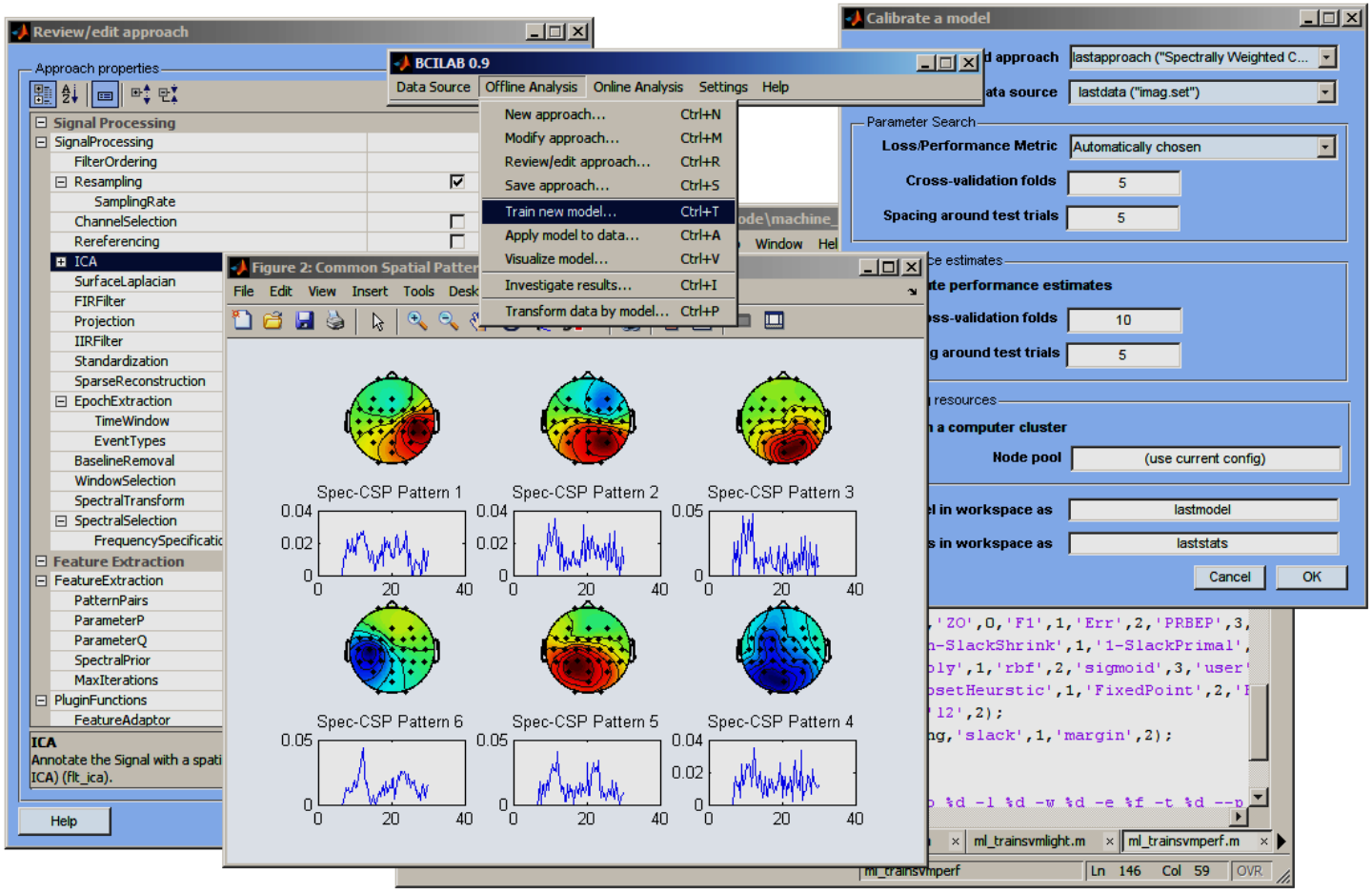
These slides are at:

ftp://sccn.ucsd.edu/pub/bcilab/mallorca

BCILAB Briefing



http://sccn.ucsd.edu/**wiki/BCILAB**

Idea & Purpose

- Like EEGLAB, but for BCI (and/or cognitive state assessment)
  - Seeding a community
  - Strengthening links between BCI and Neuroscience
- SCCN's in-house tool for BCI problems
  - Main focus: Advanced cognitive monitoring
  - Part of a large US research program (CaN CTA)
  - Funded by ARL (and ONR, Swartz Foundation, …)

