Aligning EEG Montages for Multichannel Artifact Removal Models

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Introduction

Background

Electroencephalography (EEG) has been widely used to study brain activity in static environments like shielded rooms. However, recent advancements in neuroscience emphasize the importance of mobile brain and body imaging (MOBI), which allows researchers to explore brain dynamics during real-world activities (Figure 1A). This shift expands research possibilities but also introduces new challenges, particularly the need for effective preprocessing techniques to handle artifact contamination caused by motion and environmental noise (Figure 1B).

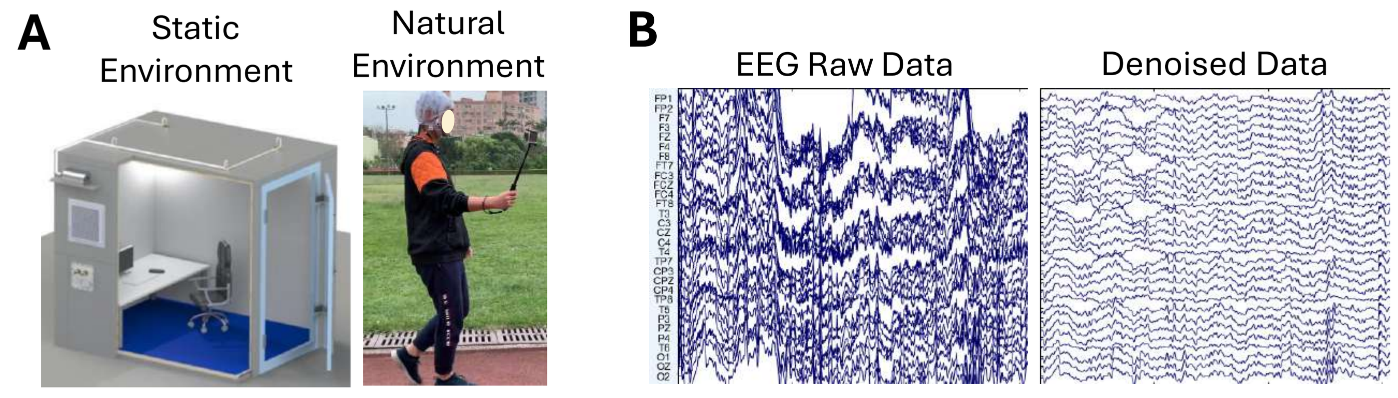

Figure 1. Transition from static to mobile EEG setups and the importance of artifact removal.

Artifact Removal and Its Limitations

Deep-learning methods, such as 1D-ResCNN, GCTNet, and DuoCL, have been developed to suppress artifacts in EEG recordings. However, these methods process channels independently, overlooking spatial relationships between electrodes. More recent approaches, such as Artifact Removal Transformer (ART)[1] and IC-U-Net[2], process multiple channels simultaneously while accounting for spatial configurations. However, these methods require input data to follow a specific montage layout matching their training setup. As shown in Figure 2, EEG devices often differ in electrode configurations, creating a compatibility challenge that typically requires manual channel mapping—a time-consuming and error-susceptible process, highlighting the need for automated solutions.

