A classifier for improving cause and effect in SSVEP-based BCIs for individuals with complex communication disorders

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Introduction

- Helping people with complex communication disorders (CCDs) communicate requires establishing cause and effect between the assistive technologies and their users.
- Steady-state visual evoked potentials (SSVEP)-based brain-computer interfaces (BCIs) can help us achieve this goal.
- We present the cumulative sum canonical correlation analysis (CCA\textsubscript{CUSUM}) classifier to improve the cause-and-effect relationship between a user’s behavior and the SSVEP-based BCI.

Methods: MusicBox

- MusicBox: Simple SSVEP-based BCI to help establish cause and effect for CCD individuals.
- User can attend to a flickering stimulus (attend state) or be at rest (rest state).
- Provision auditory feedback if user is in attend state by playing music.

Methods: Conventional Approach

- Conventional Approach: Compares samples with fixed threshold to identify whether a user is in attend or rest state.
- Feature extraction based on canonical correlation analysis (CCA).
- Discard Context → Potential information loss.

CCA\textsubscript{CUSUM}

- \(\text{CCA}\text{\textsubscript{CUSUM}}\): Identifies states by detecting transitions between them.
- Use \(\text{CCA}\text{\textsubscript{CUSUM}}\) with sliding window to extract features from EEG signals.
- Assumption: Normal distribution with parameters \(\theta_0 = (\mu_0, \sigma)\) and \(\theta_1 = (\mu_1, \sigma)\) before/after change.

CCA\textsubscript{CUSUM} • Using hypothesis testing, we obtain two different tests:

\[
g_1^+ = \max \left( \frac{g_{i+1} + r_i - \mu_0 - \nu}{\sigma} \right) \geq h \\
g_1^- = \max \left( \frac{g_{i+1} + r_i - \mu_0 + \nu}{\sigma} \right) \geq h
\]

- \(r_i\): Canonical correlation of \(i\)th sliding window.
- \(\nu = |\mu_1 - \mu_2|\): Magnitude of change.
- \(h\): Fixed threshold.
- \(g_1^+\): Detects positive changes.
- \(g_1^-\): Detects negative changes.
- Learn online model parameters \(\mu_0\) and \(\nu\).

Performance Metric

- Proposed metric \(M\): Measure cause-and-effect relationship between MusicBox and user's behavior.

\[
\begin{align*}
\text{EPOR} &= \frac{1}{l_{\text{ON}}} \times \sum_{k \in \{1+1, \ldots, i+m\}} I_k \times E_k \\
\text{ENOR} &= \frac{1}{l_{\text{OFF}}} \times \sum_{k \in \{1+1, \ldots, i+m\}} I_k \times E_k
\end{align*}
\]

\[
M = \frac{2 \times \text{EPOR} \times \text{ENOR}}{\text{EPOR} + \text{ENOR}}
\]

- \(l_{\text{ON}} / l_{\text{OFF}}\): Length of intervals where the participant was in attend/rest state.

Data and Results

- (right) Conventional method vs CCA\textsubscript{CUSUM} in a single trial experiment.
- Four participants with no CCD.
- Eight EEG channels.
- Multiple trials per participant.

Data and Results (top) Comparing metric \(M\) for CCA\textsubscript{CUSUM} and the conventional method.

Summary

- CCA\textsubscript{CUSUM}: Using change detection to improve cause and effect in BCIs.
- We evaluated CCA\textsubscript{CUSUM} using MusicBox, an SSVEP-based BCI.
- CCA\textsubscript{CUSUM} improved cause and effect when samples were less separable.

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