Personalized Sleep Staging System by combining Symbolic Fusion and Feedback System Control

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Abstract

In this paper, a personalized sleep staging system is proposed by combining symbolic intelligence and feedback system control technique. Symbolic Fusion is dedicated to mimic decision-making process of clinical sleep staging. It starts from extraction of digital parameters from raw polysomnography (PSG) signals and goes up-to high level symbolic interpretation of feature parameters. At last, decision is generated using rules inspired by international guidelines in sleep medicine and applied to feature parameters. Meanwhile, Feedback System Control (FSC) is designed to provide optimal thresholds for Symbolic Fusion in transforming digital parameters into feature parameters which can take individual variability into consideration. Proposed system can be also integrated with portable PSG system to realize personal sleep evaluation or home care application in the future.

1. Introduction

Sleep is an indispensable part in daily life which contributes to self-repairing and self- recovering. However, sleep disorders are affecting more and more people. It becomes a significant cause of morbidity and mortality [1].

Sleep Staging, as a fundamental step to diagnose and treat sleep disorders, is usually visually scored by an expert according to American Academy of Sleep Medicine (AASM) manual [2] in analysis of an overnight PSG recordings of electroencephalography (EEG), electrooculography (EOG) and electromyography (EMG). However, it is a time-consuming task and inter-rater variability exists. 82% inter-rater reliability is reported for visual sleep staging performed by different experts [3]. Due to the limitations of clinical sleep staging, automatic sleep staging methods have gained a wide spread attention of researches.

In the past few decades, different automatic sleep staging methods have been proposed. Without the requirement of complex clinical knowledge, numerical methods received much attention involving Decision Tree, Artificial Neural Network and Support Vector Machine. However, it suffers from several severe limitations: 1) Numerical classification is often thought as an independent process ; whereas sleep staging is a time dependent classification problem. The stage scored at one position can be influenced by the stage assigned to previous or/and to next position. 2) Smaller number of signals has been involved in order to reduce the dimension of the feature sets. However, to increase the accuracy and reliability of the sleep staging, there is a need to include more signals in the analysis [4].

A Symbolic Fusion method was proposed in [5] to overcome the limitations of numerical methods. It used AASM manual as guidances to imitate clinical sleep staging process and allows providing enhanced and complementary decision by combining EEG, EOG and EMG. Symbolic fusion starts from extraction of digital parameters from raw PSG signals and goes up-to high level symbolic interpretation of different features. However, this approach is limited by the manual setting-up of thresholds in transforming digital parameters to symbolic interpretation, which require manual efforts.

In this paper, a personalized system combining FSC and symbolic fusion is proposed. FSC is adopted for each subject to avoid inter-subject variability and provide optimal thresholds to symbolic fusion.

2. Personalized Sleep Staging System

In 2003, an automatic sleep staging system was proposed which adopted the three-level architecture defined by B.Dasarathy [6]. As shown in Figure 1a, it consists of data fusion, feature fusion and decision fusion. In data fusion,

digital parameters were extracted from PSG recordings to maximize the useful information and to minimize noise and artifacts. In feature fusion, digital parameters were transformed into feature parameters. It simplifies the interpretation of digital parameters, and also performs normalization, reduction and matching of digital parameters. In decision fusion, inference method was used to fulfill sleep staging on the basis of feature parameters.

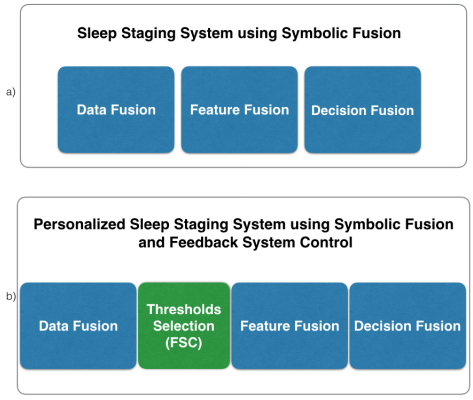

FIGURE **1.** Sleep Staging System

However, visual interpretation was performed to define thresholds in [5]. These thresholds are used in transforming digital parameters into feature parameters to differentiate the boundary of different feature parameters. E.g. According to AASM manual, chin EMG tone is low in stage Rapid Eye Movement (REM). The boundary for low or high feature of EMG is determined by a visual setting of threshold for digital parameter. Total 15 thresholds are defined for translating nine digital parameters into 24 feature parameters. It is a time-consuming process and individual variability also exists.

To overcome the limitations in [5], a personalized sleep staging is proposed, as shown in Figure 1b. A Thresholds Selection part using Feedback System Control technique is involved. A generic FSC platform was proposed by Chih-Ming Ho [7] to find optimal input parameters combination for guiding the bio-system toward to a desired state in 2012. With robustness and rapid searching ability, FSC has been demonstrated to be very effective in combinatorial parameters selection problems.

In this paper, a specific FSC for sleep staging system is proposed. As shown in Figure 2, it is dedicated to provide optimal automatic thresholds selection for releasing the burden of visual interpretation and avoiding individual variability. Digital parameters extracted from PSG are used as the inputs of Thresholds Selection. Meanwhile, initial thresholds combinations are selected by Stochastic Searching Algorithm (SSA). Based on the initially selected thresholds combinations and digital parameters, sleep staging is performed by combining feature fusion and decision fusion. To evaluate the accuracy of sleep staging, a Assessment of Sleep Staging (ASS) part is adopted. With the assessment result of sleep staging, SSA will generate a new thresholds combination for the next loop. This process is repeated until optimal thresholds combination is found which can provide good assessment in ASS. With this Thresholds Selection, an optimal threshold combination can be generated automatically for each subject.

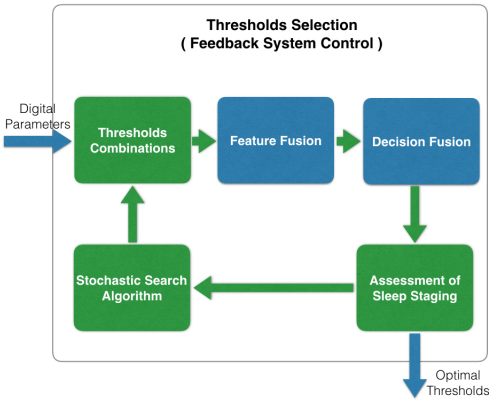

FIGURE **2.** Thresholds Selection using Feedback System Control

3. Conclusion

In this paper, a personalized sleep staging system is proposed by combining Symbolic Fusion and Feedback System Control technique. With the feasibility of FSC technique and the elasticity of symbolic intelligence, proposed system can be a reliable computer-assisted tool for assisting clinical sleep analysis and can be integrated with other medical systems for remote sleep monitoring.

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