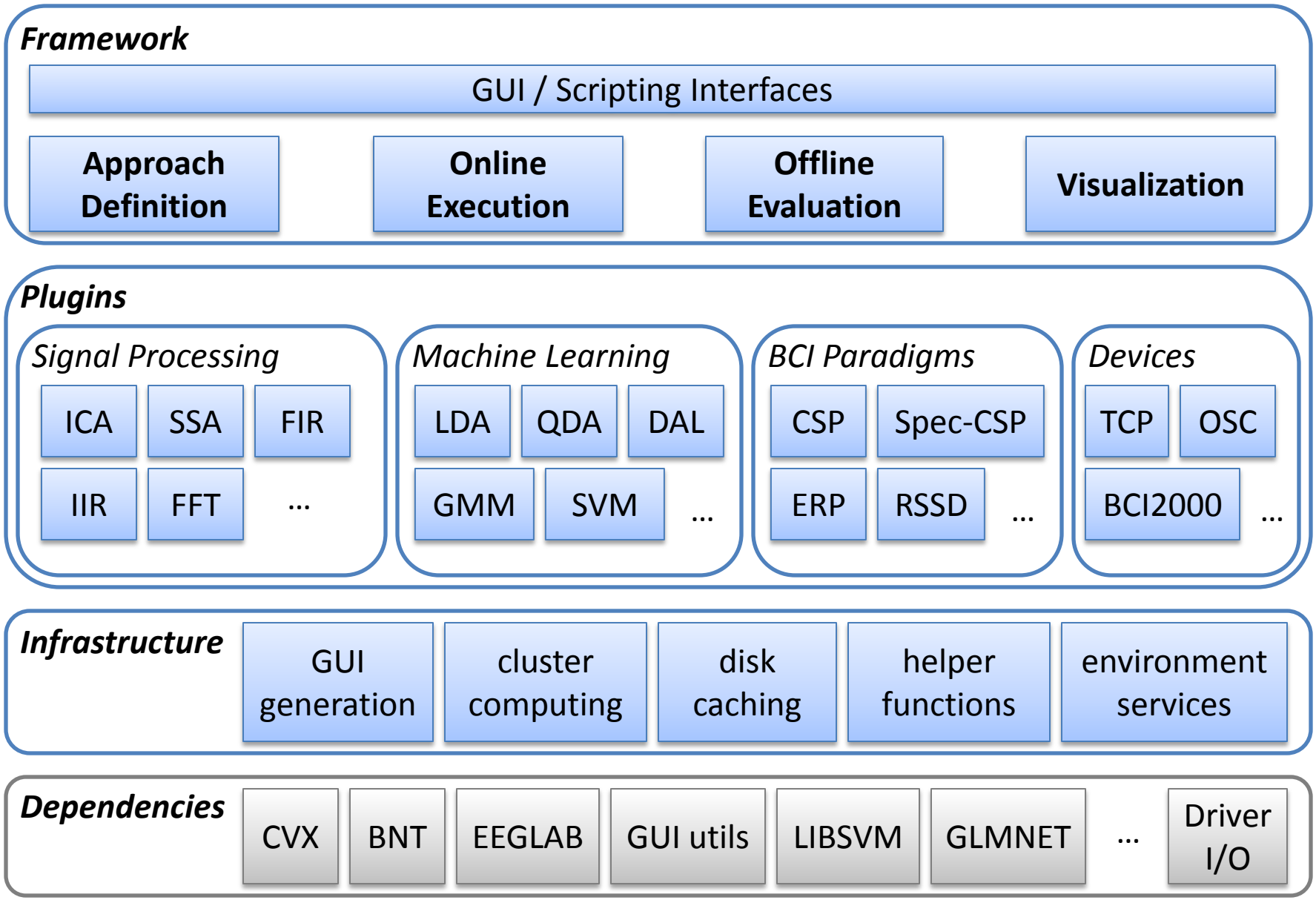
Office of Naval Research

BCILAB Specialty

- State of the art
- Largest collection of machine learning & signal processing components in any open-source BCI package
  - Many standard components (CSP, LDA, SVM, …)
  - Many modern components (SBL, SSA, AMICA, HKL, DPGMM, LR-DAL, …)
  - Some novel components (OSR, RSSD, SSB, …)
- Next-generation framework
  - Fully probabilistic
  - Model inference from data corpora*
  - Anatomical priors, other neuroscience-aware features
  - Processing of parallel streams

