CSDplotter user guide

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Please report bugs and direct comments or suggestions for future versions to klas.pettersen@umb.no.

Overview

These programs are developed to plot current source density (CSD), using an inuitive graphical user interface. The CSD methods used are the standard CSD method and the inverse CSD (iCSD) methods described in [1] (preprint at http://arken.umb.no/compneuro/extracellular.html). This user guide is meant to explain how to use the programs, it is not this manuals intention to explain the methods.

The program is completely based on a graphical user interface, thus knowledge of the underlying functions is not needed. All parameters given in the standard CSD method and the iCSD methods are easily edited through the graphical user interface, and different spatial filters can be interpreted to reduce spatial noise. When the desired plots are produced, they can be exported to standard *matlab* figures for further post-processing and saving.

The input should be extracellular potential recordings perpendicular to cortex at different cortical depths (typically using laminar electrodes). For matrix organization of these input data, see the section Pre-processing of data below.

Downloading and installation

The programs can be downloaded in a zip file from our web-pages http://arken.umb.no/compneuro/iCSD_download.html . When unzipping the file, a folder called *CSDplotter-x.x.x* should be created, within this folder a *methods* folder should be created and within the *methods* folder a *saved* folder. The *saved* folder is empty, but when running the iCSD methods this folder will be used for storing transformation matrices to save computation time in later sessions.

Pre-processing of data

The potential matrices should contain temporal data in rows, spatial in columns, so that the upper row contain data for the upper electrode contact. The matrices should be saved in mat-files. However, each mat-file may contain several potential matrices . One example file, test_data.mat, is included in the downloadable zip-file as an illustration.

Running the program

Open *matlab* and change directory to the *CSDplotter-x.x.x*. The program is run by calling *CSDplotter* from the *matlab* prompt:

```
>>CSDplotter
```

The main menu

The opening window is the menu shown in illustration 1. In the *CSD methods* field the four possible methods are shown. Choose from one to four of these methods. Browse for your pre-processed file in the *Choose file* menu. Only mat-files and folders are shown. Double click on the desired file and choose the desired matrix from the *Choose matrix* menu. The editable dt-field is the time resolution of recorded potential. Edit this and press *OK*.
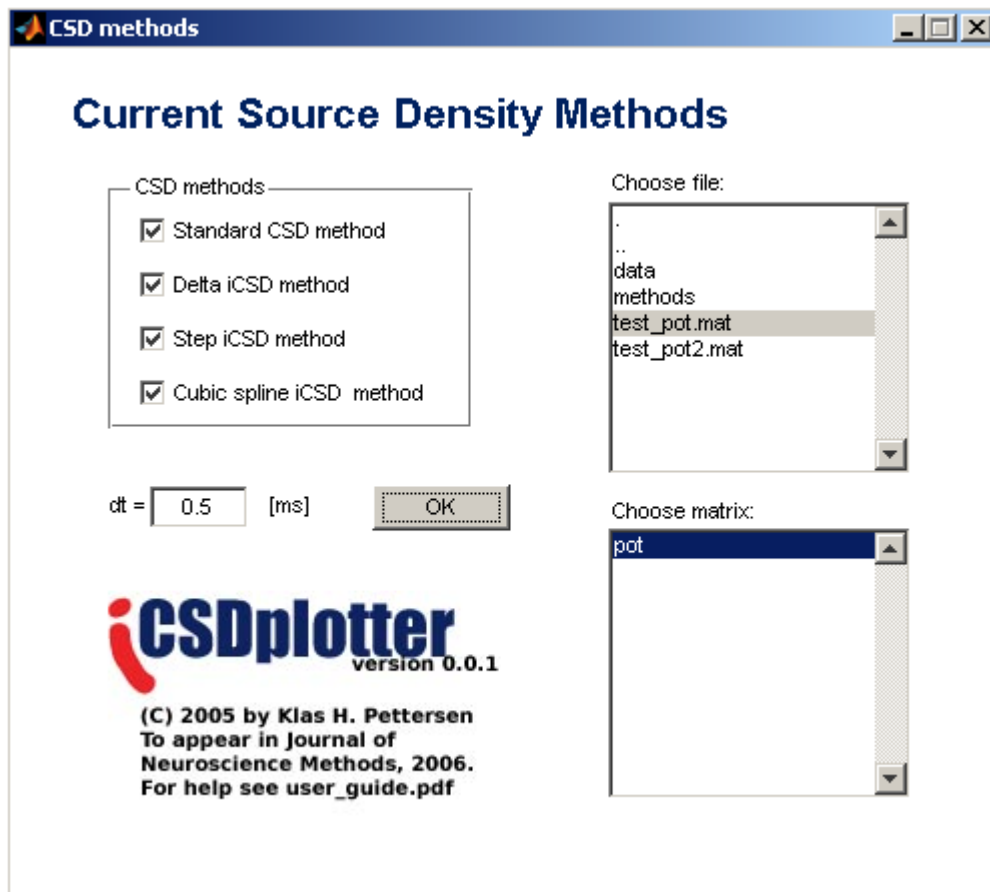

