# GAF 변환을 사용한 딥 러닝 기반 단일 리드 ECG 신호에서의 수면 무호흡 감지

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# Sleep apnea detection from a single-lead ECG signal with GAF transform feature-extraction through deep learning

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● 요 약 ●

Sleep apnea (SA) is a common chronic sleep disorder that disrupts breathing during sleep. Clinically, the standard for diagnosing SA involves nocturnal polysomnography (PSG). However, this requires expert human intervention and considerable time, which limits the availability of SA diagnoses in public health sectors. Therefore, ECG-based methods for SA detection have been proposed to automate the PSG procedure and reduce its discomfort. We propose a preprocessing method to convert the one-dimensional time series of ECG into two-dimensional images using the Gramian Angular Field (GAF) algorithm, extract temporal features, and use a two-dimensional convolutional neural network for classification. The results of this study demonstrated that the proposed method can perform SA detection with specificity, sensitivity, accuracy, and area under the curve (AUC) of 88.89%, 81.50%, 86.11%, and 0.85, respectively. Our experimental results show that SA is successfully classified by extracting preprocessing transforms with temporal features.

**키워드:** Sleep apnea, Gramian Angular Field (GAF), Deep learning

## I. Introduction

The most prevalent respiratory condition, sleep apnea (SA), is brought on by partial or total blockages of the upper respiratory tract[1]. An apnea episode is typically defined as a full halt of at least 10s in the airflow across the upper airway when a person is sleeping. One of the most often utilized diagnostics for diagnosing SA is polysomnography (PSG). However, this complicated and uncomfortable examination experience has limited the application of PSG in clinical practice.

Convolutional neural networks are utilized in the SA classification because of their superior performance. The RR interval and R peak value of the ECG signal are typically used for extracting features, alternatively by using the CWT approach to create an image, the heart rate variability (HRV) characteristic is then extracted[2].

We use the Gramian Angular Field (GAF) algorithm to preprocess one-dimensional time series of ECG into two-dimensional pictures. The images have temporal properties and use a two-dimensional convolutional neural network for classification.

## II. Database and Preprocessing

### 1. Database

To ensure reliable results, we utilized the popular and widely used Apnea-ECG database[3], which is publicly available on Physionet provided by Philipps University. The data set provided expert comments for each one-minute ECG signal recording segment. The label is the binary information of each minute recorded and encoded as “normal breathing” (N) or “respiratory disorder” (A).

### 2. Preprocessing

The Gramian Angular Field (GAF)algorithm [4] is a method of converting a one-dimensional time series in a Cartesian coordinate system into a polar coordinate system and using trigonometric functions to generate a GAF matrix diagram. The trigonometric function of the difference between the two angles is used to obtain the matrix image of the Gramian Angular Difference Field (GADF). The GADF matrix image is shown in Figure 1.

The GADF matrix image is temporal because polar coordinates retain absolute temporal relations.

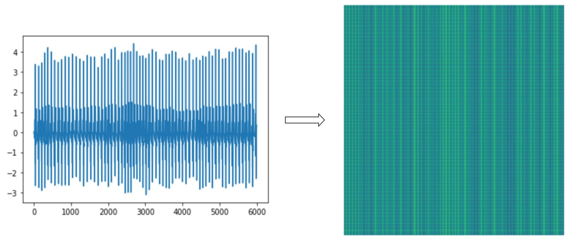


Fig. 1. Creating a GADF matrix image from a 1D signal

## III. Experiments and Results

After GADF preprocessing, the experiment trains the ResNet model[5] on the matrix images. The results are shown in Table 1. This study demonstrated that the proposed method could classify SA with specificity, sensitivity, accuracy, and area under the curve (AUC) of 88.89%, 81.50%, 86.11%, and 0.85 respectively.

Table 1. Experimental performance results

| Performance | Value |
|---|---|
| Specificity | 88.89% |
| Sensitivity | 81.50% |
| Accuracy | 86.11% |
| AUC | 0.85 |

## IV. Conclusion

In this study, the ECG one-dimensional time-series signal is converted into matrix images using the GADF algorithm, and the convolutional neural network can be used to successfully classify SA. It is efficient for classification to extract preprocessing transforms with temporal properties. It provides a new direction for SA classification.

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