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Pre-processing of Biomedical Signals: Removal of the Signals Saturations Artifacts

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***Abstract*— Sleep diagnosis is established by the physiological signals recording during a sleepy night called polysomnographic (PSG). Four biomedical signals composed the PSG: Electroencephalography (EEG), Electrooculography (EOG), Electrocardiography (ECG), and Electromyography (EMG). During the recording of these signals, different types of noise from various sources can be superimposed on the original signals. This noise called artifacts. In this paper we present a new method to remove the technical artifacts particularly the signal saturation artifacts. To eliminate these artifacts we have developed a new technique based on adaptive rectangular window in amplitude and in width. Our method consists firstly to detect the artifacts. Subsequently, we determine the time interval occupied by the artifacts. Finally, we put this interval to zero and identify by one to avoid their use in the descriptor extraction and classification processes. To offer a reliable automatic system to remove the artifacts, we tested our approach on polysomnographic signals obtained through CIDELEC system (CID 102-108). The experimental results obtained by our algorithm to remove the signal saturation artifacts set from 98.2% to 90.35%, compared with the manual detection results achieved by an expert.**

***Keywords*— Artifacts, Biomedical signals, pre-processing, amplifier saturation and signal saturation artifacts.**

I. INTRODUCTION

During the recording of biomedical signals in a night's sleep, different types of noise from various sources can be superimposed on the original signal [1], [2] and [3]. These noises are called artifacts that do not have bottom phenomena of physiological monitored body [4]. The appearance of these artifacts is related to the method used in an experiment, causing an analyzed error.

Several criteria can be used to classify these artifacts. Grouping them according to their origins is one of the most powerful techniques of gathering. According to this criterion, two types of artifacts can be observed: Biological artifacts (physiological origin) and Technical artifacts (non-physiological origin). Biological artifacts are caused by sources within the person's body. In other words, biological artifacts are usually produced by the normal activities of the body. It is very difficult to avoid their presence. By cons, the technical artifacts are caused by non-physiological sources. These artifacts are mainly caused by external sources or equipment in the exam's room. The existence of external sources close to the measuring apparatus or patient can contaminate the measured signal. The technical artifacts are caused by: the electrode, the connection wire and acquisition card. These artifacts are a major problem for the analysis of biomedical signals.

In this paper, we focus on the detection and the correction of technical artifacts basically the signal saturation artifacts are non-physiological origin. These artifacts are caused by the amplifier saturation of the acquisition card. The amplifier saturation resulted by the potential electrode / skin. Indeed, the biomedical signals are very weak requires an amplifying stage for being interpretable. There are several strategies for biological signals amplifying [5], [6], [7], [8] and [9]. These strategies depend on exchanges between the biological tissue (skin) and the electrode measuring metal nature [10], [11] and the ground electrode metal [12], [13]. These amplification strategies are extremely sensitive at the electrical potential at the Sharp level (the interface electrode / skin). If the electric potential is very low, case of electrode disconnection, the amplification is too low then we have zero saturation and the signal amplitude levels are blocked at zero. If electrical potential is very high, case of electrode or wire connection movements, the gain is too high and the amplifiers are "saturated" then we have the maximum saturation levels and the signal amplitude are blocked in maximum or minimum amplitudes levels.

Indeed, to avoid the effect of these artifacts on the automatic detection of certain medical phenomena (cardiac disease, evoked potential and sleep stages); it is important to go through a pre-processing step signals before any application of descriptor extraction and classification methods.

In this context, we have developed a new technique based on adaptive rectangular window in amplitude and in width. Our method consists firstly to detect the artifacts. Subsequently, we determine the time interval occupied by the artifacts. Finally, we put this interval to zero and identify by one to avoid their use in the descriptor extraction and classification processes.

This paper is organized as follows: in the next section, we describe our technique for removing the signal saturation artifacts. We present our experimental results in Section 3. Finally, a conclusion of this work is given in Section 4.

