

NeuroPath: Practically Adopting Motor Imagery Decoding through EEG Signals

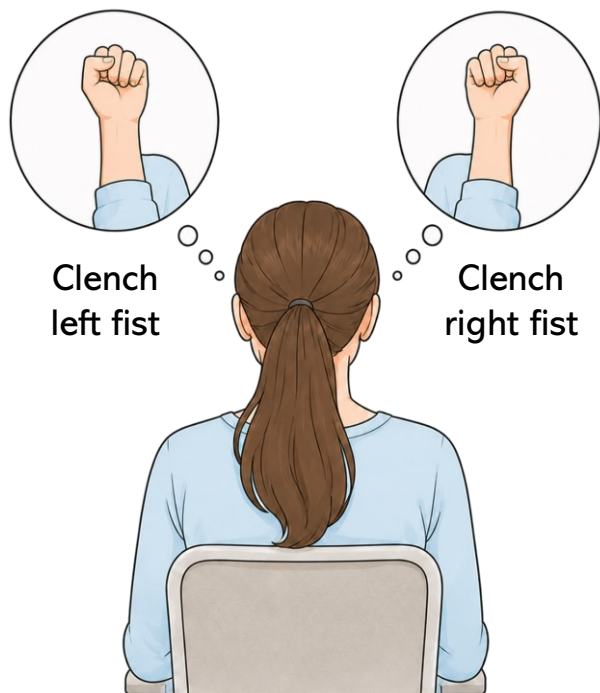
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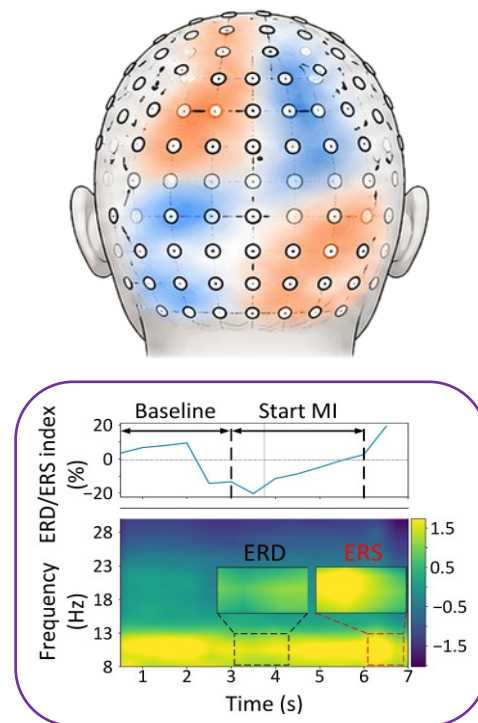
What is Motor Imagery

1 Imagined movement



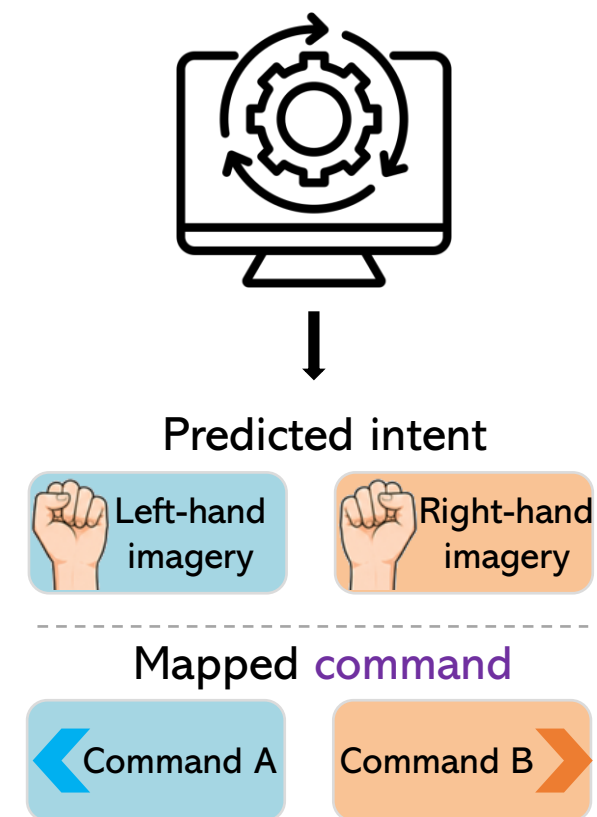
- ✓ Imagine a specific **body-part** movement **without** moving

