

# eBridge Tutorial



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## **1: Background on Electrical Bridging**

### *A. Electrical bridges*

An electrical bridge occurs when two EEG electrodes are joined together by a low-impedance electrical connection (Tenke and Kayser, 2001). A bridge can be caused by a fault in the EEG hardware (e.g., problem with a connector, two bare wires touching, etc.) or, more commonly, by excessive use of electrolyte, causing the gel or liquid from neighboring channels to touch (Greischar et al., 2004; Tenke and Kayser, 2001).

When EEG electrodes are electrically bridged, the information in their respective channels will be nearly identical, distorting the EEG topography. Unfortunately, electrical bridging is not readily apparent when viewing continuous, epoched, or averaged data, even for a limited number of EEG channels.

In a systematic survey of publicly-available EEG data sets (Alschuler et al., 2013), channels were identified as bridged in 3 out of the 5 tested datasets. For 2 of those 3 datasets, bridged channels were identified in 75% or more of sessions. Furthermore, up to 50% of the electrodes in the montage were bridged in some sessions.

### *B. Identifying bridged channels*

The only reliable methods in the literature for finding bridged electrodes rely on pairwise comparisons between channels to find those whose signals are nearly identical. This can be accomplished by graphically superimposing two EEG/ERP waveforms. However, this requires considerable scrutiny and diligence on the part of the researcher as well as the willingness to invest the considerable extra time, especially as the number of channels increases. Unsystematic inspections using this approach, while faster and easier, may miss bridged electrodes. However, a direct visual comparison can be replaced by a systematic numerical approach based on the temporal variance of pairwise differences between waveforms recorded at each electrode in a montage.

A potential difference waveform is defined as the difference between the time-varying potentials  $P$  of channels  $i$  and  $j$ , computed as:

$$P_{i-j}(t) = P_i(t) - P_j(t)$$

Because any two channels that are electrically bridged will have near-identical waveforms, bridged channels can be identified as those pairs with low-amplitude difference waveforms. The overall amplitude of a difference waveform can be quantified by its variance over time  $T$  (temporal variance; Tenke and Kayser, 2001; Neuroscan Inc., 1993; 1995), defined as:

$$ED_{ij} = \frac{1}{T} \sum_{t=1}^T (P_{i-j}(t) - \overline{P_{i-j}(t)})^2$$

*eBridge.m* uses the algorithm outlined in Alschuler et al. (2013), employing electrical distance frequency distributions to identify bridged channels.

The continuous EEG data are first epoched, resulting in a channels x epochs x sample points MATLAB matrix. A channels x channels x epochs ED matrix is then computed from the epoched data, and each ED value in the matrix is multiplied by a scale factor (100 / median ED value). The set of EDs is summarized by its frequency distribution and, in order to improve reliability and resolution, the distribution is interpolated to a bin size of .05.

 [Enlarge figure](#)

Annotated ED frequency distributions (0-10)

Please note the near-zero local peak (LP) evident in the above distribution with 6 bridged channels. Such local peaks are confined almost exclusively to sessions with bridging, and accurately represent the extremely low EDs of bridged pairs of channels. The algorithm accordingly determines the presence of a near-zero local peak ( $ED \leq 3$ ). If no such peak exists, no channels are flagged as bridged. If a peak exists, the local minimum (LM) with an  $ED \leq 5$  following the peak is automatically identified and set as the ED cutoff. If 50% or more of all epochs for any given pair of channels are less than or equal to this ED cutoff, both channels are classified as bridged.

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## 2: Using *eBridge.m*

This section of the tutorial was written for MATLAB v7.10.0 (R2010a) and EEGLAB v11.0.3.1b. However, the instructions should still apply, albeit with slight modifications, if you have a different version of MATLAB or EEGLAB.

### A. Getting started

MATLAB must be installed. For some of the additional *eBridge* options to be available, the Signal Processing Toolbox must also be installed (a toolbox can be added to an existing MATLAB installation using the MATLAB installer). EEGLAB must also have been downloaded and added to the MATLAB search path (in MATLAB, select File >> Set Path >> Add with Subfolders, then select the EEGLAB folder).

To begin, download [eBridge.m](#) and the [eBridge.cnt](#) sample EEG file (make sure that *eBridge.m* is in a folder in the MATLAB search path). Continue by opening MATLAB; then enter

```
>> eeglab
```

### B. Importing data

The NeuroScan format file *eBridge.cnt* is included with the software as an example of continuous EEG data. To import it with the EEGLAB GUI, go to the EEGLAB window, then select File >> Import data >> Using EEGLAB functions and plugins >> From Neuroscan .cnt file. Select *eBridge.cnt* and click “Open”. When the “Load a CNT dataset” and “Dataset info” windows pop up, just click “Ok” for each. The EEG data will now be imported into MATLAB as the data structure named “EEG”.

Alternatively, you can import the file using the `pop_loadcnt` function on the command line. For more information, just enter

```
>> help pop_loadcnt
```

### C. Running *eBridge*

To test the data with *eBridge.m*, enter

```
>> EB = eBridge(EEG);
```

This will run the *eBridge* function with the “EEG” data structure that you just imported. Information about identified bridges will appear in the command window, but will also be stored in the EB structure.

### D. *eBridge* screen output

The following messages will appear as *eBridge.m* runs:

>> eBridge: Configuring inputs.