II. Material and Methodology

A. Material

To provide a reliable automatic system to remove the artifacts, we tested our approach on polysomnographic signals recorded by CIDELEC system (CID 102-108):

1) Subjects: Subjects were selected over a 4-month period (September 02 to February 03) from patients referred to the Sleep Disorders (sleep apnea). Complete database contains records from 15 adult patients. Generally, these records are collected during a night's sleep for 9 hours.

2) Signals: Polysomnographic signals obtained using the CID102 system is: EEG (C3-A2), EEG (F3-A2), EEG (O2-A1), EOGL, EOGR, EMG, ECG

These recordings were collected under the direction of Dr.ABOUDA Maher specialist in pulmonology and sleep disorders.

B. Methodology

Automatic analysis of biomedical signal is based on a robust pre-processing of these signals. Among the noise that contaminates the biomedical signals, we find the signal saturation artifacts. These artifacts are caused by the amplifier saturation of the acquisition card.

Signal saturation artifacts are short term. These artifacts are strongly random which makes it difficult or impossible to detect these. By cons, the time they occupy in the registration is very short (fig.1 and fig.2).

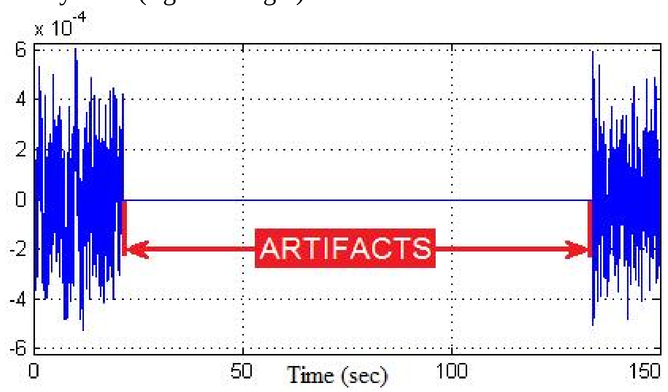

Fig. 1 Example of signal saturation zero level artifacts.

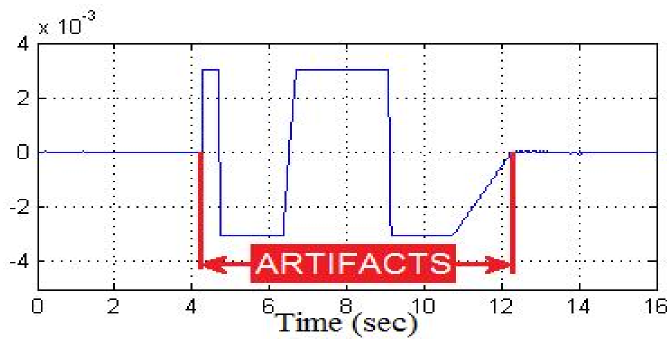

Fig. 1 Example of signal saturation maximum levels artifacts.

In this context, we have developed a new method for removing the signal saturation artifacts based on adaptive rectangular window in amplitude and in width. Our correction strategy of these artifacts is composed in two steps:

- Detection step: To eliminate saturation artifacts we have developed a new technique based on adaptive rectangular window in amplitude and in width. The equation that represents our window is given by the following function:

$$Rw = A * reg(X) \tag{1}$$

With A the amplitude and X the interval of artifacts.

- Identification step: Artifacts identification strategy is based on the detection of contaminate intervals by artifacts in the analysed recording. Indeed, we provide a label for each interval contaminated for deviate from the descriptors extraction and classification processes. Each interval contaminated is assigned the value 1.

3) Signal saturation zero level: is characterized by blocking of signal amplitude in zero levels. Our strategy to detect these artifacts consists firstly to apply our rectangular window with A amplitude close to zero and width equal to 0.04 sec (fig 3.a). If the zeros sequence less than four zeros is not a saturation level zero artifacts. By cons, if the zeros sequence than four then it is saturation zero level artifacts. In the last case, the window width is expanded both side until the first value of samples deferential to zero (fig 3.b). Segment will be identified by one for deviate from the descriptors extraction and classification processes.