2 Neural response



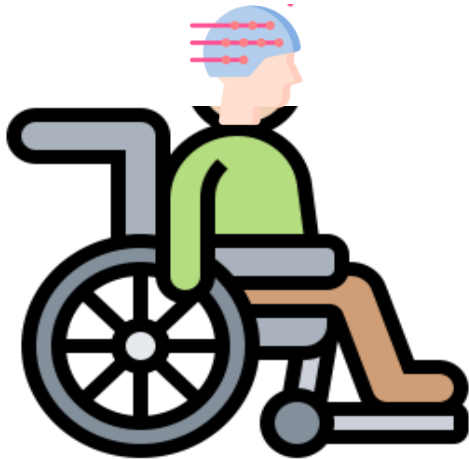
- ✓ Motor-related **patterns**

3 Decoding algorithm



Why Study Motor Imagery

Assistive control



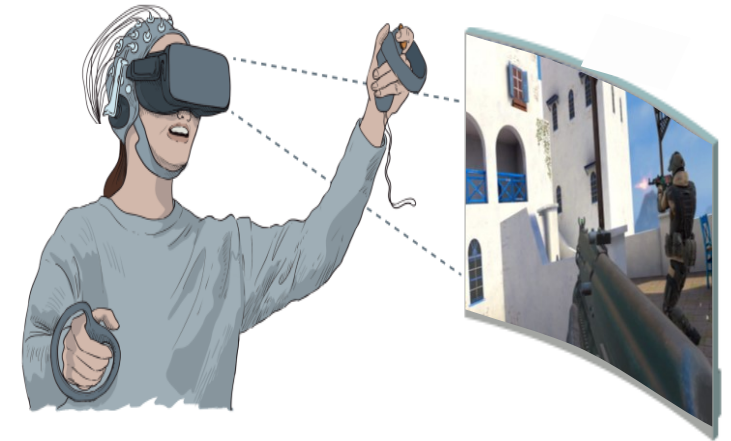
- ✓ Empower independence and daily living

Rehabilitation



- ✓ Support motor recovery and neuroplasticity

Human-computer interaction

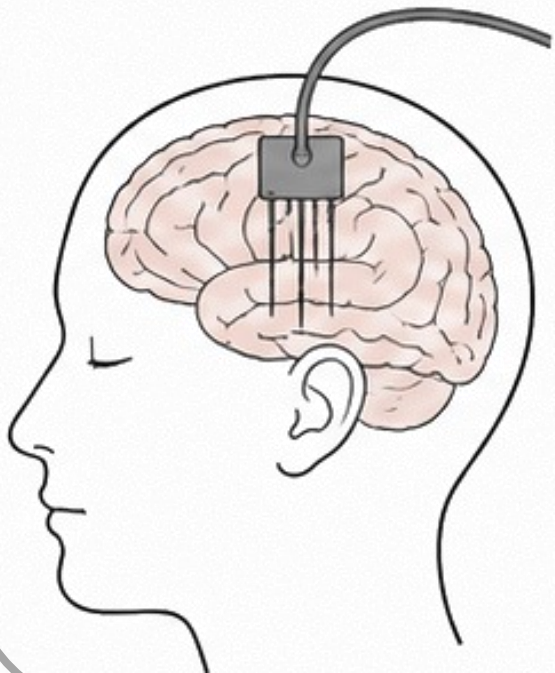


- ✓ Natural, hands-free digital interaction

MI enables **intuitive, hands-free** control.
Users can **express intent** without physical movement.

