the angular position of the dental mountings. The authors consider a series of peaks in the spectra, which can be considered as quantitative parameters.

There is an attempt to establish physical models for explaining speech sound alterations [10].

The next important step in correlation between prosthetic geometry and speech sound alteration must be of a practical nature: a rigorous computer assisted method to establish optimal parameters of prosthetic mounts in order to ensure best speech quality, needs to be obtained. It is important to note that, in principle, a series of parameters exists, which can be used as quantitative parameters.

However, we must stress that speech sounds are also widely investigated in other fields such as speaker recognition and verification [23–25,30], forensic speech investigations [26,27], communication problems, and so on. Cepstrum analysis [25,29] and two-dimensional transforms such as the wavelet transform [28], Wigner–Ville transform, and Gabor transform were introduced several years ago in the field of sound processing. The cepstrum transform of a signal gives the envelope of a signal, and for speaker recognition and verification purposes it reflects personal differences between the modality in which two persons say a word. The Wigner–Ville transform is a two-dimensional representation of a signal which reflects fine frequency shifts or delays in the signals. The Gabor transform is a time–frequency transform, similar to the short-time Fourier transform and gives at each moment the content of the sound's frequencies. The wavelet transform uses a series of kinds of functions (mother wavelet), in order to give two-dimensional representations of the signals. These representations do not have a simply physical interpretation, but amplify small changes in the shape of the signal.

Due to the complicated dependence of speech sounds on the oral cavity configuration, at this moment the problem of obtaining high quality dental mountings depends on science and on the professional art of the dentistry specialist.

In this paper the wavelet transform and short-time Fourier transform are used to analyze the dependence of speech sounds on dental mountings, due to the fact that these transforms are sensitive to small alterations of the measured sounds.

The aim of our paper, as a next important step in the study of the correlation between prosthetic geometry and speech sound alteration, is to establish a series of quantitative parameters which reflect the dependence between speech alteration and the position of the dental prosthesis.

These studies will provide the possibility in the future for obtaining a rigorous, computer assisted method to establish the optimal parameters of prosthetic mounts and best speech quality.

In two previous papers devoted to this problem a wavelet transform was used, fractal Hurst exponent, correlation function and the power spectra [31,32].