

Submission ID #: 70425

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Project Page Link: <https://review.jove.com/account/file-uploader?src=21479673>

Title: STFEEG–Tool: A Spatial–Temporal–Frequency EEG Analysis Tool for Motor Imagery Brain–Computer Interfaces

Authors and Affiliations:

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Author Questionnaire

1. Microscopy: Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **No.**

2. Software: Does the part of your protocol being filmed include step-by-step descriptions of software usage? **Yes, all done**

3. Filming location: Will the filming need to take place in multiple locations? **No.**

4. Testimonials (optional): Would you be open to filming two short testimonial statements **live during your JoVE shoot**? These will **not appear in your JoVE video** but may be used in JoVE's promotional materials. **No.**

Current Protocol Length

Number of Steps: 21

Number of Shots: 35

Introduction

Videographer: Obtain headshots for all authors available at the filming location.

Authors: Please note that **the questions will not appear on screen**. Please answer in **stand-alone full sentence with sufficient context**

INTRODUCTION:

~~REQUIRED: Summarize your research focus and the main questions it aims to answer.~~

- 1.1. **Rui Zhang:** This work develops a GUI-based toolbox for fine-grained motor imagery EEG decoding and interpretable spatial-temporal-frequency analysis.
 - 1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

~~Describe the research gap or limitation in existing methods and how this protocol addresses them.~~

- 1.2. **Rui Zhang:** Existing platforms lack integrated fine-grained spatial, temporal, and frequency configuration with intuitive visualization for motor imagery EEG analysis.
 - 1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

CONCLUSION:

~~What does this protocol allow researchers to study or measure?~~

- 1.3. **Rui Zhang:** This protocol enables standardized decoding, quantitative evaluation, and visualization of subject-specific motor imagery EEG patterns.
 - 1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera *Suggested B roll: 3.2.1*

~~Describe the most important consideration or challenge when performing this protocol.~~

- 1.4. **Rui Zhang:** A key challenge is ensuring that preprocessing, classification, and multiscale segmentation remain flexible and practical across different datasets.

- 1.4.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

~~How can future studies build on this work? Describe the questions or research directions that can be investigated next.~~

- 1.5. **Rui Zhang:** This workflow can support interpretable analysis of subject-specific differences and guide development of more adaptive and generalizable MI-EEG decoding models.
 - 1.5.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

Videographer: Obtain headshots for all authors available at the filming location.

Protocol

***Videographer:** Please always record an audio slate while filming each shot mentioned in the shotlist.*

2. Preparation for STFEEG–Tool GUI-Based Motor Imagery -EEG Analysis

Demonstrator: Rui Zhang

- 2.1. To begin, download STFEEG (*S-T-F-E-E-G*)–Tool from the online repository [1]. Unzip the downloaded file to a local folder [2] and locate the installer file STFEEG–Tool.mlappinstall (*S-T-F-E-E-G-Tool-M-Lapp-Install*) in the extracted contents [3].
 - 2.1.1. WIDE: Talent working on the laptop downloading STFEEG–Tool from an online repository on a computer. **TXT: STFEEG: Spatial-Temporal-Frequency EEG**
 - 2.1.2. SCREEN: 70425_screenshot_1.mp4: 00:00-00:08, 00:13-00:15
 - 2.1.3. SCREEN: 70425_screenshot_1.mp4: 00:16-00:19.
- 2.2. Double-click on STFEEG–Tool.mlappinstall to launch the installer and follow the on-screen instructions to complete the installation [1].
 - 2.2.1. SCREEN: 70425_screenshot_1.mp4: 00:27-00:30, 00:36-00:40
 - 2.2.2. Talent downloading the Data.mat file from an online repository.
- 2.3. After downloading the example MAT (*Mat*) file, launch the STFEEG–Tool graphical user interface to open the motor imagery EEG (*E-E-G*) analysis window [1].
 - 2.3.1. SCREEN: 70425_screenshot_1.mp4: 00:42-00:48
- 2.4. In the Data Loading panel, click on **Browser** next to Data Path [1] and select the folder containing the prepared MAT-file [2].
 - 2.4.1. SCREEN: 70425_screenshot_2.mp4: 00:00-00:02
 - 2.4.2. SCREEN: 70425_screenshot_2.mp4: 00:02-00:05
- 2.5. Now, click on **Browser** next to Save Path and select an output folder for results [1]. Click on **Load** in the Data Loading panel to import the MAT-file [2].
 - 2.5.1. SCREEN: 70425_screenshot_2.mp4: 00:05-00:08
 - 2.5.2. SCREEN: 70425_screenshot_2.mp4: 00:08-00:11

3. Configuring the Fine-grained Segmentation Strategy

- 3.1. In the Segmentation Strategy panel of the main graphical user interface, click on **Edit** to open the Segmentation configuration window, where the default parameter settings are already provided [1].