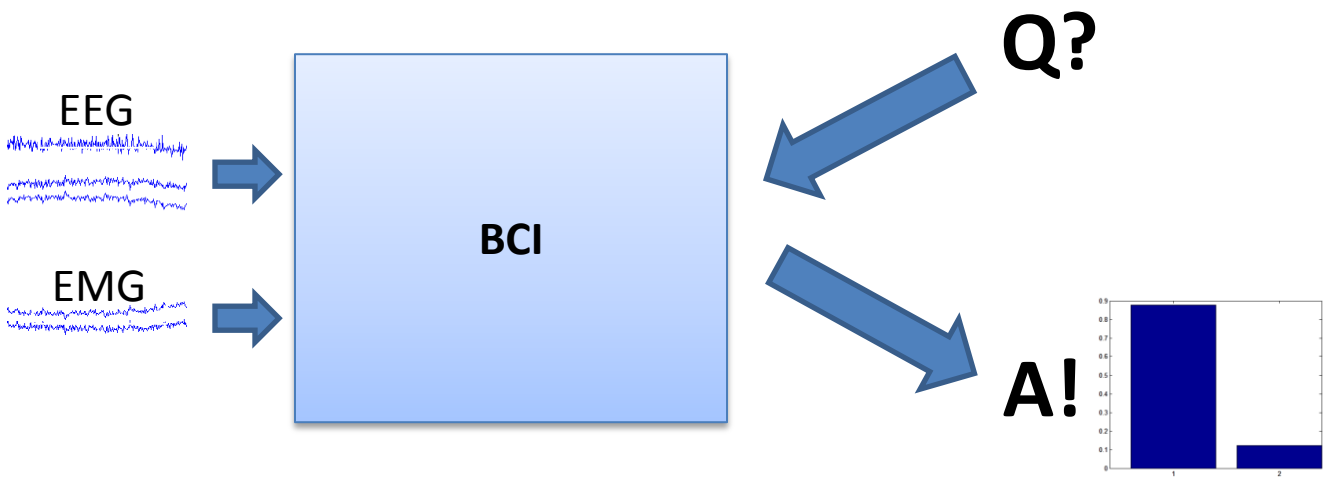
(*: not yet in the current release)

BCILAB Components



BCI Behavior

- BCIs in BCILAB are acting as an oracle that consumes one or more biosignals and can respond to (pre-defined) queries about cognitive state

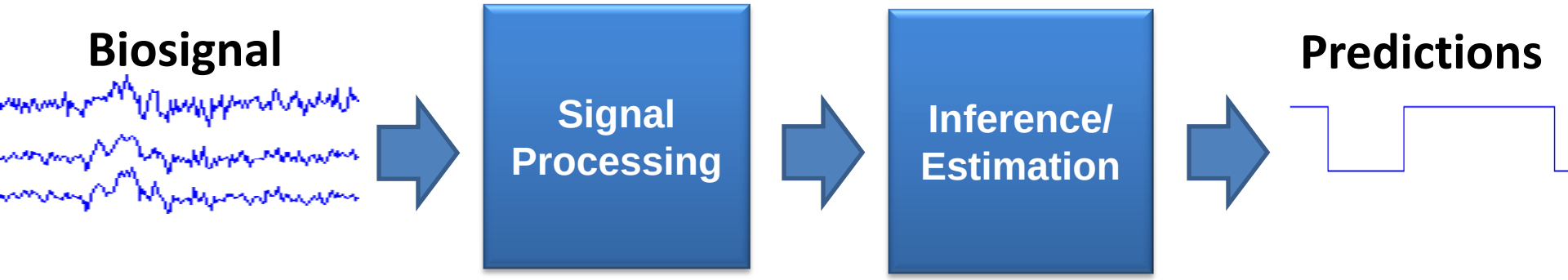


Signal Processing?

- Some signal-level computations can be done more efficiently than window-by-window (esp. when successive windows overlap a lot)

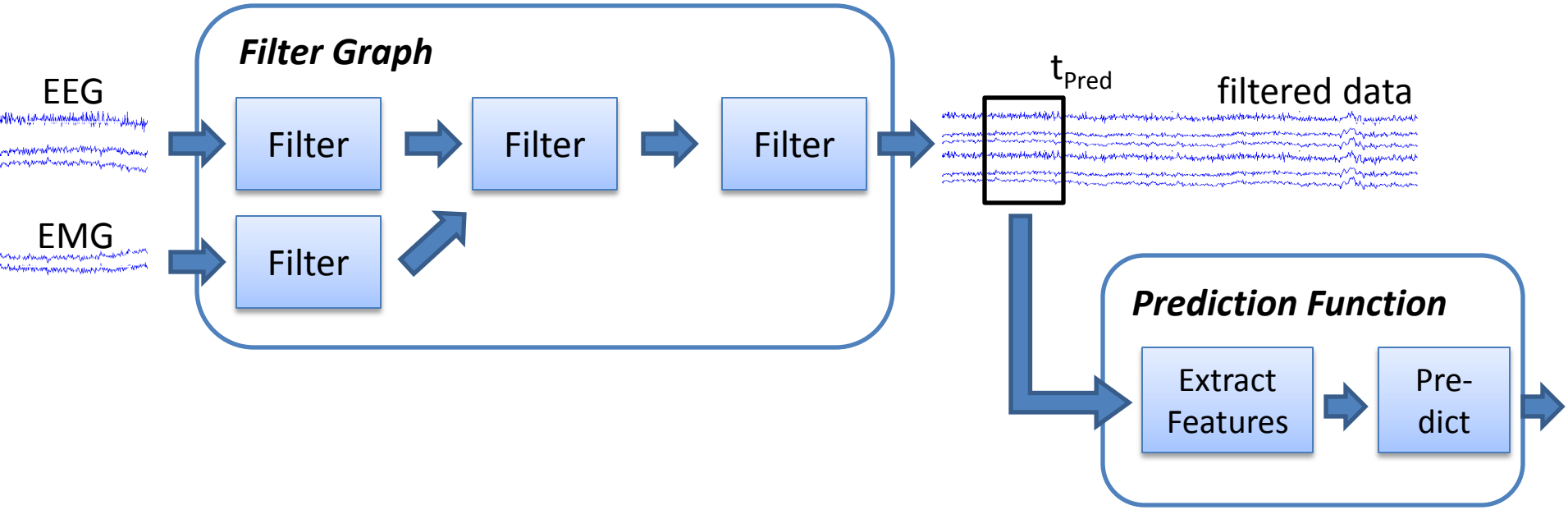
Signal Processing?

