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Feature selection for spontaneous speech analysis to aid in Alzheimer's disease diagnosis: A fractal dimension approach

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Abstract

Alzheimer's disease (AD) is the most prevalent form of degenerative dementia; it has a high socio-economic impact in Western countries. The purpose of our project is to contribute to earlier diagnosis of AD and allow better estimates of its severity by using automatic analysis performed through new biomarkers extracted through non-invasive intelligent methods. The method selected is based on speech biomarkers derived from the analysis of spontaneous speech (SS). Thus the main goal of the present work is feature search in SS, aiming at pre-clinical evaluation whose results can be used to select appropriate tests for AD diagnosis. The feature set employed in our earlier work offered some hopeful conclusions but failed to capture the nonlinear dynamics of speech that are present in the speech waveforms. The extra information provided by the nonlinear features could be especially useful when training data is limited. In this work, the fractal dimension (FD) of the observed time series is combined with linear parameters in the feature vector in order to enhance the performance of the original system while controlling the computational cost.

Keywords: Nonlinear speech processing; Alzheimer's disease diagnosis; Spontaneous speech; Fractal dimensions

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1. Introduction

Alzheimer's disease (AD) is the most common type of dementia among the elderly. It is characterized by progressive and irreversible cognitive deterioration with memory loss and impairments in judgment and language, together with other cognitive deficits and behavioral symptoms. The cognitive deficits and behavioral symptoms are severe enough to limit the ability of an individual to perform everyday professional, social or family activities. As the disease progresses, patients develop severe disability and full dependence. An early and accurate diagnosis of AD helps patients and their families to plan for the future and offers the best possibilities of treating the symptoms of the disease. According to current criteria, the diagnosis is expressed with different degrees of certainty as possible or probable AD when dementia is present and other possible causes have been ruled out. The diagnosis of definite AD requires the demonstration of the typical AD pathological changes at autopsy (McKhann et al., 1984, 2011; Van de Pole et al., 2005). The clinical hallmark and earliest manifestation of AD is episodic memory impairment. At the time of clinical presentation, other cognitive deficits are present in areas like language, executive functions, orientation, perceptual abilities and constructional skills (Morris, 1993; APA, 2000). All these symptoms lead to impaired performance in everyday activities. Approaches to the early diagnosis of AD have in the past few years made significant advances in the development of reliable clinical biomarkers (AA, 2014).

Despite the usefulness of biomarkers, the cost and technology requirements involved make it impossible to apply such tests to all patients with memory complaints. Given these problems, non-invasive intelligent techniques of diagnosis may become valuable tools for early detection of dementia. Non-technical staff in the habitual environments of the patient could use these methodologies, which include e.g. automatic spontaneous speech analysis (ASSA) (Fig. 1), without altering or blocking the patients' abilities, as the spontaneous speech involved in these techniques is not perceived as a stressful test by the patient. Moreover, these techniques are very low-cost and do not require extensive infrastructure or the availability of medical equipment. They are thus capable of yielding information easily, quickly, and inexpensively (Faundez-Zanuy et al., 2012; López-de-Ipiña et al., 2013a,b).

In addition to the loss of memory, one of the major problems caused by AD is the loss of language skills. We can detect different communication deficits in the area of language, including aphasia (difficulty in speaking and understanding) and anomia (difficulty in recognizing and naming things). The specific communication problems the patient encounters depend on the stage of the disease (McKhann et al., 2011; Van de Pole et al., 2005; Morris, 1993):

1. First stage or early stage (ES): difficulty in finding the right word in spontaneous speech. Often remains undetected.
2. Second stage or intermediate stage (IS): impoverishment of language and vocabulary in everyday use.
3. Third stage or advanced stage (AS): answers sometimes very limited and restricted to very few words.

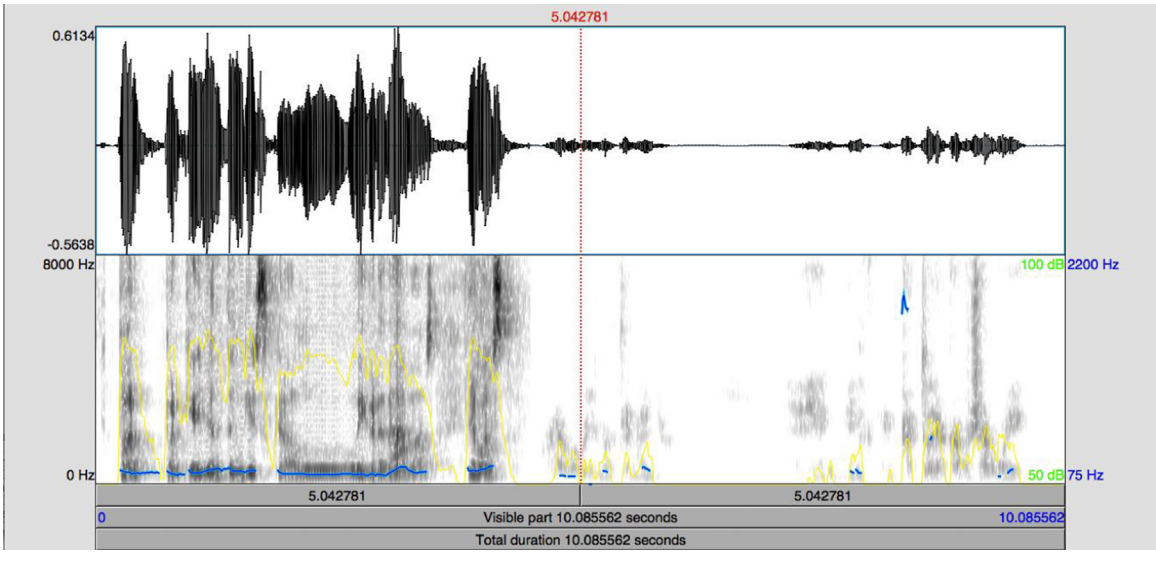

Fig. 1. Signal and spectrogram of a control subject (left) and a subject with AD (right) during spontaneous speech.

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