Artificial Intelligence in Medicine (2005) **34**, 65—76

ARTIFICIAL INTELLIGENCE IN MEDICINE

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A new method for sleep apnea classification using wavelets and feedforward neural networks

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Received 17 March 2004; received in revised form 15 July 2004; accepted 22 July 2004

KEYWORDS
Sleep apnea syndrome;
Detection and classification of apneas;
Supervised neural networks;
Discrete wavelet transformation

Summary

Objectives: This paper presents a novel approach for sleep apnea classification. The goal is to classify each apnea in one of three basic types: obstructive, central and mixed.
Materials and methods: Three different supervised learning methods using a neural network were tested. The inputs of the neural network are the first level-5-detail coefficients obtained from a discrete wavelet transformation of the samples (previously detected as apnea) in the thoracic effort signal. In order to train and test the systems, 120 events from six different patients were used. The true error rate was estimated using a 10-fold cross validation. The results presented in this work were averaged over 100 different simulations and a multiple comparison procedure was used for model selection.
Results: The method finally selected is based on a feedforward neural network trained using the Bayesian framework and a cross-entropy error function. The mean classification accuracy, obtained over the test set was $83.78 \pm 1.90\%$.
Conclusion: The proposed classifier surpasses, up to the author's knowledge, other previous results. Finally, a scheme to maintain and improve this system during its clinical use is also proposed.

1. Introduction

The sleep apnea syndrome (SAS) is a respiratory disorder suffered by people who stop breathing during their sleep. The number of apneic events per hour in order to diagnose the syndrome is age dependent. For example, for patients between 20 and 40 years old, the minimum number of apneas

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0933-3657/$ — see front matter
doi:10.1016/j.artmed.2004.07.014

per hour is five. The apneic events can be characterized as either apneas, defined by respiratory pauses with cessation of airflow lasting at least 10 s, or hypoapneas, defined as reductions in airflow accompanied by desaturations or arousals or both. A patient with SAS can suffer until 200 apneic episodes by night, usually with intermittent snoring; respiratory pauses of 30—60 s in duration, or even more, with intense inspiration noises at the end of the apnea; and diurnal tiredness due to a scarce repairing nighttime sleep. Besides, it has been proved that SAS is associated with cardiovascular problems such as systemic and pulmonar hypertension, arrythmias and ischemic cardiac illness [1,2]. The most common method for the diagnosis of the SAS is based on nocturnal polysomnography. It consists of a polygraphic recording during sleep of the electrophysiological and pneumological signals. Thus, this method uses the electroencephalogram (EEG), electrocardiogram (ECG), electro-oculogram (EOG), electromyogram (EMG), airflow, thoracic breathing movements, the position of the body during sleep, and arterial oxygen saturation signals [3,4].

Typically, the diagnostic process comprises the detection of possible apneic events, their confirmation and later classification in three basic types of respiratory disfunctions:

- Obstructive apneas (OA): This is the more frequent pattern, characterized by the presence of thoracic effort for continuing breathing while air flow completely stops.
- Central apneas (CA): These are characterized by a complete cessation of both respiratory movements and airflow during, at least, 10 s.
- Mixed apneas (MA): This pattern is a combination of the previous two, defined by a central respiratory pause followed, in a relatively short interval of time, by an obstructive ventilatory effort.

Following conventional clinical criteria, the apneic episodes are detected in the airflow signal, the thoracic effort is used for classification, and the information derived from electrophysiological and oxygen saturation signals is used as context for interpretation [5]. Fig. 1 shows examples of sleep apneas together with the two signals employed in the detection and classification tasks. In this respect, and strictly from a clinical point of view, it is specially important to be able to distinguish correctly between OAs and CAs, because the appropriate therapy will depend on that [6].

As already mentioned, the analysis of a nocturnal polysomnography, implies the study of a considerable number of physiological variables during a prolonged lapse of time. For this reason, computational systems are almost indispensable in order to facilitate the evaluation process of the polysomnographic records. Several approaches can be found regarding these systems. Thus, Rauscher et al. proposed a method to detect apneas and hypopneas during sleep investigating rapid resaturations from the oxygen saturation signal [7]. Macey et al. proposed and implemented an algorithm for apnea's detection that analyzes the statistical properties of the respiratory effort signal with the aim of finding respiratory pauses [8]. Recently, some approaches based on neural networks have been proposed for the detection and classification of apneas [9—12]. Also, Daniels et al. presented a decision-support knowledge-based system for the differential diagnosis of OA [13]. Other valuable contributions to this field can be found in [11,12,14,15].

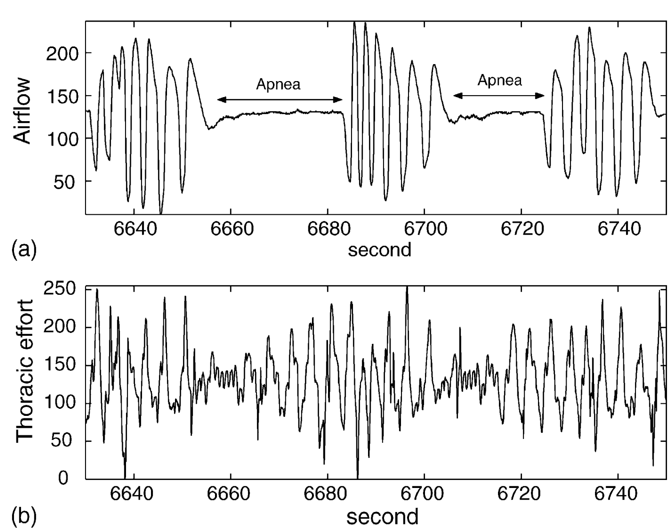

Figure 1 (a) Airflow and (b) thoracic effort signals.