Illustration 1: Main menu.

The standard CSD method

If the standard CSD method is chosen, the menu showed in illustration 2 pops up when OK. The *three point spatial filter* is activated if the *neighbor value* is different from zero. Note that activation of the filter will decrease the number of rows of predicted CSD with two

The standard CSD method is based on the standard three point double derivative formula, thus this method itself will also reduce the number the CSD matrix with two spatial dimensions.

However, if *add Vaknin electrodes* is checked, the method of [2] is used to gain two additional rows (see [1] for discussion of the correctness of this procedure). The default filter is the Hamming filter, which has a center weight of 0.54 and neighboring weights of 0.23.

The *ex. cond.* parameter is the extracellular cortical conductivity given in units of siemens per meter (S/m).

The Electrode Positions is the vector containing the electrode contact positions. This vector could

be written on any matlab vector form, i.e. [0.1 0.2 0.3], [0.1,0.2,0.3] and 0.1:0.1:0.3 all produces the same result, three electrode contacts placed at cortical depths 0.1 mm, 0.2 mm and 0.3 mm. Default value is 0.1:0.1:2.3 which means that the first electrode contact is placed 0.1 mm below the cortical surface, the inter-contact distance is 0.1 mm and the electrode contains 23 electrode contacts. Note: In contrast to the iCSD methods the standard CSD method does not use the electrode contact positions in its evaluation, only vector size (which must equal the number of rows of the potential matrix) and inter-contact distance.
