# Convolutional Transformer Network for Motor Imagery Finger Classification in EEG-Based BCI

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## INTRODUCTION

Brain-computer interface (BCI), which decode neural signals such as electroencephalograph (EEG), provides a direct communication bridge between human brain and external devices. Motor imagery (MI) relies on the mental simulation of motor actions without actual physical execution. MI-BCI enable control of external devices through imagined movements and demonstrated significant potential in neurorehabilitation for stroke patients and robotics control. However, the reliable classification of fine motor tasks, such as differentiating individual finger movements within the same hand, remains highly challenging due to overlapping regions in the sensorimotor cortex. This overlap complicates their differentiation from noninvasive recordings and often results in low classification accuracy. To address this, we propose a convolutional neural network–based method to improve the discrimination between thumb and little finger movements.

## MATERIALS AND METHODS

### Dataset

In this study we used EEG-BCI Dataset for Real-time Robotic Hand Control at Individual Finger Level [1] from Carnegie Mellon University, which contains 128-channel EEG signals from 21 subjects recorded at 1024 Hz during finger motor tasks.

### Proposed Model Architecture

In this paper, we applied a convolutional neural network to extracting local and spatial features from EEG time series followed by Transformer module [2] to capture the global dependencies of EEG's high-level features (Figure 1). We applied this approach to enhance the discrimination between thumb and little finger movements.

### Training and Evaluation

The method was evaluated subject-specific, with each subject's data split into 80% for training and 20% for testing. Implementation was in PyTorch, and performance was measured using Accuracy and Cohen's Kappa metrics.

## RESULTS AND DISCUSSION

The performance of the proposed CNN–Transformer network was evaluated and compared with a CNN-only model for discrimination between thumb and little finger movements. As shown in Table 1, the CNN–Transformer achieved a higher mean accuracy of 0.8384, compared to 0.8233 for the CNN-only model. Furthermore, the CNN–Transformer demonstrated better agreement and more reliable classification of finger movements improvement in Cohen's Kappa score (0.676 vs. 0.646).

## CONCLUSIONS

In this paper we proposed a CNN-Transformer model that outperforms standard CNNs in classifying finger movements from EEG. These results suggest that integrating the Transformer module enhances the network's ability to capture global dependencies in EEG features, thereby improving classification performance.

## REFERENCES

[1] Ding Y et al. *J Nat Commun. 16:5401*, 2025.
[2] Zhao W et al. *J Scientific Reports 14, 20237*, 2024.

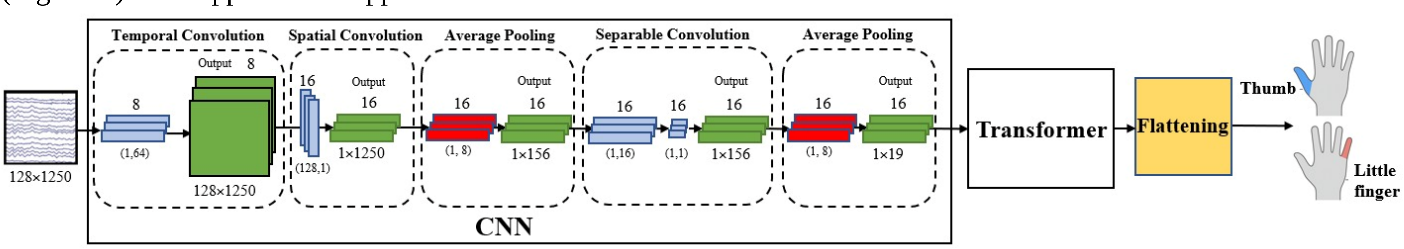


**Figure 1.** Proposed convolutional-Transformer network architecture for finger movement classification.

**Table 1:** Subject-specific classification accuracy (mean ± std) and Kappa for thumb and little finger classification.

| | Accuracy | Kappa |
|---|---|---|
| CNN | 0.823 ±0.114 | 0.646 ± 0.228 |
| **CNN-Transformer** | **0.838 ±0.107** | **0.676 ± 0.214** |