- Some signal-level computations can be done more efficiently than window-by-window (esp. when successive windows overlap a lot)
- Room for good DSP use (e.g., frequency filter, spatial filter, …) before actual prediction
- Also, can assemble approaches from existing components



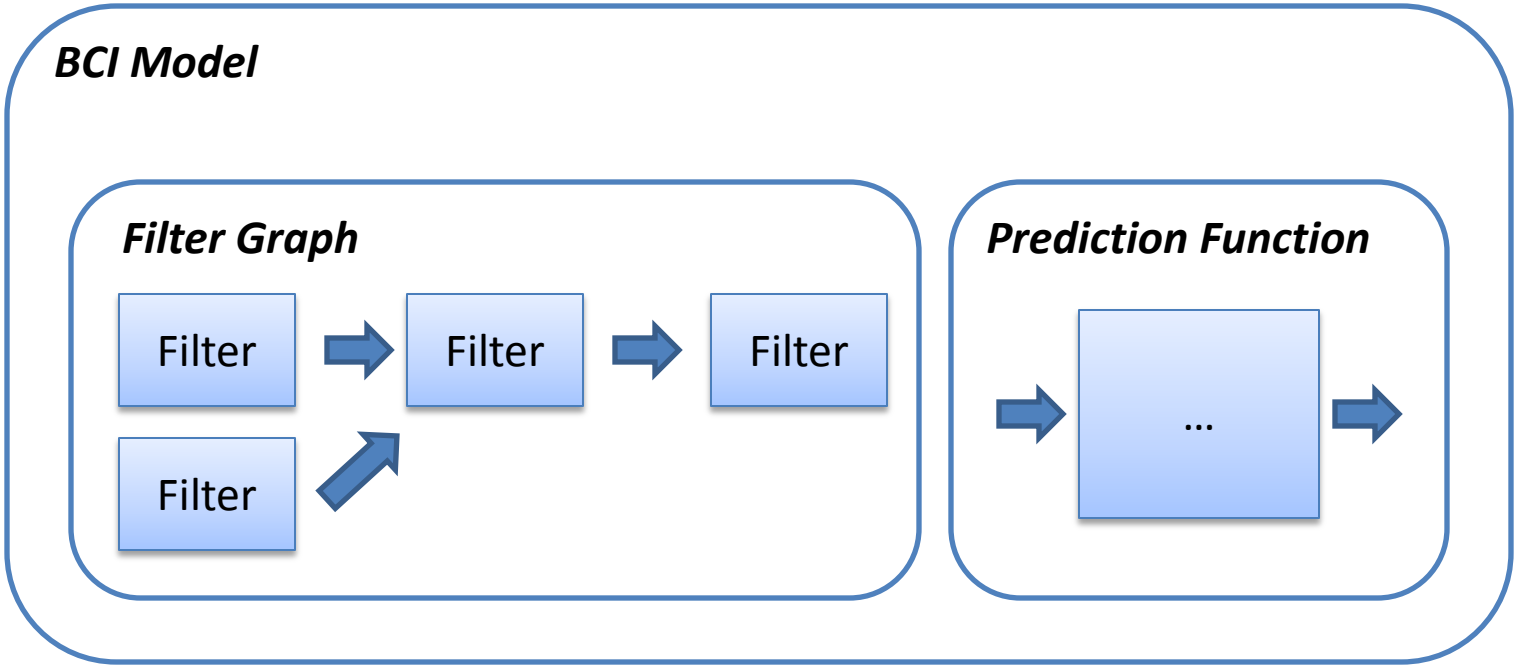
Online Data Flow

- A filter graph receives all input samples and produces pre-filtered data (signal flows through it)
- The prediction function may be queried on demand on the filter graph's outputs