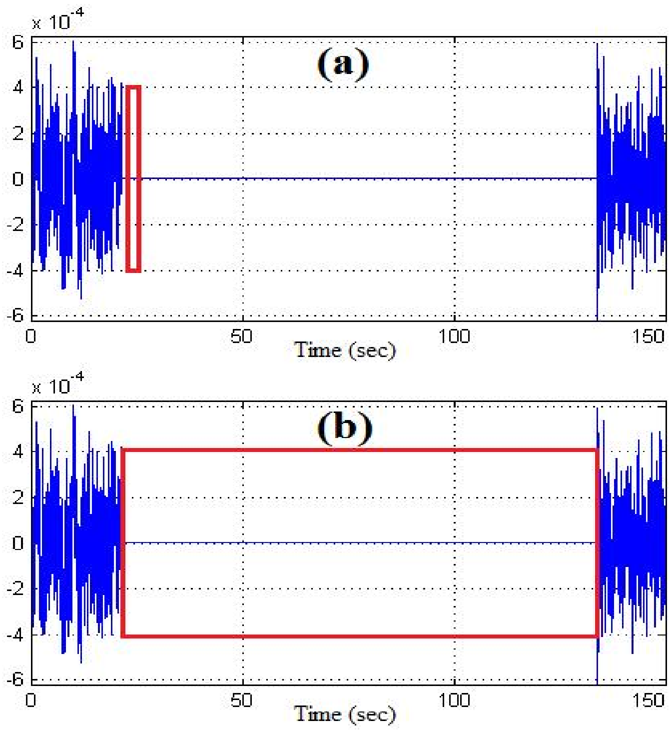

Fig. 3 Example of detection and remove the signal saturation zero levels artifacts.(a) Detection step.(b) identification step.

2) Signal saturation maximum levels: is characterized by signal blocking in maximum or minimum amplitudes levels.

Firstly, to detect these artifacts our strategy consists to calculate the absolute value of the signal (figure). Then, we apply our rectangular window with amplitude equal to the maximum absolute values of the signal given by the equation (2) and width equal to 0.04 sec.

$$A = \max(abs(signal)) \qquad (2)$$

If the interval superior to 0.04 sec the window width is expanded both side until the first value of sample equal to zero. The width of rectangular window is detected from the maximum absolute values abscissa of signal . This interval is given by the equation (3). Finally this segment of signal is set to zero (figure).

$$Iw = (Abscissa(\max) + Y_i) - Abscissa(\max) \qquad (3)$$

With Y_i is the samples number.