This message indicates that the function is checking and assigning input variables and flags.

>> eBridge: Epoch length set to XXX sample points. YYYY epochs extracted.

The function has now extracted YYYY epochs, each composed of XXX sample points.

>> eBridge: Computing EDs for xx/XX chans, YYYY epochs, and ZZ points/epoch.

The function is computing the electrical distances.

>> eBridge: Creating ED frequency distribution and finding bridged channels.

The function is creating a frequency distribution and finding the bridged channels, as described above.

>> eBridge: Number of bridged channels: #

The total number of channels flagged as bridged (6 for eBridge.cnt).

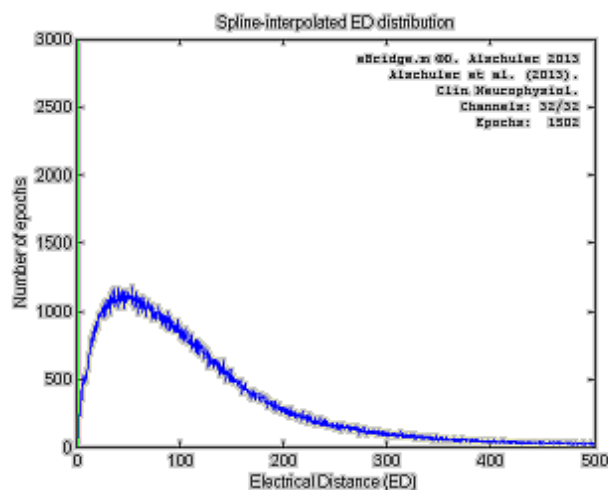
>> eBridge: Bridged channel labels: Label1 Label2 ... LabelN

The labels of the bridged channels (PO7 PO3 IZ I1 I2 PO9 for eBridge.cnt).

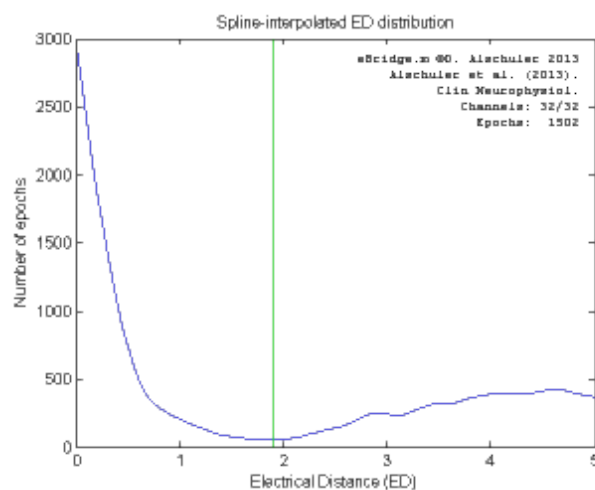
>> eBridge: Bridged channel pairs: (Pair1a,Pair1b) (Pair2a,Pair2b) ... (PairNa,PairNb)

This message will appear if 'Verbose' is set to 2 (see additional help). It indicates which pairs of channels were near-identical ((PO7,PO3) (IZ,I2) (I1,PO9) for eBridge.cnt) .

A plot of the ED distribution will also appear.



ED distribution plot (0-500)



ED distribution plot (0-5)

To zoom in on the early local peak and local min, you can change the x-axis limits from 0-500 to 0-5. Just enter

>> set(gca,'XLim',[0 5]);

For more information on the output variables, additional options, and methods to improve the accuracy and speed of *eBridge.m*, please see the in-function help. The help is available by entering

>> help eBridge

Additional, more-detailed help is available by entering

>> eBridge /?

or

>> eBridge /h

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### 3. Preventing and Addressing Electrical Bridges


As a general rule, using as little electrolyte as possible for the scalp-sensor interface will minimize the risk of bridges between electrodes, provided that a sufficient (i.e., low impedance) contact to scalp has been established. While it is commonly assumed that more electrolyte (i.e., electrode gel) will yield better scalp contact, only a small amount placed in the space directly beneath the electrode is actually needed. For our 72-channel Biosemi system, we have found that 10 to 20 mL of SignaGel electrolyte is optimal for subjects with little to no hair or long, thick hair, respectively, although this may differ between recording systems and types of electrolyte. In practice, since it is impossible to undo an electrolyte bridge between two sites, it is usually advisable to use less electrolyte at the start of the cap setup. For sites with high impedances, the scalp can be gently abraded at the electrode site (Kappenmann and Luck, 2010), and more electrolyte can be added only if necessary. Amplifier and electrode cables, plugs, and connectors should also be checked to make sure that there are no physical shorts between or within the wires.

Bridged electrodes can be addressed after recording by excluding affected channels or averages or by interpolating the data of bridged channels if warranted by the EEG montage (i.e., if there is a sufficient number of artifact-free channels).

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### 4: References

 Alschuler, D.M., Tenke, C.E., Brudge, G.E., Kayser, J. (2014). *Clinical Neurophysiology*, 125(3), 484-490.  
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Greischar L.L., Burghy C.A., van Reekum C.M., Jackson D.C., Pizzagalli D.A., Mueller C., Davidson R.J. (2004). Effects of electrode density and electrolyte spreading in dense array electroencephalographic recording. *Clinical Neurophysiology*, 115(3), 710-720.

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