Existing Solutions

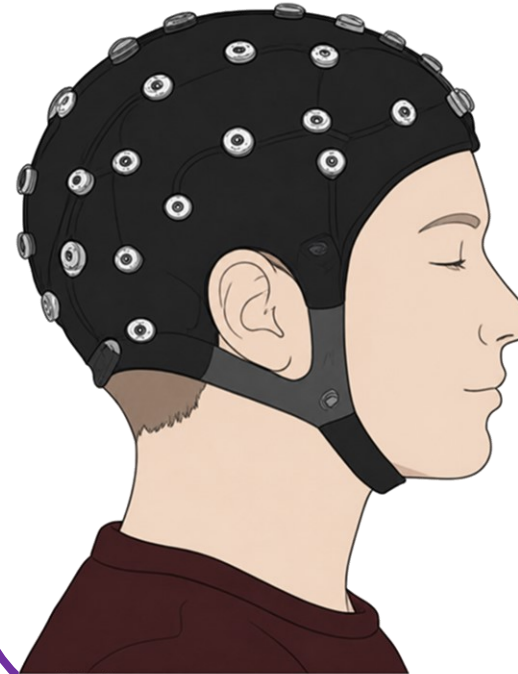
Invasive



- High signal quality
- Requires surgery
- Hard to scale

Our choice

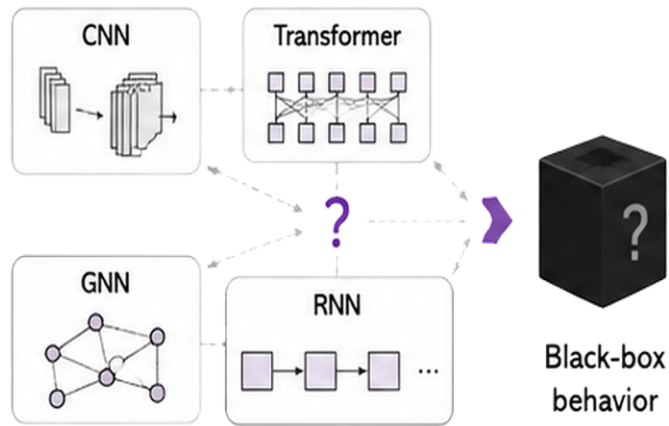
Non-invasive EEG



- Safe and practical
- Low-cost and reusable
- Easy to wear

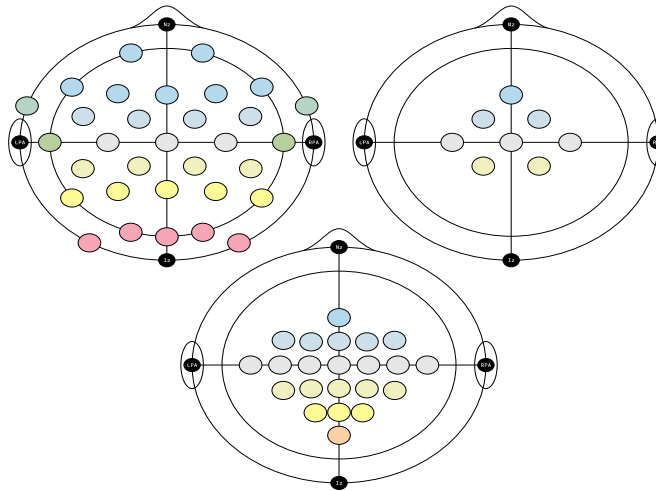
Challenges of Non-invasive EEG

1 Architecture design



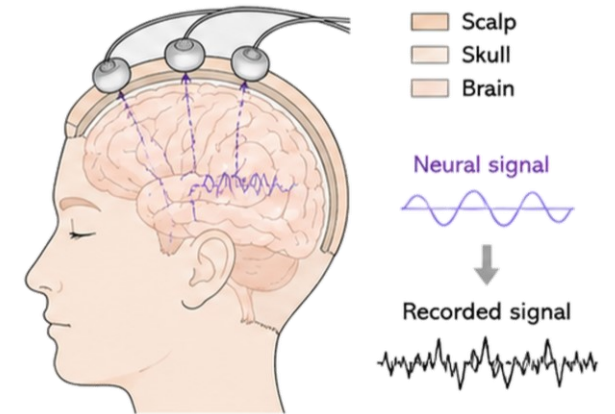
- Many model choices and **variants**.
- Lack of principled **design guidelines**.

2 Electrode variability



- Devices differ in **electrode** number and placement.
- A model trained on one setup may **fail** on another.