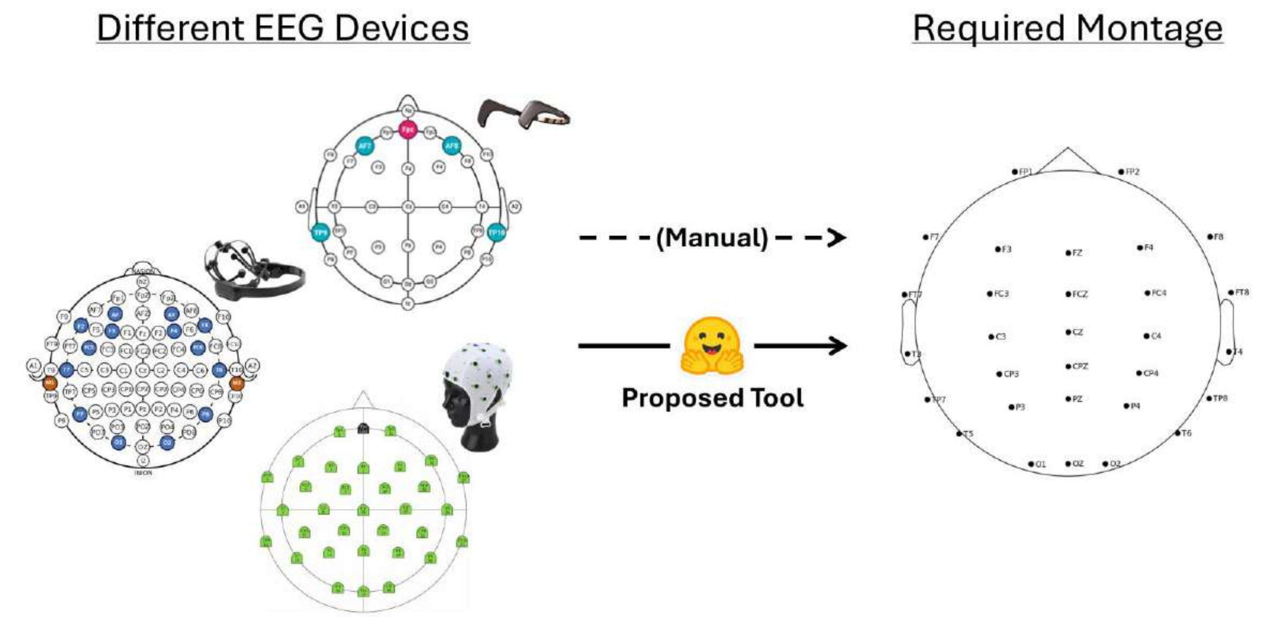

Figure 2. Mapping EEG channels from various device layouts to the required configuration.

Proposed solution

To overcome these challenges, we developed a semi-automated EEG channel mapping tool, accessible on Hugging Face, to eliminate the need for manual mapping and simplify preprocessing workflows (Figure 2).

Key features of the tool:

- **User-friendly interface** – Intuitive design for quick and easy operation.
- **Interactive mapping workflow** – Combines automatic matching, manual adjustments, and visual guidance through each step.
- **Compatible with ART and IC-U-Net** – Easily integrates with preprocessing pipelines of ART and IC-U-Net.

Methods

The proposed tool consists of a three-step pipeline designed to align input montages to a specified template (Figure 3):

Step 1: Channel Matching and Scale Alignment

- Match input channels to template channels by their names.
- Use thin plate spline (TPS) interpolation to align the spatial scales between the input and template montages.

Step 2: Handling Unmatched Channels

- Identify template positions that remain empty.
- Allow users to forward unmatched channels into empty positions.

Step 3: Filling Empty Template Positions

Ensure all positions have valid values using one of the following methods:

- Mean Method: Fill empty positions with the average values of selected channels. (default: 4 nearest channels).
- Zero Method: Fill empty positions with zeros.

This process forms a primary group of channels, ensuring alignment with the required template layout.