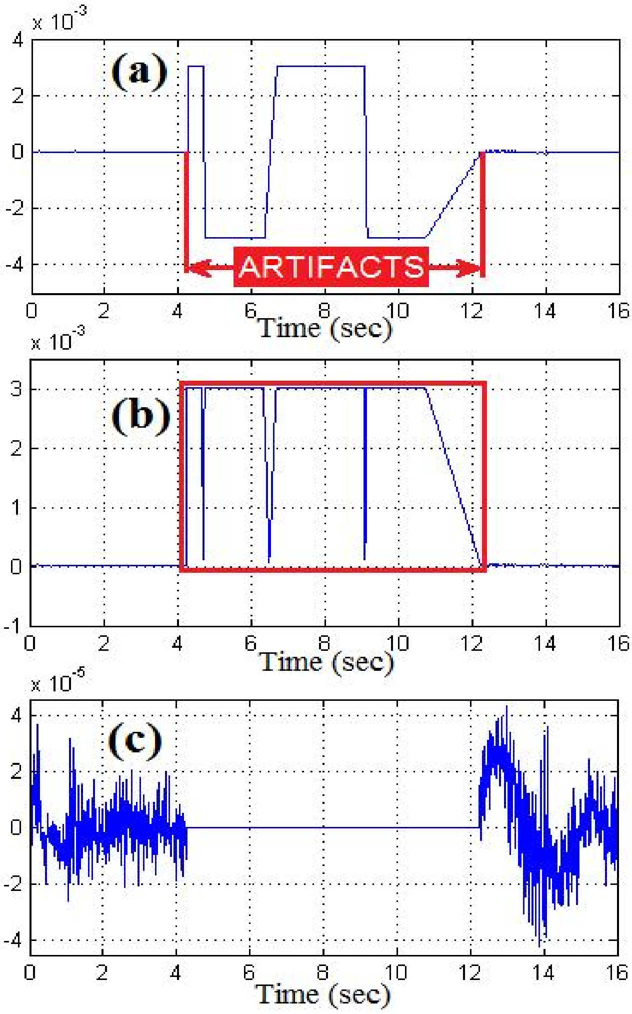

Fig. 4 Example of detection and remove the signal saturation maximum levels artifacts.(a) original signal.(b) detection of saturation maximum levels artifacts.(c) Remove of the artefacts.

III. Experimental Results

To offer a reliable automatic system, we tested our approach on polysomnographic signals recorded by CIDELEC system (CID 102-108). The complete database contains the following polysomnographic signals: EEG (C3-A2), EEG (F3-A2), EEG (O2-A1), EOGL, EOGR, EMG, ECG. Generally, these records are collected during a night's sleep for 9 hours.

Figure 5 shows the percentages of signals time contaminated by artifact. We note that the signal saturation artifacts percentages are important in EMG and ECG. These important values are explained by the patients' movements during sleep.

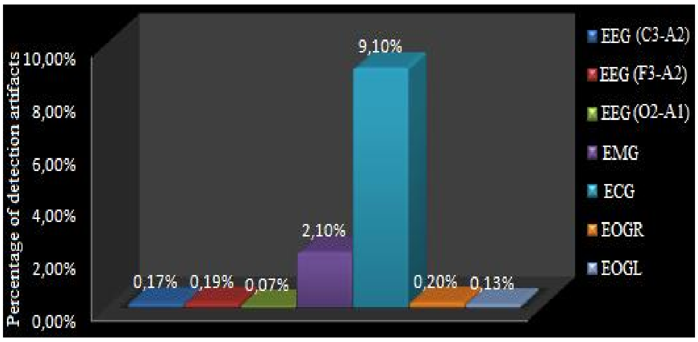

Fig. 5 Signals saturation artifacts percentages.

Figure 6 shows the experimental results obtained by our algorithm to remove the signal saturation artifacts set from 98.2% to 90.35%, compared with the manual detection results achieved by an expert.

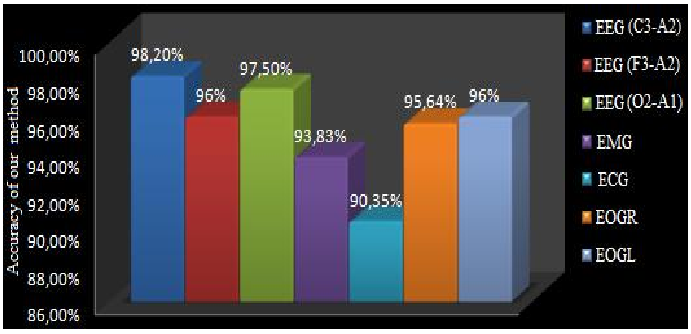

Fig. 6 Accuracy of our method

IV. Conclusions

In this paper, we proposed a new automatic method to remove the signal saturation artifacts from biomedical signals using an adaptive rectangular window in amplitude and in width. Our method to remove these artifacts is composed in two steps: Detection step to localize the segments contaminated by signals saturation artifacts. The second step is the identification consists to provide a label for each segments contaminated for deviate from the descriptors extraction and classification processes.

Our experimental results to remove the signal saturation artifacts presented important percentages of these artifacts in EMG and ECG. These important values are explained by the patients' movements during sleep. According to these results we can ask a question:

It is possible to reduce the appearance of saturation artifacts in ECG and EMG by the estimation of these signals from EEG???

Answers to this question will be presented in my upcoming research works.

ACKNOWLEDGMENT

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