Universität Rostock

Traditio et Innovatio

Masterproject on the subject of

Artificial intelligence framework for Human Activity Recognition using EEG Signals

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Abstract

In the realm of Human Activity Recognition (HAR), Electroencephalography (EEG) signals have been underutilized due to susceptibility to non-cerebral noise and variations in magnitude attributed to individual physiological differences. To combat this challenge, this project introduces a novel deep learning-based framework named FCEA (EEG Artifact Classification) tailored to identify and classify EEG artifacts linked to a person's physiological activity.

FCEA presents a unique processing pipeline employing a blend of Convolutional Neural Network (CNN) and Long Short-Term Memory Recurrent Neural Network (LSTM) to categorize raw EEG signals based on their associated artifacts. To evaluate the efficacy of FCEA, a specialized 3-class EEG activity dataset was curated. Data collection involved the use of a consumer-grade EEG wearable device recording from two prefrontal EEG channels across 8 participants engaged in activities such as speaking loudly, reading printed text, and watching TV programs. These activities encompass nuanced movements like jaw-clenching and head/eye movements, often part of everyday activities, challenging for traditional HAR sensory technologies to detect.

Comparative performance analysis reveals that the 1- and 2-channel models trained via FCEA surpass existing state-of-the-art deep learning models in both HAR and raw EEG data processing. The FCEA's deep learning approach significantly enhances raw data processing, leading to superior generalization performance and promising implications for advancing EEG-based HAR systems."

Introduction

Human Activity Recognition (HAR) systems have traditionally used various sensors like cameras and accelerometers to detect user movements automatically. However, there's been growing interest in using biosensors like EEG to understand brain activity related to movements and actions.

Wireless EEG devices, which detect brain activity through electrodes on the scalp, have shown promise in areas like healthcare and Human-Computer Interaction (HCI). Despite their potential, they haven't been extensively utilized in HAR systems, partly due to challenges in detecting facial muscle-related EEG signals and processing such data.

Machine Learning (ML) has significantly improved activity recognition from sensor data. Deep Learning (DL) techniques, especially Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks, have shown success in HAR using various sensor data.

This paper introduces a framework called FCEA (EEG Artifact Classification) designed specifically to detect EEG artifacts related to facial activities. It utilizes a dataset recorded from prefrontal EEG channels, capturing activities like reading, speaking, and watching TV. We compare FCEA-trained models against existing DL approaches for EEG and HAR classification.

This research aims to:

1. Improve EEG artifact classification using a CNN-LSTM combination, enhancing performance while reducing network complexity and training time.

2. Highlight the potential of consumer-grade EEG devices in advancing HAR by leveraging facial activity data.

3. Investigate daily human activities generating EEG artifacts not easily captured by traditional sensors used in HAR systems.

The paper's structure includes a review of related work, details about the proposed framework, methodology used for evaluation, results, implications, and conclusions.

Chapter 1

EEG Preprocessing

- Describe the preprocessing steps involved in preparing EEG data for analysis
- Emphasize the importance of artifact removal, signal filtering, and normalization techniques
- Discuss the challenges and techniques for handling inter-subject variability in EEG data

Chapter 2

Datasets for EEG-based HAR(Human activity recognition)

Describe the dataset used for the project, including its characteristics, sampling rate, and activity categories.

Explain the data preprocessing steps, such as artifact removal, bandpass filtering, and signal normalization.

Discuss the rationale behind the chosen preprocessing methods and their impact on HAR performance.

Chapter 3

Feature Extraction

Chapter 4

Deep Learning Architectures for HAR

- Present different deep learning architectures commonly used in EEG-based HAR: Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Long Short-Term Memory (LSTM) networks
- Explain the principles and applications of each architecture for capturing temporal and spatial patterns in EEG signals
- Discuss the advantages and limitations of each architecture in the context of HAR

Chapter 5

Evaluation Methods

Introduce various evaluation metrics used to assess the performance of HAR models.

Discuss the importance of considering both accuracy and real-time processing capabilities in evaluating HAR systems.

Emphasize the need for cross-validation and generalizability studies when evaluating HAR models on different datasets.

Chapter 6

Case Studies

Present two or three case studies that demonstrate the application of deep learning-based EEG HAR in real-world scenarios.

For each case study, describe the specific HAR task, the dataset used, the deep learning model employed, and the achieved performance.

Discuss the challenges and limitations encountered in each case study and highlight the potential benefits of EEG-based HAR for these applications.

Chapter 7

Future Directions

Identify future research directions for enhancing the accuracy and robustness of deep learning-based EEG HAR systems.

Propose new deep learning architectures and feature extraction techniques tailored for EEG HAR tasks.

Explore the integration of EEG-based HAR with other sensing modalities for enhanced human-computer interaction and healthcare applications.

Chapter 8

Conclusion

Summarize the key findings of the project and discuss the overall contribution to the field of EEG-based HAR.

Emphasize the potential of deep learning for overcoming the challenges of EEG HAR and enabling more accurate and reliable recognition of human activities.

Highlight the promising future of EEG-based HAR in various application domains, such as rehabilitation, mental health assessment, and brain-computer interfaces. [SCG20]

List of Figures

Bibliography

[SCG20] Amirsaleh Salehzadeh, Andre P. Calitz, and Jean Greyling. “Human activity recognition using deep electroencephalography learning”. In: *Biomedical Signal Processing and Control* 62 (2020), p. 102094. ISSN: 1746-8094. DOI: https://doi.org/10.1016/j.bspc.2020.102094. URL: https://www.sciencedirect.com/science/article/pii/S1746809420302500 (cit. on p. 15).

Erklärung

Hiermit erkläre ich, dass ich die vorliegende Masterarbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

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Die Arbeit ist noch nicht veröffentlicht und ist in ähnlicher oder gleicher Weise noch nicht als Prüfungsleistung zur Anerkennung oder Bewertung vorgelegt worden.

Rostock, den December 10, 2023