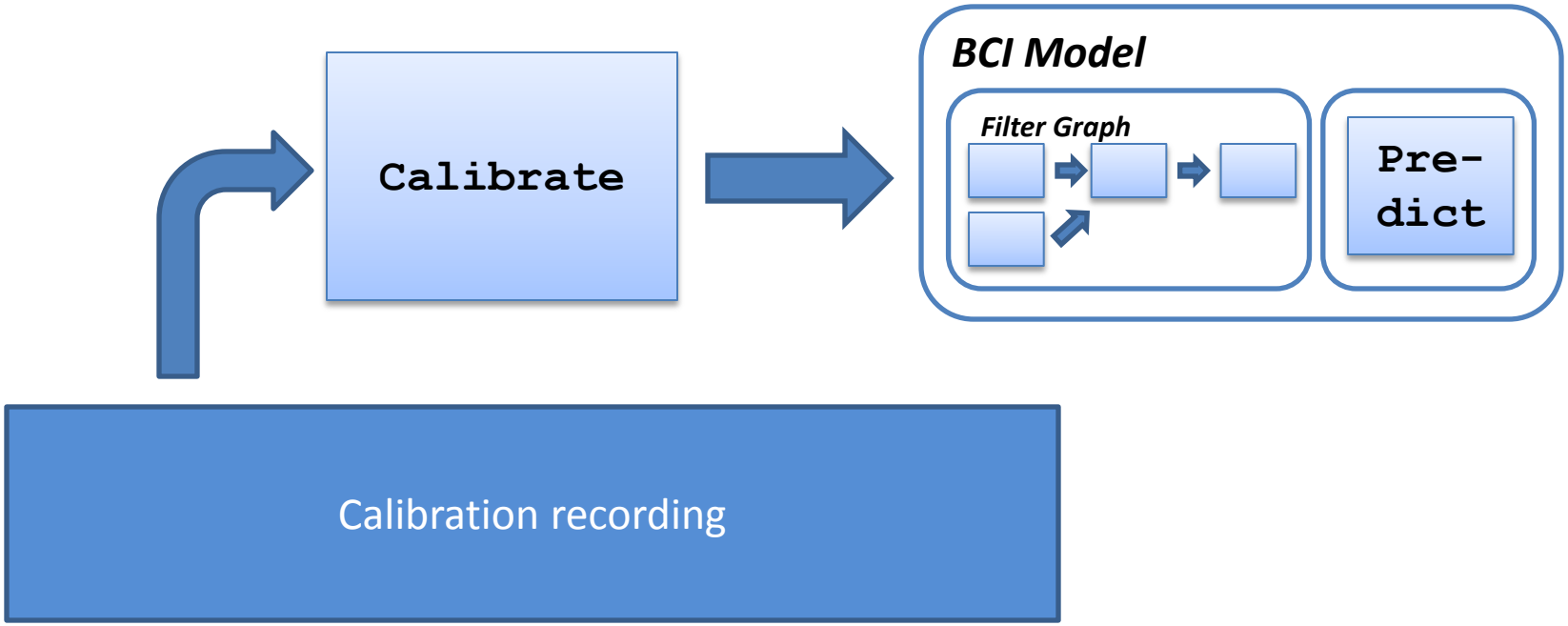
BCI Models

- BCIs are described by "BCI models" that specify both the *filter graph* and the *prediction function* (incl. parameters)



