Neurocomputing 150 (2015) 392–401

Contents lists available at ScienceDirect

Neurocomputing

journal homepage: www.elsevier.com/locate/neucom

Feature selection for automatic analysis of emotional response based on nonlinear speech modeling suitable for diagnosis of Alzheimer's disease

K. López-de-Ipiña [a,*], J.B. Alonso-Hernández [b], J. Solé-Casals [c], C.M. Travieso-González [b], A. Ezeiza [a], M. Faúndez-Zanuy [d], P.M. Calvo [a], B. Beitia [e]

[a] System Engineering and Automation Department, University of the Basque Country (UPV/EHU), Donostia 20008, Spain
[b] Instituto para el Desarrollo Tecnológico y la Innovación en Comunicaciones (IDeTIC), Universidad de Las Palmas de Gran Canaria, IDeTIC, Spain
[c] Data and Signal Processing Research Group, University of Vic - Central University of Catalonia, Spain
[d] Escola Universitaria Politécnica de Mataró (UPC), Tecnocampus, Spain
[e] Department of Mathematics, University of the Basque Country (UPV/EHU), Spain

ARTICLE INFO

Article history:
Received 15 December 2013
Received in revised form
26 March 2014
Accepted 2 May 2014
Available online 23 October 2014

Keywords:
Emotional response
Automatic speech analysis
Emotion recognition
Non-linear modeling
Fractal dimension
Emotional temperature

ABSTRACT

Alzheimer's disease (AD) is the most common type of dementia among the elderly. This work is part of a larger study that aims to identify novel technologies and biomarkers or features for the early detection of AD and its degree of severity. The diagnosis is made by analyzing several biomarkers and conducting a variety of tests (although only a post-mortem examination of the patients' brain tissue is considered to provide definitive confirmation). Non-invasive intelligent diagnosis techniques would be a very valuable diagnostic aid. This paper concerns the Automatic Analysis of Emotional Response (AAER) in spontaneous speech based on classical and new emotional speech features: Emotional Temperature (ET) and fractal dimension (FD). This is a pre-clinical study aiming to validate tests and biomarkers for future diagnostic use. The method has the great advantage of being non-invasive, low cost, and without any side effects. The AAER shows very promising results for the definition of features useful in the early diagnosis of AD.

1. Introduction

Alzheimer's disease (AD) is the most common type of dementia among the elderly; its socioeconomic cost to society is sizeable and expected to increase. It is characterized by progressive and irreversible cognitive deterioration with memory loss, impairments in judgment and language, and other cognitive deficits and behavioral symptoms that finally become severe enough to limit the ability of an individual to carry out the professional, social or family activities of daily life. As the disease progresses, patients develop increasingly severe disabilities, becoming in the end completely dependent on others. An early and accurate diagnosis of AD would be of much help to patients and their families, both in facilitating planning for the future and in beginning treatment of the symptoms of the disease early.

A diagnosis of AD requires, on the one hand, the confirmation of the presence of a progressive dementia syndrome and, on the other, the exclusion of other potential causes of dementia as demonstrated by the patient's clinical history. According to current criteria, the diagnosis is expressed with different degrees of certainty as possible or probable AD; an unambiguous diagnosis of AD is considered to require that a post-mortem analysis demonstrate the typical AD pathological changes in brain tissue [1–4]. The clinical hallmark of the earliest manifestations of AD is episodic memory impairment. At the time of clinical presentation, other cognitive deficits are usually already present in the patient's language, executive functions, orientation, perceptual abilities and constructional skills. Associated behavioral and psychological symptoms include apathy, irritability, depression, anxiety, delusions, hallucinations, inhibition decrease, aggression, aberrant motor behavior, as well as changes in eating or sleeping patterns [4–6]. While the presence of these symptoms is indicative, reaching a reliable diagnosis in some cases requires expensive and invasive diagnostic tests such as computer tomography (CT), magnetic resonance imaging (MRI) and/or lumbar puncture. The development of non-invasive intelligent diagnosis techniques would therefore be very valuable for the early detection and classification of different types of dementia. A particular advantage of such techniques is that they do not require specialized personnel or laboratory equipment, so that anyone in the habitual

* Corresponding author.
E-mail addresses: karmele.ipina@ehu.es (K. López-de-Ipiña), jalonso@dsc.ulpgc.es (J.B. Alonso-Hernández), jordi.sole@uvic.cat (J. Solé-Casals), ctravieso@dsc.ulpgc.es (C.M. Travieso-González), aitzol.ezeiza@ehu.es (A. Ezeiza), faundez@tecnocampus.cat (M. Faúndez-Zanuy).

http://dx.doi.org/10.1016/j.neucom.2014.05.083
0925-2312/

environment of the patient could, after proper training, apply them without altering or blocking the patient's abilities [7,8].

In addition to the loss of memory, one of the major problems caused by AD is the loss of language skills. This offers possibilities for non-invasive diagnostic techniques, as 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 or grade of severity [2,3,5]:

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.

Emotional Speech Analysis (ESA) has the potential to identify symptoms of Alzheimer's by drawing on such changes in the patient's speech (Fig. 1). Emotions are cognitive processes related to the architecture of the human mind, such as decision-making, memory or attention; they are closely linked to the learning and understanding that arise in intelligent natural or artificial systems when such learning becomes necessary for survival in a changing and partially unpredictable world [9–14]. Emotional information is transmitted through language not only explicitly but also implicitly through nonverbal communication [15–17].