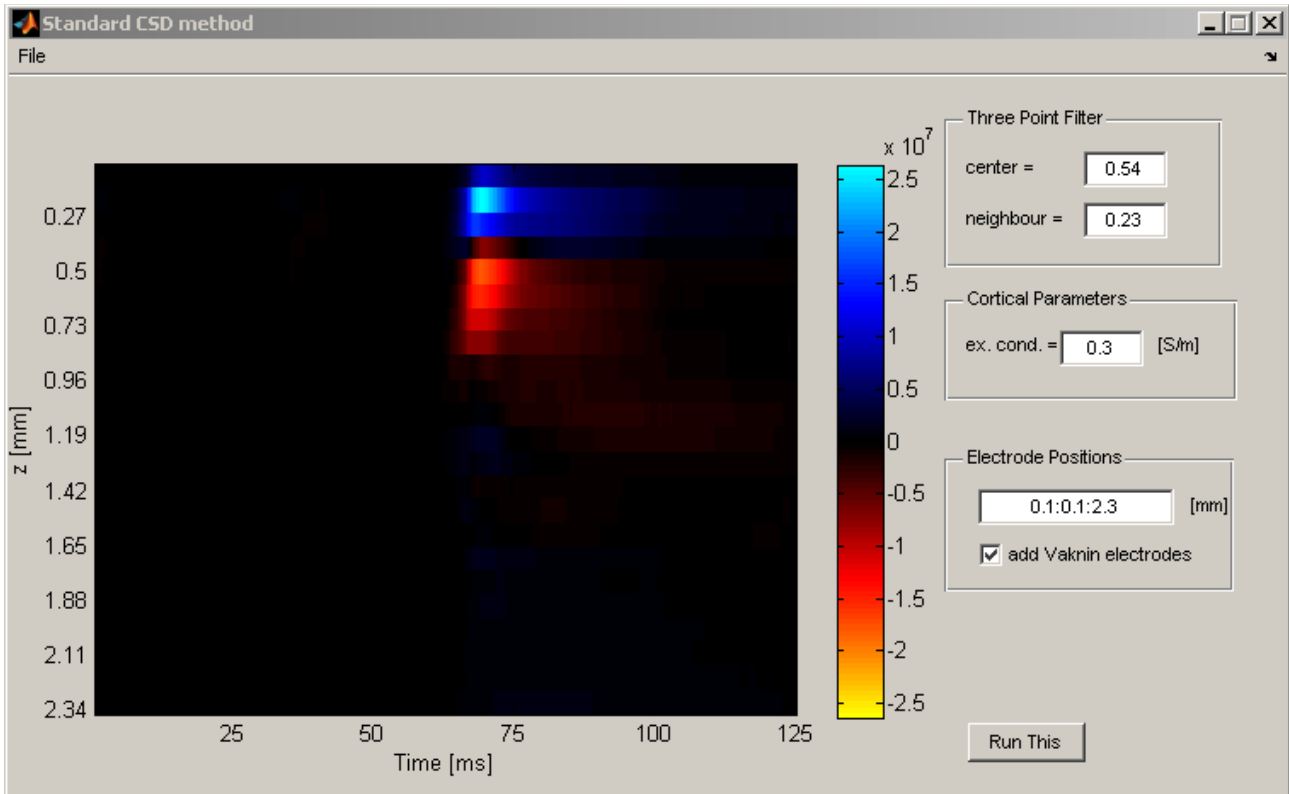

Illustration 2: Standard CSD method.

When numbers are edited, press *Run This*, and the CSD plot is shown in the panel. One can further edit the parameters, then press *Run This* again to show the new result. For post-processing and saving of the figure click File > Paste as New Figure. This creates a standard matlab figure (with all its menus) of the plot.

The delta iCSD method

Illustration 3 shows the delta iCSD methods. The parameters here are similar to the standard CSD method, however, there are some important differences. First of all, the iCSD methods uses the activity diameter as a parameter (the standard CSD method estimate can be achieved if the diameter in the delta iCSD method is large compared to the electrode length, see [1]). Secondly, the method handles a two-layered conductivity, where *top cond.* corresponds to the conductivity above cortex (z<0), which is dependent on which substance the experimentalist has used on top of cortex to prevent it from drying out during the experiment. If *top cond.* is different from *ex. cond.,* the absolute positions of the electrode contacts are used, and the method require that all contacts are put into cortex (z>0). If *top cond.* equals *ex. cond.,* the inter-contact distances are the only important values, thus all values are accepted. Note, however, different from the standard CSD method *the inter-contact distances do not need to be constant in the iCSD methods*. This could be a big advantage, e.g. if one electrode contact is shown to be defect. This problem could be solved by