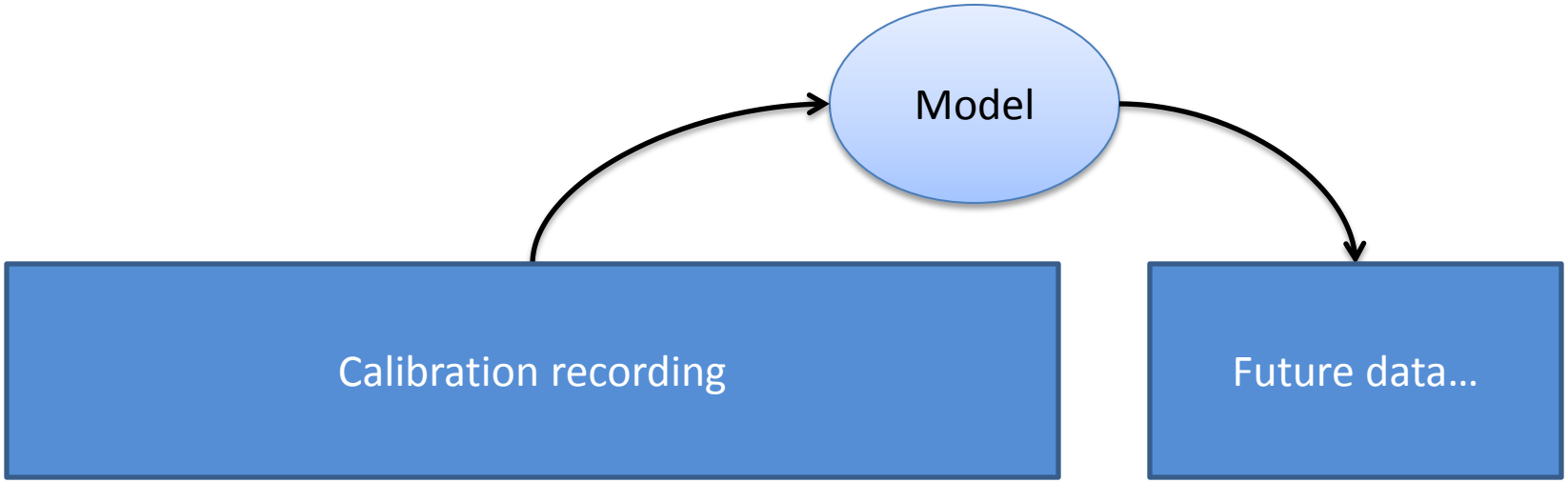
BCI Paradigms

- BCI paradigms are the coarsest plugin type in BCILAB and tie all parts of a BCI approach together
- They are seeds for new BCI designs and cornerstones of BCILAB usage



Offline Evaluation

- Given calibration data
- Estimate model parameters (spatial filters, statistics)
- Apply the model to new data (online / single-trial)
- Optionally: compare outputs with known state, compute loss statistics for the model / approach (e.g., mis-classification rate)



Offline Evaluation

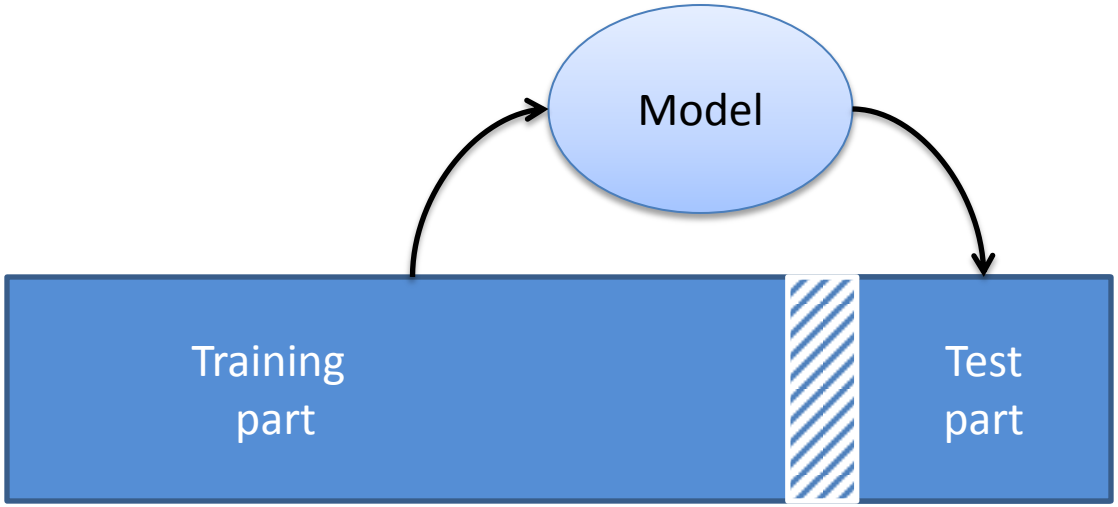
- Evaluation of computational approaches on a **single** data set?

?