3.1.1. SCREEN: 70425_screenshot_3.mp4: 00:00-00:08

- 3.2. To configure the temporal windows, select the **Temporal Windows** tab in the configuration window [1]. Enter the Start, End, and Interval values to define temporal windows [2]. Then, click on **Add** to append the generated windows to the list [3].

3.2.1. SCREEN: 70425_screenshot_3.mp4: 00:08-00:12

3.2.2. SCREEN: 70425_screenshot_3.mp4: 00:12-00:18

3.2.3. SCREEN: 70425_screenshot_3.mp4: 00:18-00:21

- 3.3. Now, right-click on the corresponding row in the table to remove an existing window. Select **Delete** from the menu to delete the window [1].

3.3.1. SCREEN: 70425_screenshot_3.mp4: 00:21-00:25

- 3.4. To configure filter bank frequency bands, select the **Frequency Bands** tab in the configuration window [1].

3.4.1. SCREEN: 70425_screenshot_3.mp4: 00:30-00:31

- 3.5. Enter the Start, End, and Interval values to define frequency bands [1]. Then, click on **Add** to append the generated bands to the list [2].

3.5.1. SCREEN: 70425_screenshot_3.mp4: 00:34-00:37

3.5.2. SCREEN: 70425_screenshot_3.mp4: 00:37-00:40

- 3.6. Now, right-click on the corresponding row in the table to remove an existing frequency band [1]. Select **Delete** from the menu to delete the band [2].

3.6.1. SCREEN: 70425_screenshot_3.mp4: 00:40-00:41

3.6.2. SCREEN: 70425_screenshot_3.mp4: 00:41-00:42

- 3.7. To configure spatial segmentation by channel groups, select the **Spatial Segmentation** tab in the configuration window [1]. Click on Browser next to Channel Groups to select a channel-group definition MAT-file [2].

3.7.1. SCREEN: 70425_screenshot_3.mp4: 00:47-00:52

3.7.2. SCREEN: 70425_screenshot_3.mp4: 00:52-00:56

- 3.8. Click on **Replace** to load the selected channel-group file and update the Groups of Channel Number list [1]. If a channel-location file has been selected in Channel Location, the tool also loads it for subsequent scalp visualizations [2].

3.8.1. SCREEN: 70425_screenshot_3.mp4: 00:56-00:58

3.8.2. SCREEN: 70425_screenshot_3.mp4: 00:58-01:02

- 3.9. Click on **OK** at the bottom of the Segmentation window to apply the updated temporal windows, frequency bands, and spatial segmentation. The Segmentation Strategy panel of the main graphical user interface is updated accordingly [2].

3.9.1. SCREEN: 70425_screenshot_3.mp4: 01:02-01:10

4. Configuring the Feature Extraction, Classifiers, and Cross-validation

- 4.1. In the Classification Configuration panel, select the feature extraction method from the drop-down menu [1].

4.1.1. SCREEN: 70425_screenshot_4.mp4: 00:00-00:03

- 4.2. Set nCSP (*N-C-S-P*) to retain features from both ends of the feature vector [1]. Then, select the classifiers by checking the corresponding boxes [2].

4.2.1. SCREEN: 70425_screenshot_4.mp4: 00:03-00:06

4.2.2. SCREEN: 70425_screenshot_4.mp4: 00:06-00:08

- 4.3. Set the Selection Bands Number to specify how many fine-grained segments or features are retained in wrapper-based selection [1]. Set Cross-Validation to specify the number of folds for k-fold cross-validation on TrainData (*Train-Data*) and TrainLabel (*Train-Label*) [2].

4.3.1. SCREEN: 70425_screenshot_4.mp4: 00:08-00:14

4.3.2. SCREEN: 70425_screenshot_4.mp4: 00:14-00:18

- 4.4. Then, click on **Cross-Validation** to perform k-fold cross-validation [2].