3 Low-SNR signals

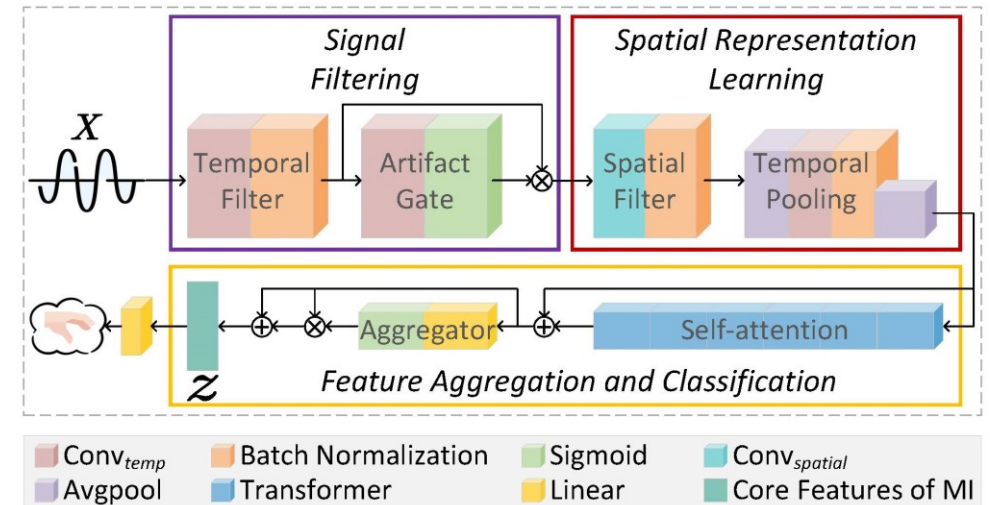
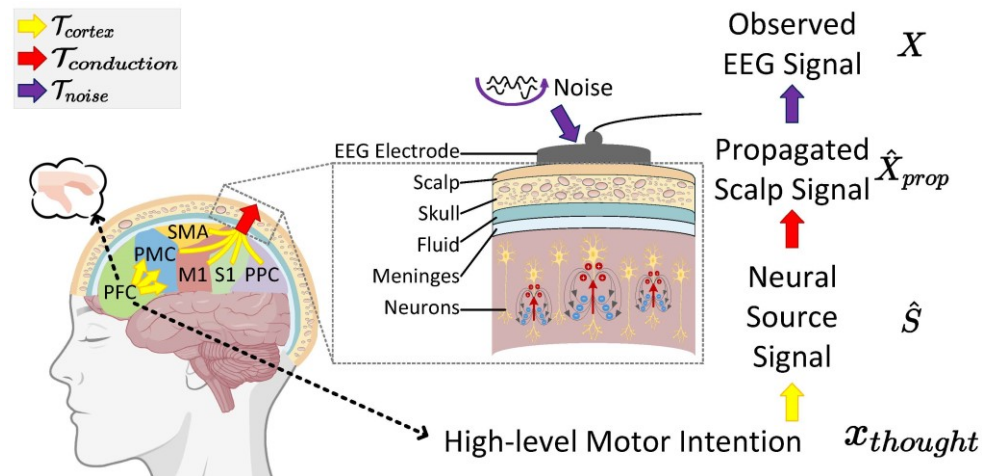


- **Attenuated** and **mixed** by skull/scalp.
- Easily **corrupted** by motion and eye blinks.

Design 1: Brain-inspired MI Decoder

➤ Abstracted signal generation process

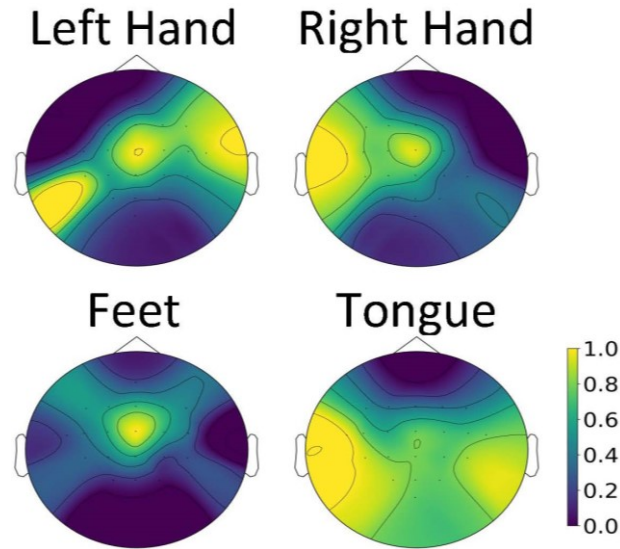
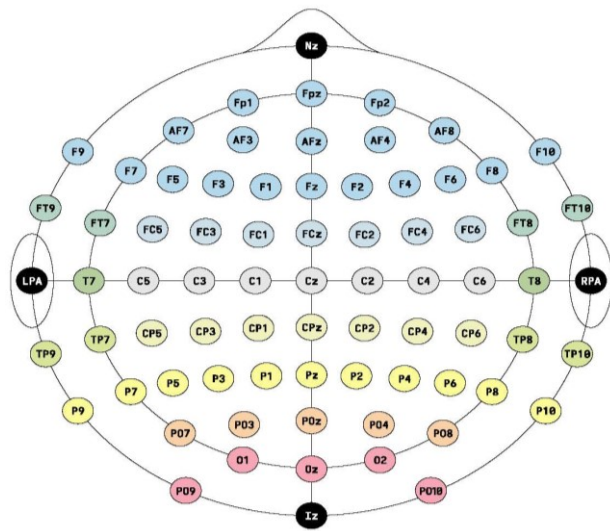
➤ Brain-inspired MI decoder architecture



