Smoothed ℓ^0(SL0) Based Burst Suppression Detection Method

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Introduction: Accurate automatic detection of burst suppression electroencephalographic (EEG) patterns (BSP) is important as its presence is an indicator of deep unconsciousness [1]. Accurate automatic BSP detection can reduce the risk of over-sedation during surgery by giving early warning to the attending anesthesiologist.

Based on our experience, the commercially available NeuroSENSE monitor [2] tends to overestimate suppressions as it is shown in Fig. 1. We aim to address the overestimation of detected suppression by EEG monitors as it can result in alarm fatigue leading the anesthesiologist to ignore real BSP episodes due to repeated false alarms.

Method: We use machine learning to develop a real-time algorithm to detect BSPs in the EEG signals of patients under general anesthesia during surgery. The RUSBoost technique [3] is used to train an ensemble classifier to address the problem of class imbalance in our application, as the non-suppression class instances greatly outnumber suppression class instances.

The smoothed ℓ^0(SL0) norm of a vector [4] is utilized to introduce novel appropriate features for the BSP classification. We propose SL0-based features in order to track the time-evolution of spatial properties of the EEG signal. We refer to the proposed algorithm as the SL0-based BSP detection method, emphasizing that the proposed BSP detection method successfully uses the SL0 norm of a vector for the BSP detection.

For the time-varying EEG signal denoted, we consider the SL0 norm [4] of EEG epochs, as a good candidate for suppression detection. We also used several spectral features in addition to the SL0-based features to design our classifier.

Results: We use an EEG database collected from adult patients of age 19 and older [6]. We employed a large and diverse amount of training data of 192 hours of EEG recordings over 90 subjects under surgery.

Our results show that the proposed automatic BSP detection method greatly outperforms the method in [1] as well as the method in [5] which is currently under use by the NeuroSENSE monitor, NeuroWave Systems Inc. [2] in terms of reducing false alarms and the overall classification accuracy. Our proposed method results in 38.74 minutes of false detections over 45.86 hours of test data, i.e. a substantial improvement compared to 60.64 [5] and 353.21 [1] minutes of false detections. In terms of true suppression detection, the proposed SL0-based algorithms performs similarly to the existing methods in [5] and [1]. Our method correctly detects 33.38 minutes of suppressions comparing to 34.74 and 33.64 minutes of suppression correctly detected by the methods in [5] and [1].

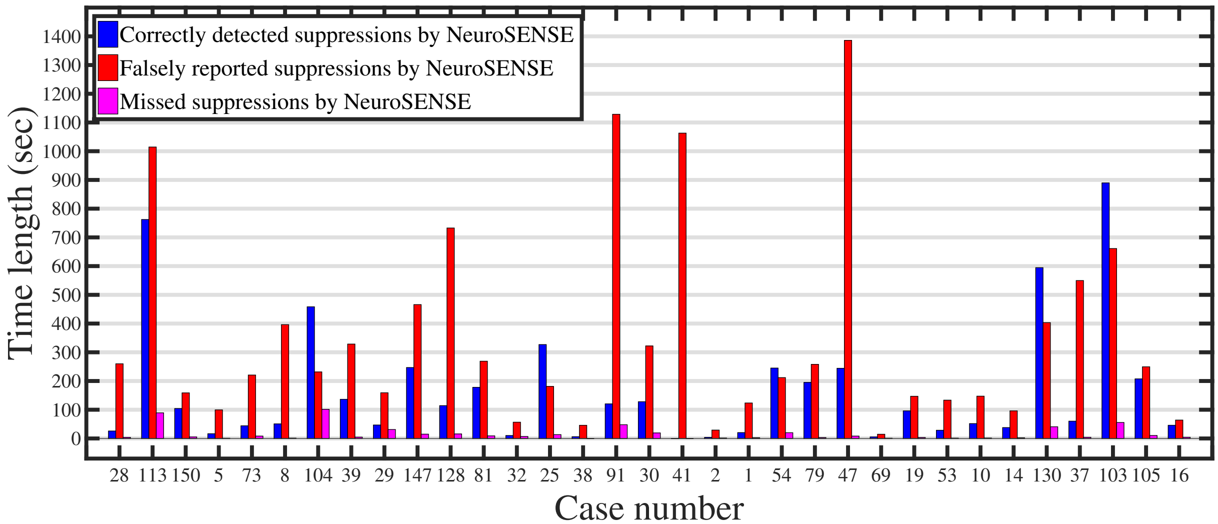

Fig. 1 The false alarm time length reported by NeuroSENSE monitors compared to the time length of accurately detected and missed suppressions for several selected cases.

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