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simply taking the erroneous electrode contact data out of the potential matrix in the pre-processing stage and omitting the electrode contact position in the Electrode Positions vector.
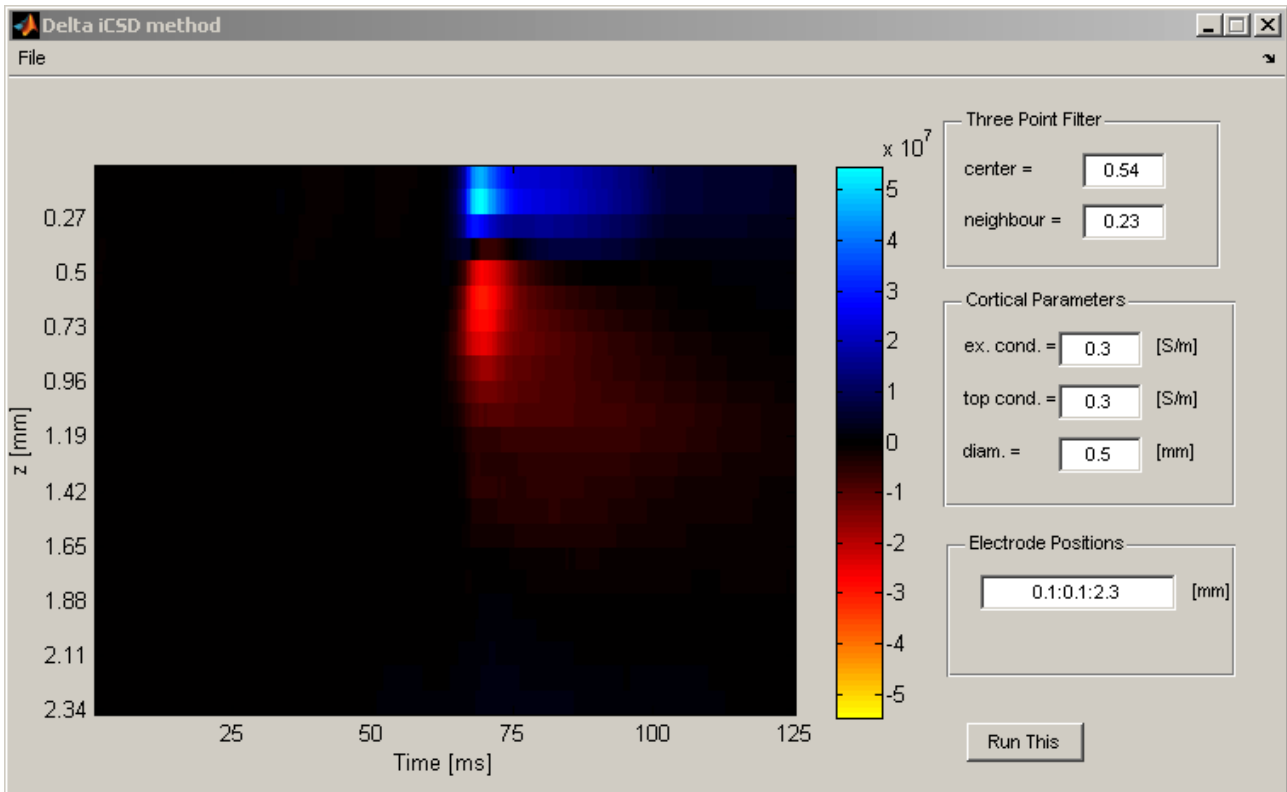

Illustration 3: Delta iCSD method

The step iCSD method

This method has the same parameters as the delta iCSD method except for its filter. In contradiction to the standard CSD method and the delta iCSD method this method predicts a CSD which is a continuous function, therefore continuous spatial filters can be used instead of the three-point filters above. Here a Gaussian filter is used, and the parameter, *std. dev.* is the standard deviation. Default value is 0.1 mm.