Calibration recording

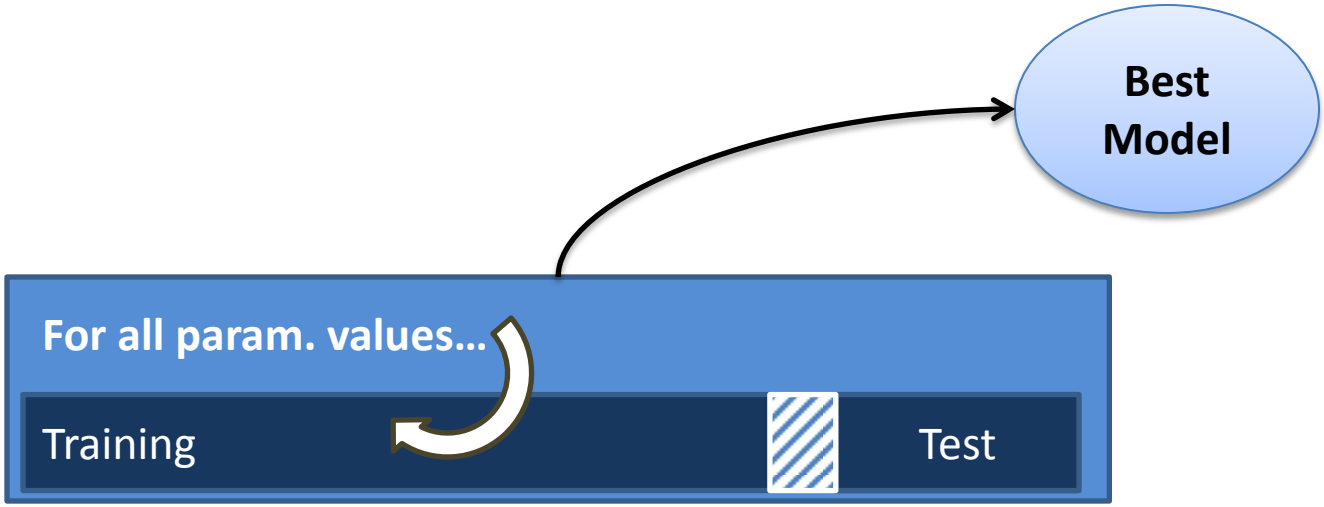
Offline Evaluation

- Evaluation of computational approaches on a single data set?
  - Can not test on the training data! (always on separate data)
  - Instead can split data set repeatedly into training/test blocks systematically, a.k.a. *cross-validation*



Resolving Free Parameters

- Can be done using cross-validation in a grid search (try all values of free parameters)
- **Caveat**: Resulting "optimal" numbers are *non-reportable* (cherry-picked!)



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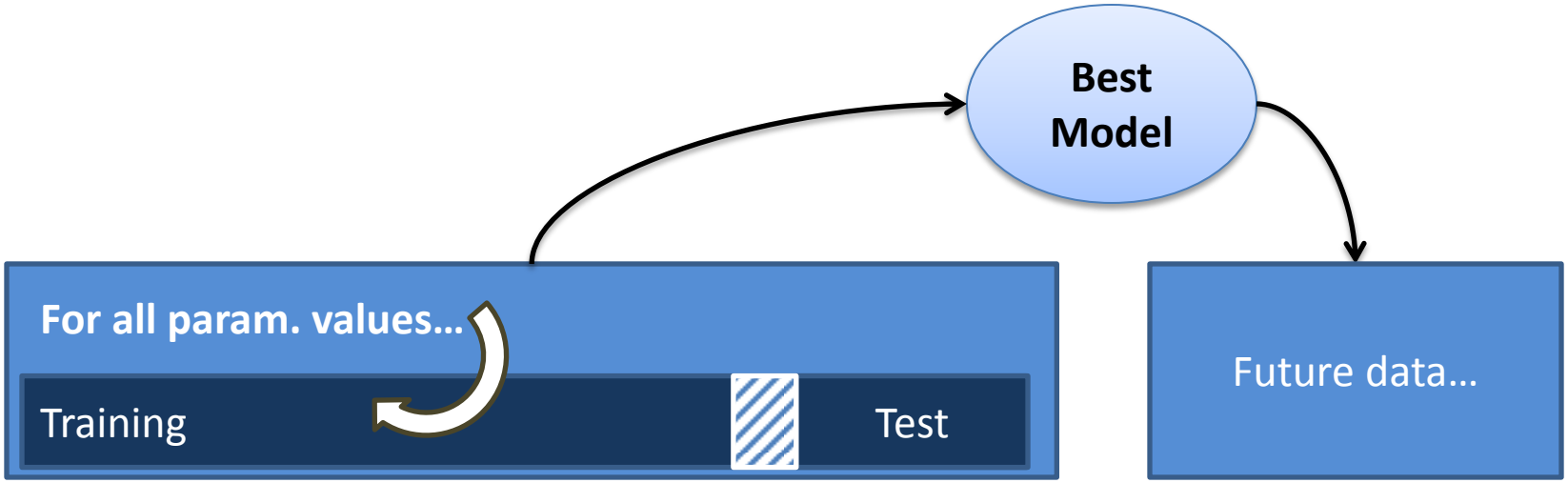
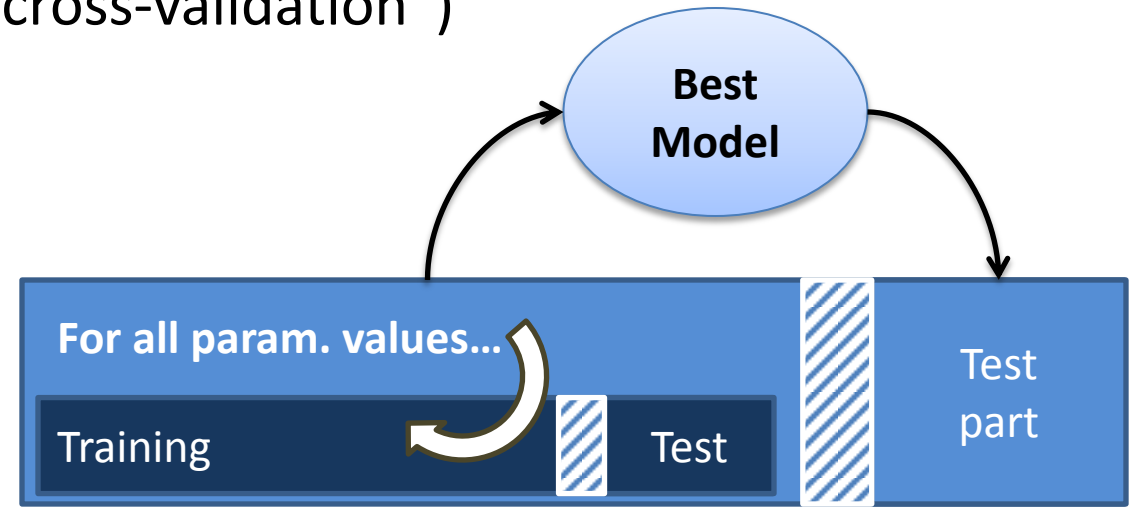