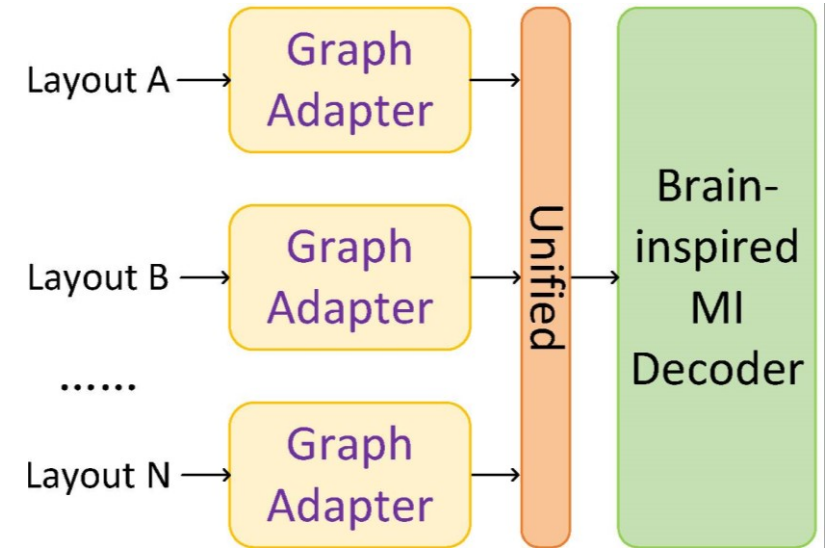
✓ Inspired by **key stages**, not literal biological inversion.