Besides visual elements like body language, non-verbal information also includes audio components, such as modulation of voice [15–17]. These emotion-transmitting non-verbal cues in speech, unlike facial expressions or body language, are relatively independent of cultural and social factors, and are thus particularly well suited for analysis [9,18]. Our work makes use of the changes that Alzheimer's disease causes in the emotional response measurable in speech to develop non-invasive diagnostic techniques.While it should be noted that cultural differences influence the character of non-verbal cues about emotional response, the non-verbal audio information nevertheless remain useful for detecting the changes introduced by the onset and progress of Alzheimer's disease.

The emotional response in Alzheimer's disease patients becomes impaired, and such impairment appears to go through different stages. In the early stages, sociability and even inhibition decreases and behavioral changes are also observed (for example, anger and inability to perform common tasks, express oneself or remember) [8,18]. However, even as social contact diminishes, the emotional memory of it remains, and Alzheimer's sufferers often cry easily and acknowledge caresses, smiles and hugs with grateful appreciation. The Alzheimer's disease patient reacts aggressively to things that for healthy people seem harmless and perceives threats or dangers where none exist. In more advanced stages, the person affected by Alzheimer's disease may often seem shy and apathetic – symptoms often attributed to memory loss and/or difficulty in finding the right words. Some of these responses are likely to be magnified due to an alteration in perception. Alternatively, it has been suggested that the reduced ability to feel emotions is due to memory loss, which may in turn induce the appearance of apathy and depression [19–23].

The work presented here is part of a larger study that aims to identify novel technologies and biomarkers or features for the early detection of AD. The purpose of this work is to evaluate the suitability of a new approach in Automatic Analysis of Emotional Response (AAER) for early AD diagnosis. This approach is based on the analysis of classical parameters, Emotional Temperature and

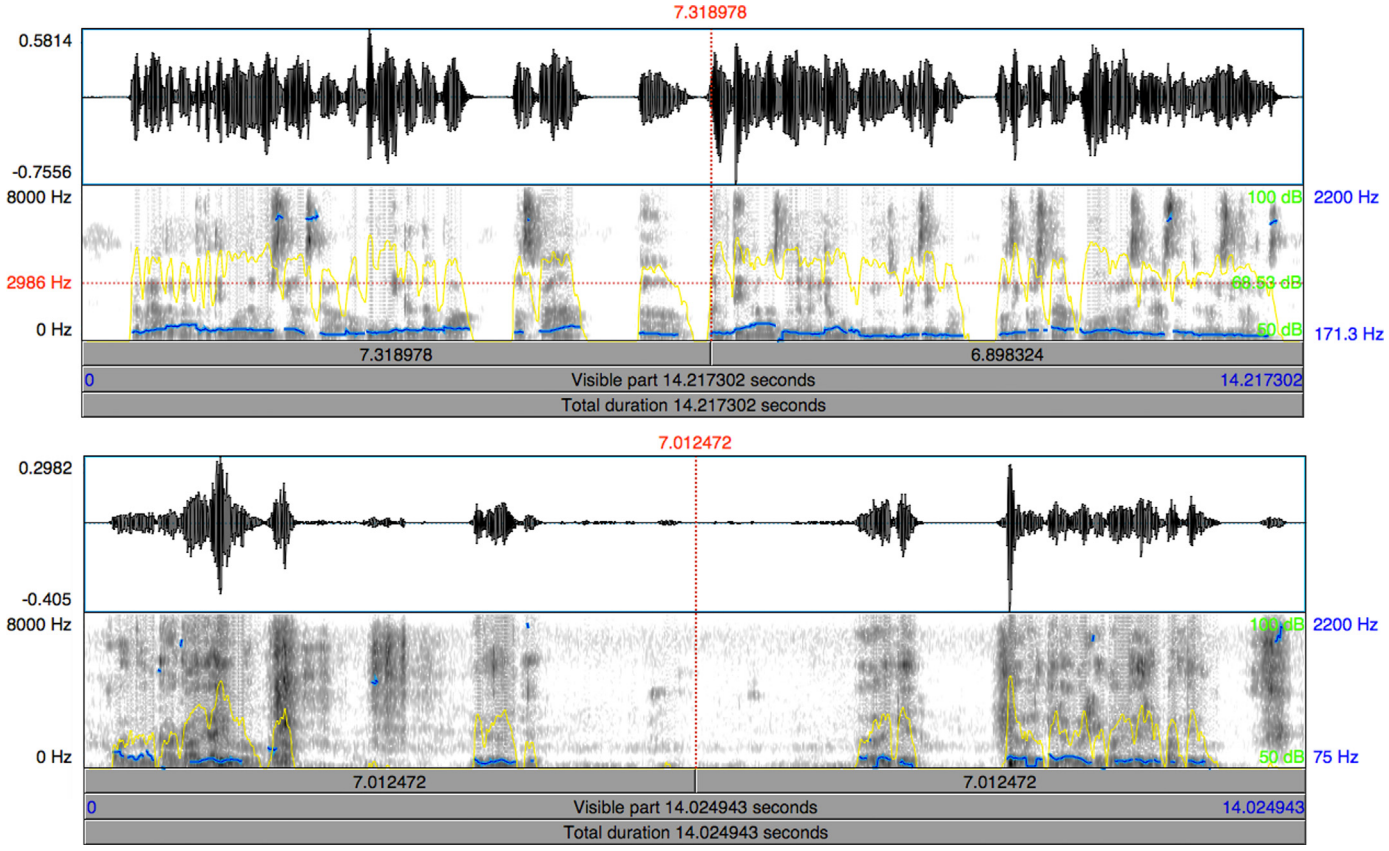

Fig. 1. Speech signal and spectrogram for a control (top) and a person with AD (bottom).