The spline iCSD method

The panel of the iCSD method is shown in illustration 4. In contradiction to the other methods this method predicts a CSD which is a continuous function, therefore one can use continuous noise filters instead of the three-point filters above. The Gaussian Filter parameter, *std. dev.*, is the standard deviation of the gaussian filter. Default value is 0.1 mm.
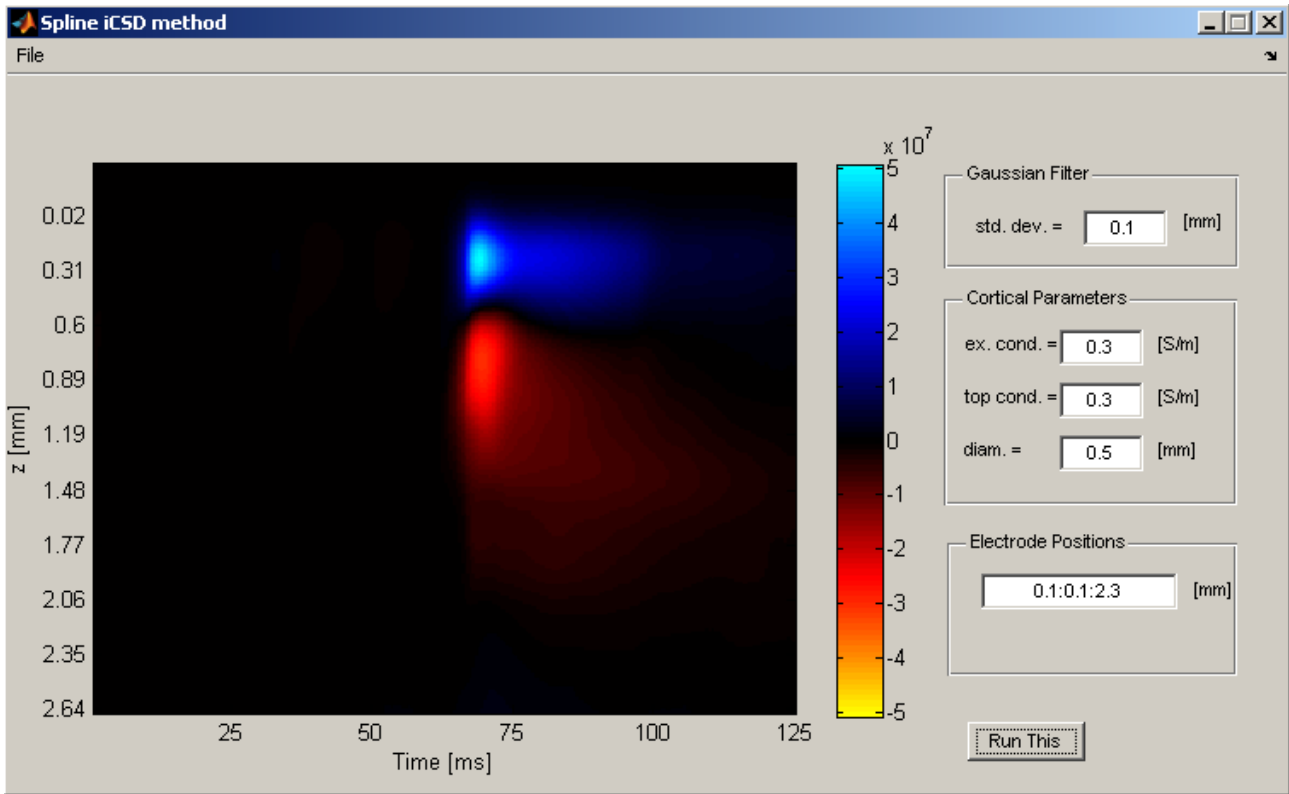
Illustration 4: Spline iCSD method.

Bibliography

[1] K. Pettersen, A. Devor, I. Ulbert, A.M. Dale and G.T. Einevoll, *Current-source density estimation based on inversion of electrostatic forward solution: Effects of finite extent of neuronal activity and conductivity discontinuities*, accepted (2005) for publication in J Neurosci Methods.

[2] G. Vaknin and P. G. DiScenna and T. J. Teyler. *A method for calculating current source density (CSD) analysis without resorting to recording sites outside the sampling volume.* J Neurosci Methods, 24, pp. 131—135 (1988).