Automatic Artifact Component Removal Using a Neural Network in MCG Signal

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ABSTRACT

An algorithm combining a neural network and a principal component analysis (PCA) is proposed to remove a pulse-type artifact which often occurs in the 61 channel MCG system installed at Samsung Medical Center in Seoul, Korea. In the proposed work, the acquired signal is first decomposed into components by the PCA, and the components corresponding to the artifact are identified and removed by the neural network. The neural network is an essential component in the automation procedure. Unlike existing artifact rejection algorithms, the proposed algorithm is on a component-by-component basis, and the restored signal is used for further processing once the artifact components are successfully removed. Seven parameters are extracted from each time-domain component and are used as the input to the neural network. They are maximum, minimum, peak-to-peak value, variance, mean, skewness, and kurtosis. In the experiments with volunteers, 97% of the decisions made by the neural network are identical to those by the human experts. Using the proposed technique, the artifact was successfully removed from the MCG signal.

KEY WORDS

Magnetocardiography, Artifact, Principal component analysis, Neural network

INTRODUCTION

Biomagnetic signal carries important information related to organ functions. Since the intensity of the biomagnetic field is so weak it is often suppressed by external environmental noise. In our 61 channel MCG system installed at Samsung Medical Center in Seoul, Korea, a pulse-type artifact is often observed in some channels related to the operations of other machines near the MCG system. In our experience, the occurrence of the artifact is random, and its duration of the artifact is about 50-100 milliseconds with a broad range of frequencies. Therefore, it was difficult to remove it by conventional filtering techniques or time-domain analysis. In order to remove the artifact, an algorithm combining a neural network and a principal component analysis (PCA) is proposed.

METHODS

Principal component analysis (PCA) has been known as an effective technique to remove a correlated noise [Kobayashi, 1999]. For instance, it has been successfully applied to the improvement of the signal/noise ratio in the evoked neuromagnetic field, by eliminating any correlated spontaneous fields. In this paper, the technique is applied to the removal of a pulse-type artifact in the 61 channel MCG system installed at Samsung Medical Center. The noise is assumed to be correlated in character due to operations of other machines nearby the MCG system. With a pulse-type shape with a relative long duration (50~100ms), it is difficult to remove it by simply applying filtering or time domain analysis.

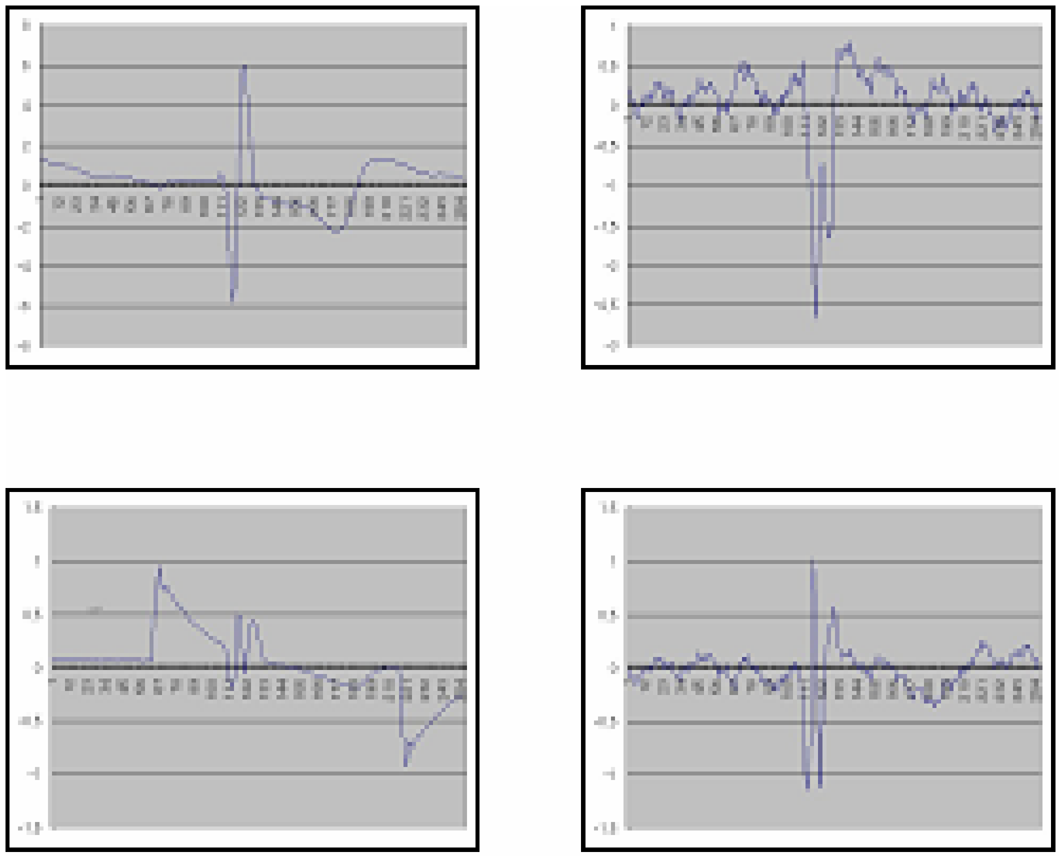

Figure 1. Dominant components of the measured MCG signal

In our approach, the MCG signal is decomposed into components by the PCA method, and some dominant components are identified as either signal or noise components. The PCA is computed on a time window with the duration of a heart beat interval. Dominant components are chosen based on the PC score, the relative magnitude of the eigenvalues associated with each component. Fig. 1 shows some dominant components of the acquired MCG signal. As seen in Fig. 1, the component in the lower left corner can be clearly identified as a noise component. In order to minimize possible interferences of the signal involved in the artifact components, removal of the artifact components is applied to only several dominant components determined by the PC score. Although the identification of the noise component is not difficult, it is useful to implement automatic procedure for artifact component selection. For this purpose, a neural network is combined for an automatic identification as shown in Fig. 2 [Ahn 1996]. Seven parameters (maximum, minimum, peak-to-peak value, variance, average, skewness, and kurtosis) calculated from each component are used as the input to