4.4.1. SCREEN: 70425_screenshot_4.mp4: 00:18-00:21

- 4.5. Review the performance summary displayed in the Results panel [1].

4.5.1. SCREEN: 70425_screenshot_5.mp4: 00:00-00:06

- 4.6. Review the time-frequency topographical map to identify discriminative patterns across time, frequency, and scalp regions [1]. Review the electrode group significance map to identify channel groups that contribute most to decoding [2].

4.6.1. SCREEN: 70425_screenshot_5.mp4: 00:07-00:11

4.6.2. SCREEN: 70425_screenshot_5.mp4: 00:11-00:13

Results

5. Results

5.1. The time–frequency topographical map illustrated the spatial distribution of discriminative EEG patterns across frequency and temporal segments [1].

5.1.1. LAB MEDIA: Figure 8. *Video editor: Highlight the colored grid labeled “Time-Frequency Topographical Map” in the lower left of the results panel*

5.2. The Electrode Group Significance Map quantified the contribution of predefined electrode groups to decoding performance [1].

5.2.1. LAB MEDIA: Figure 8. *Video editor: Highlight the panel labeled “Electrode Group Significance Map” in the lower right showing the grouped circular layouts*

1. STFEED
Pronunciation link: No confirmed link found
IPA: /,es ti: ef i: i: dʒi:/
Phonetic Spelling: es·tee·ef·ee·ee·jee
2. Electroencephalography (EEG)
Pronunciation link: <https://www.merriam-webster.com/dictionary/electroencephalography>
IPA: /ɪˌlɛk.troʊ.ɛnˌsɛf.əˈlɑː.grə.fɪ/
Phonetic Spelling: ih·lek·troh·en·sef·uh·laa·gruh·fee
3. Graphical
Pronunciation link: <https://www.merriam-webster.com/dictionary/graphical>
IPA: /ˈɡræf.i.kəl/
Phonetic Spelling: graf·ih·kuhl
4. Segmentation
Pronunciation link: <https://www.merriam-webster.com/dictionary/segmentation>
IPA: /,sɛɡ.mənˈteɪ.ʃən/
Phonetic Spelling: seg·muhn·tay·shuhn
5. Temporal
Pronunciation link: <https://www.merriam-webster.com/dictionary/temporal>
IPA: /ˈtɛm.pə.rəl/
Phonetic Spelling: tem·puh·ruhl
6. Frequency
Pronunciation link: <https://www.merriam-webster.com/dictionary/frequency>
IPA: /ˈfriː.kwən.si/
Phonetic Spelling: free·kwuhn·see
7. Spatial
Pronunciation link: <https://www.merriam-webster.com/dictionary/spatial>
IPA: /ˈspeɪ.ʃəl/
Phonetic Spelling: spay·shuhl
8. Classifier
Pronunciation link: <https://www.merriam-webster.com/dictionary/classifier>
IPA: /ˈklæs.əˈfaɪ.ər/
Phonetic Spelling: klas·uh·fai·er
9. Cross-validation
Pronunciation link: <https://www.merriam-webster.com/dictionary/cross-validation>
IPA: /,krɒsˌvæl.əˈdeɪ.ʃən/
Phonetic Spelling: kraws·val·uh·day·shuhn
10. Topographical
Pronunciation link: <https://www.merriam-webster.com/dictionary/topographical>
IPA: /,tɑː.pəˈɡræf.i.kəl/
Phonetic Spelling: taa·puh·graf·ih·kuhl
11. Electrode
Pronunciation link: <https://www.merriam-webster.com/dictionary/electrode>
IPA: /ɪˌlɛk.troʊd/
Phonetic Spelling: ih·lek·trohd

12. Discriminative

Pronunciation link: <https://www.merriam-webster.com/dictionary/discriminative>

IPA: /dɪˈskrɪm.ə.nə.tɪv/

Phonetic Spelling: dih·skrim·uh·nuh·tiv

13. Imagery

Pronunciation link: <https://www.merriam-webster.com/dictionary/imagery>

IPA: /ˈɪm.ɪ.dʒəri/

Phonetic Spelling: im·uh·juh·ree

14. Parameter

Pronunciation link: <https://www.merriam-webster.com/dictionary/parameter>

IPA: /pəˈræm.ə.tər/

Phonetic Spelling: puh·ram·uh·ter