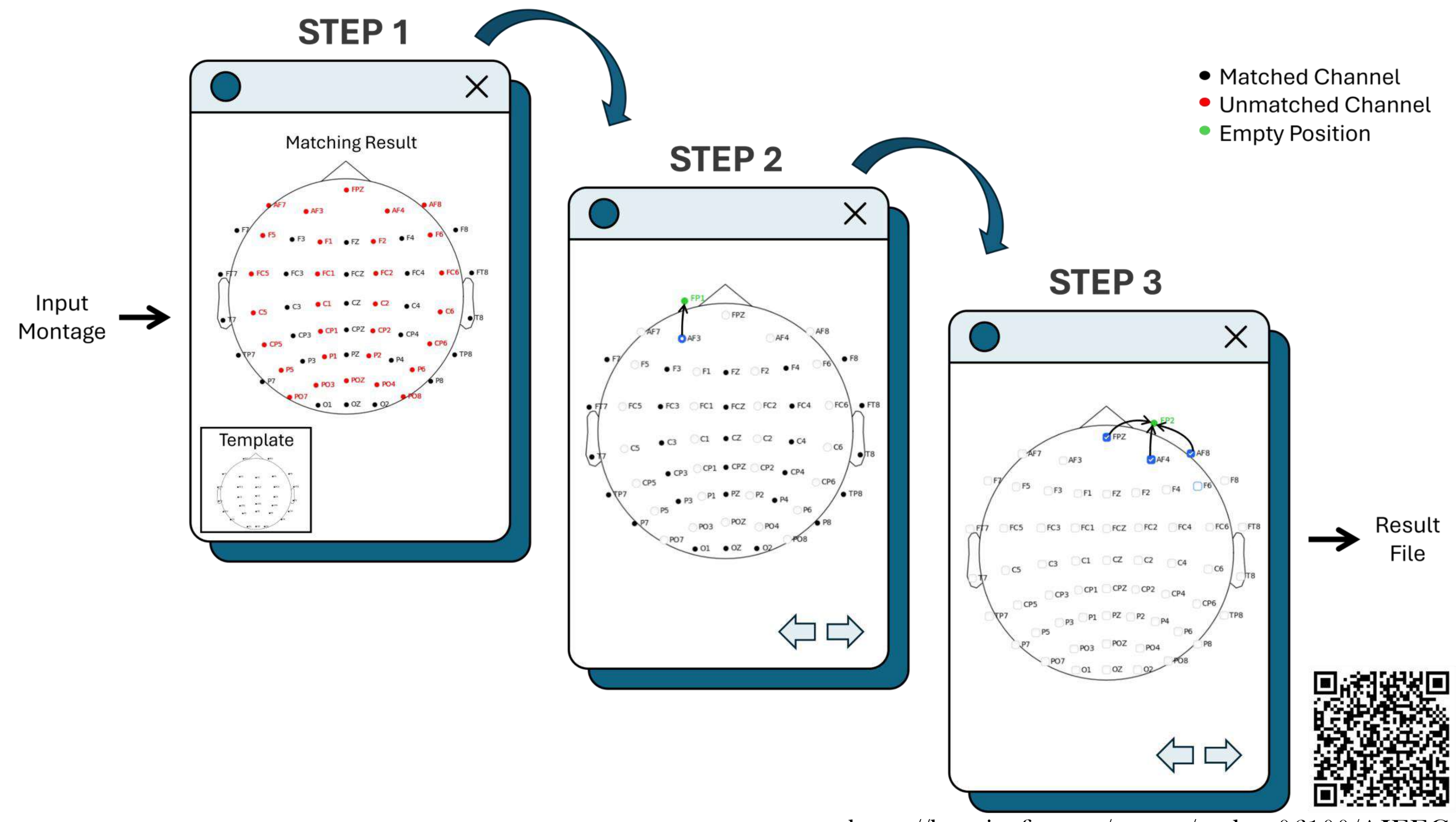

Figure 3. Illustration of the three-step channel mapping workflow.

Subsequent Groups and Final Output

- Any remaining unmapped channels will be automatically grouped and aligned to the template.
- The mapping result file will then be generated. This file can be incorporated into the preprocessing pipeline, ensuring aligned data ready for artifact removal.

Results

- Supports a wide variety of EEG montages.
- Successfully integrated with ART and IC-U-Net.
- Reduces channel mapping time and effort.

Discussion

Current Limitations

One limitation of this tool is that it requires at least two matched channels in Step 1 for TPS interpolation, which may restrict its use with datasets lacking sufficient matches.

Effect of Filling Strategies

The method used to fill empty positions in Step 3 may affect the performance of the models. Further investigation is needed to assess the impact of different filling strategies on model behavior.

Conclusion

We developed a semi-automated EEG channel mapping tool to simplify montage alignment for artifact removal tasks. With its user-friendly interface, the tool enable researchers to efficiently adapt montage layouts to meet model-specific requirements. Successfully integrated with ART and IC-U-Net, it has demonstrated practical utility in addressing montage compatibility challenges commonly encountered in EEG signal processing. While initially designed for artifact removal, the tool may also support other EEG research tasks, offering potential for broader applications.

References

1 Chuang, C.-H., Chang, K.-Y., Huang, C.-S. & Bessas, A.-M. ART: Artifact Removal Transformer for Reconstructing Noise-Free Multichannel Electroencephalographic Signals. *arXiv preprint arXiv:2409.07326* (2024).

2 Chuang, C.-H., Chang, K.-Y., Huang, C.-S. & Jung, T.-P. IC-U-Net: A U-Net-based Denoising Autoencoder Using Mixtures of Independent Components for Automatic EEG Artifact Removal. *NeuroImage* 263, 119586 (2022).

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