Design 2: Unify Different Electrode Layouts

➤ Two key observations



➤ Design takeaway

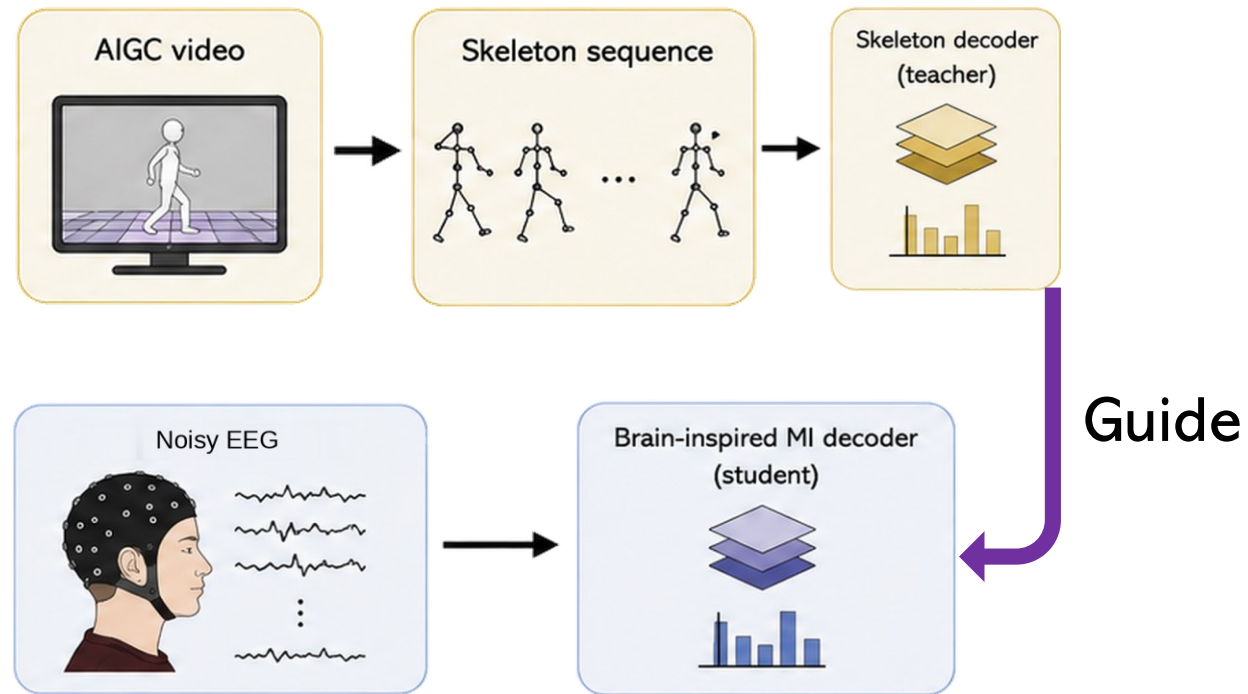


- ✓ Use the 10-10 spatial prior to align layouts and focus on task-relevant channels.
- ✓ This enables one decoder to work across different devices.

Design 3: Cross-modality Knowledge Transfer

- Key idea: let a **clean, low-cost** teacher guide noisy EEG learning

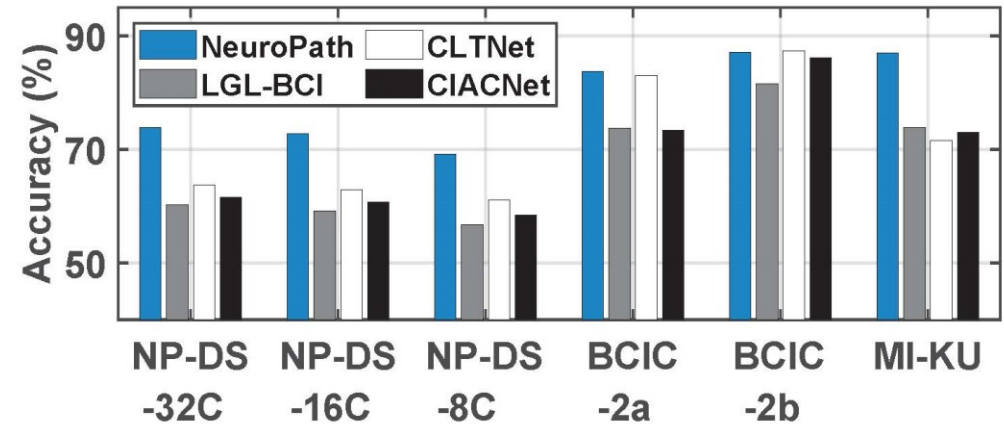
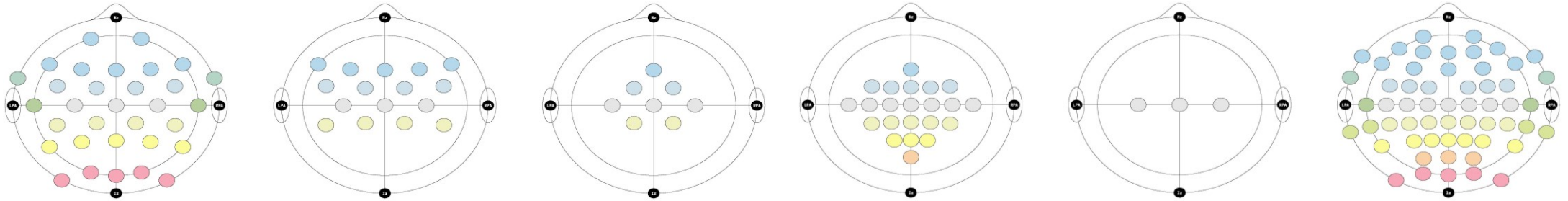
High-quality modality (teacher): automatically generated, no extra sensors



Low-quality modality (student): noisy EEG (inference only needs EEG)

Evaluation

➤ Three public datasets, three self-collected datasets



✓ NeuroPath achieves good performance.

Conclusion 1, 2, 3

1. One goal:

- Practical MI decoding using **non-invasive EEG**

2. Two aspects:

- Adapt to different electrode **layouts**
- Work with **low-SNR EEG**

3. Three modules:

- Brain-inspired MI decoder
- Spatially-aware graph adapter
- Cross-modality knowledge transfer

Thank you
Q&A

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