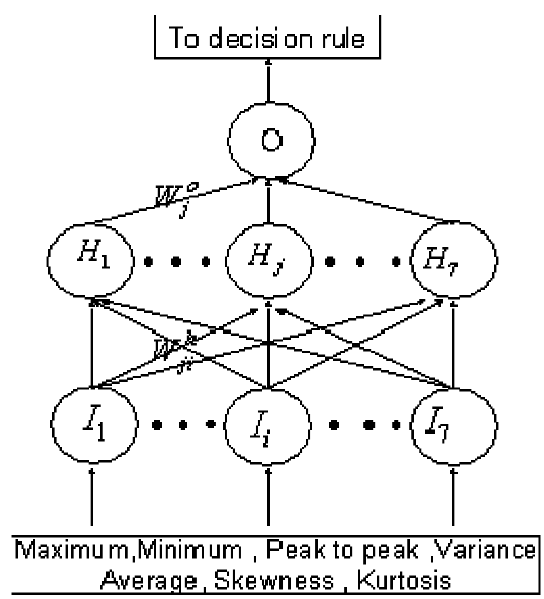

Figure 2. Architecture of the neural network used for the automatic identification of the noise component

the neural network. Single hidden layer with 7 nodes are used. After applying a sigmoid function, output node has a value between [0,1]. The component is more likely to be signal if the value is close to 1, while it belongs to the artifact if the output is near to 0. A threshold-based decision rule is applied to the output. For a test component set 0 and 1 are assigned to the artifact and signal, respectively. During the training, if the decision made by the neural network is different from the desired one, the difference between the output value and desired value (0 or 1) is fed back to the modification of the weight matrices by the error back propagation algorithm. Once the noise components are removed, the signal components are reconstructed to restore the signal for further processing.

RESULTS

Experiments for the artifact removal were carried out for five volunteers. For each volunteer, 100 epochs of MCG signal were acquired. For the training of the network, a supervised learning was applied with an error back propagation algorithm. Ninety-seven percent of identical decisions were obtained from the neural network compared to human experts after completion of the training. Figure 3 shows the signal waveforms before and after processing with the proposed method. As seen in Fig. 3, the pulse-type noise can be completely removed by the proposed method.

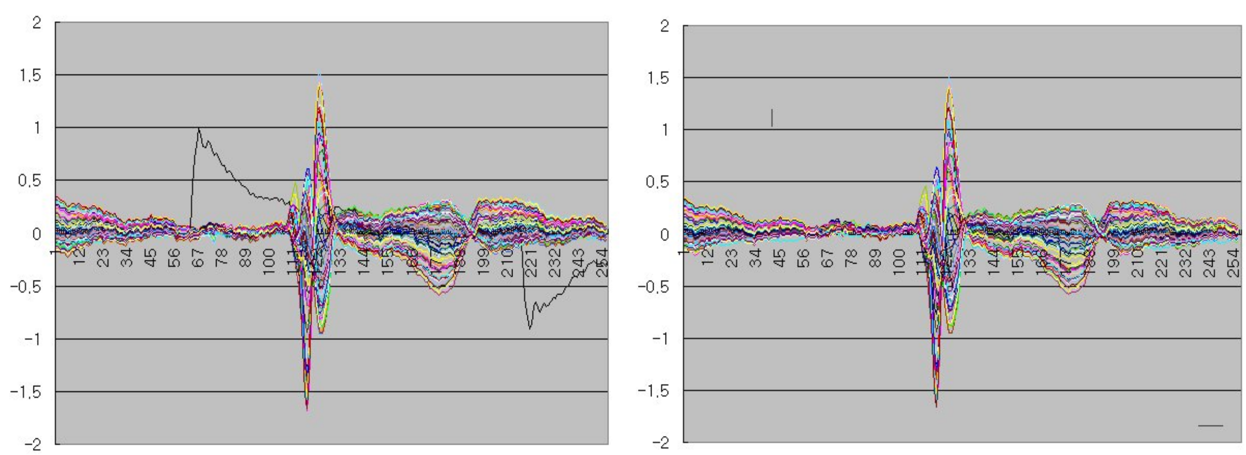

Figure 3. Multichannel MCG signal before (left) and after (right) processing with the proposed method.

DISCUSSION

Unlike previous artifact removal methods mainly based on the entire waveform of the signal, the proposed technique is applied to the component after the principal component analysis, which appears more advantageous over previous methods in the characterization of the noise. Instead of rejection of the contaminated signal, the proposed algorithm restores the signal, which may be an important feature when signal averaging is limited, e.g., single event experiment or measurement of evoked field with some organs easily adopted to stimuli.

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