



SAPIENZA  
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# EEG signal denoising using machine learning techniques

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*dedication*



## Abstract

This thesis aims to investigate the use of machine learning techniques for EEG signal denoising. The first part of the thesis is dedicated to the introduction of the problem, the statement of the research questions and an overview of the basic concepts. The second part is dedicated to history and the state of the art of the signal analysis, and more specifically of the EEG signal analysis and denoising methods. The third part is dedicated to the machine learning techniques. The fourth part is dedicated to the experimental results and the last part is dedicated to the conclusions and future work.



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# Chapter 1

## Introduction

The chapter is built as follows: in the first section there is a brief introduction of the problem, the reasons that led to the choice of the topic and the outline of the thesis. In the second section there is the statement of the research questions. In the third section there is a brief description of the basic concepts.

### 1.1 Problem statement

What is EEG in the first place and why is it important? Electroencephalography (EEG) is a non-invasive technique used to measure the electrical activity of the brain. EEG signals are still among the less explored ones in the field of signal processing, despite their widespread use in clinical practice and research. In recent years, there has been a growing interest in developing denoising methods for EEG data to improve their quality and reliability.

The main objective of this thesis is to investigate and compare different EEG denoising methods, and to evaluate their performance in terms of signal quality, artifact removal, and preservation of underlying brain activity. Specifically, we will focus on the most recent machine learning techniques, such as generative adversarial networks (GANs), autoencoders (AEs), and deep learning (DL) models. We will also investigate the potential of combining different denoising methods to improve the performance of EEG denoising.

Overall, this thesis aims to provide a better understanding of the strengths and limitations of different EEG denoising methods, and to help researchers and clinicians make informed decisions when selecting the most appropriate denoising method for their EEG data analysis. By improving the quality of EEG signals, we can enhance our understanding of brain function and ultimately contribute to the development of more effective diagnostic and therapeutic tools for neurological disorders.

### 1.2 Research questions

The research questions are the following:

- How can we remove artifacts from EEG signals?
- How can we exploit the most recent machine learning techniques for EEG denoising?
- What are the strengths and limitations of these new methods?
- What are the performance of these new methods?

## 1.3 Basic concepts

### 1.3.1 EEG

When talking about EEG, in this thesis, we are referring to the electroencephalogram, in particular we are interested in the EEG waves. Electroencephalogram (EEG) waves are the patterns of electrical activity that are recorded by EEG measurements. These waves have different frequencies and amplitudes, and they reveal different states of brain activity. We divide the EEG waves in 5 main categories depending on their frequency: Alpha, Beta, Theta, Delta and Gamma waves.

Alpha waves are typically observed when someone is relaxed and awake, with a frequency of 8-13 Hz. Beta waves, on the other hand, are associated with active cognitive processing and have a higher frequency of 14-30 Hz. Theta waves are usually observed during drowsiness or light sleep and have a frequency of 4-7 Hz, while delta waves are typically observed during deep sleep and have a frequency of less than 4 Hz.

Gamma waves have a frequency of 30-100 Hz and are associated with higher cognitive functions such as attention and memory. Mu waves, with a frequency of 8-13 Hz, are observed in the sensorimotor cortex during movement and motor planning.

It's important to remember that EEG waves are not distinct entities but represent a continuous spectrum of activity that can be influenced by various factors such as task demands, attention, and emotion. Interpreting EEG waves requires expertise and context since different patterns of EEG activity may reflect different states of brain activity depending on the individual and the experimental conditions. Furthermore, research has shown that EEG waves can be useful in clinical diagnosis and prognosis, as well as in the assessment of cognitive function and brain injury. Therefore, understanding the various EEG waves and their characteristics can provide valuable insights into brain function and activity.

### 1.3.2 EEG denoising

EEG signals can be influenced by various factor that alter the real waves originated from neural activities, those factors are defined as artifacts. The artifacts can be classified as [1]:

- intrinsic artifacts: artifacts that depend on physiological sources, such as ocular artifacts (EOG) that come from eye movement and blinking, muscle artifacts (EMG) and cardiac artifacts (ECG)

- extrinsic artifacts: artifacts generated from external electromagnetic such as power line noise sources.

Denoising of EEG data is an essential task to be able to work on data and to extract meaningful information from it. The denoising process is complex and it does lead to different level of quality of the data depending on the method used, the quality of the data and the type of artifact.

There are several challenges [2] related both to single methods characteristic and general artifact removal. For example, some methods are computationally expensive and require a lot of time to be applied, some methods are not able to remove all kind of artifacts, some methods require a lot of data to be applied. On a general level, there is the problem of the lack of a standard method to evaluate the quality of the denoised data and the EEG applications are not yet fully commercial, so there hasn't been a sufficient investment in hardware and software to make the denoising process easier.

However the main goal of latest studies is to find a method that can denoise from all kind of artifacts and that can be used in a flexible and fast way, to accomodate the needs of all the different EEG applications.



## Chapter 2

# Literature review

2.1 Signal analysis

2.2 EEG denoising

2.3 Machine learning



## Chapter 3

# Methodology

3.1 Data

3.2 Preprocessing

3.3 Denoising

3.4 Machine learning





## Chapter 4

# Experimental results

### 4.1 Results

### 4.2 Discussion



## Chapter 5

# Conclusions and future work

### 5.1 Conclusions

### 5.2 Future work



## Chapter 6

# Bibliography



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Chapter 7

Appendix