Resolving Free Parameters

- Can be done using cross-validation in a grid search (try all values of free parameters)
- **Caveat**: Resulting "optimal" numbers are *non-reportable* (cherry-picked!)
- But may test resulting best model on separate data
- **Or** run grid search *within* an outer cross-validation ("nested cross-validation")



System requirements

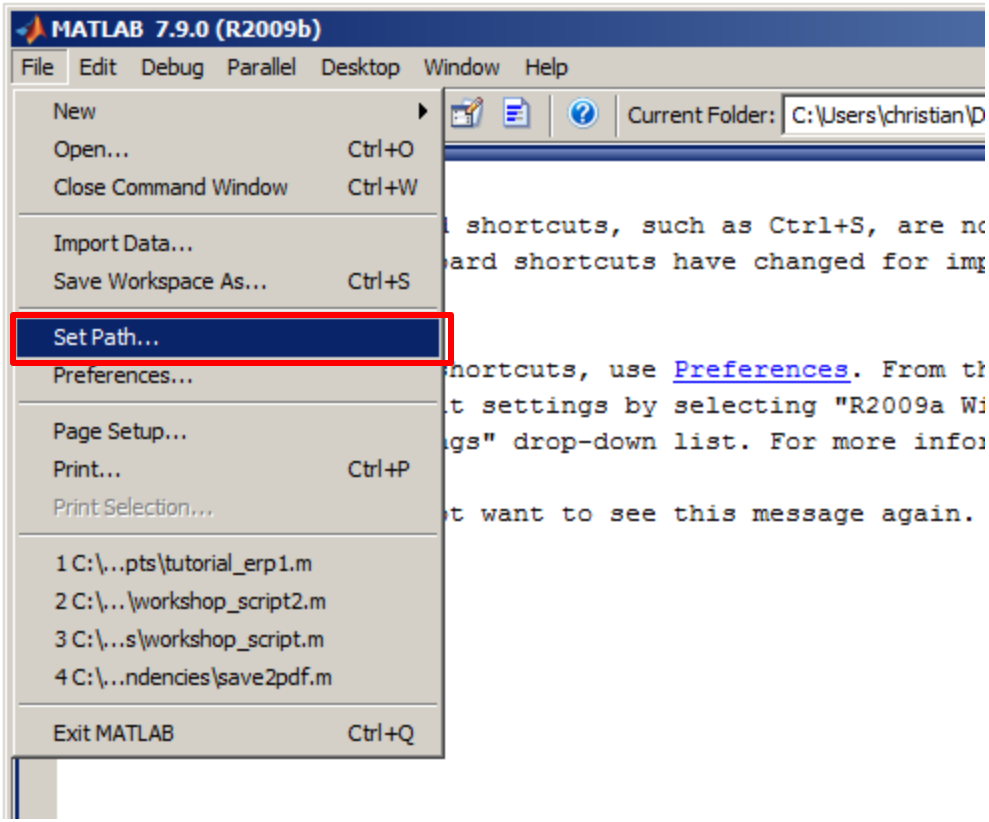
- MATLAB 2008a
- 1GB+ RAM (better: 2GB+)
- Windows, Linux, or Mac
- For smooth workshop: **No** toolboxes in MATLAB path other than Mathworks toolboxes (or EEGLAB)
- To use certain additional features (not covered today): Signal Processing Toolbox, Statistics Toolbox, Real-time experimentation environment (DataRiver, BCI2000, OpenViBE or your own)
- To use certain advanced features (also not covered today): Correct MEX compiler setting (this requires Microsoft Visual C++ Express under Win64 and Xcode/gcc under Mac)

When Processing your own Data

- Note the following requirements:
  - You need proper channel labels (usually the 10-20 labels); 3d locations not necessary
  - You need event markers in your data for the time points with known target condition
  - BCILAB needs raw (unprocessed) data
  - Make sure you have a file format supported by EEGLAB

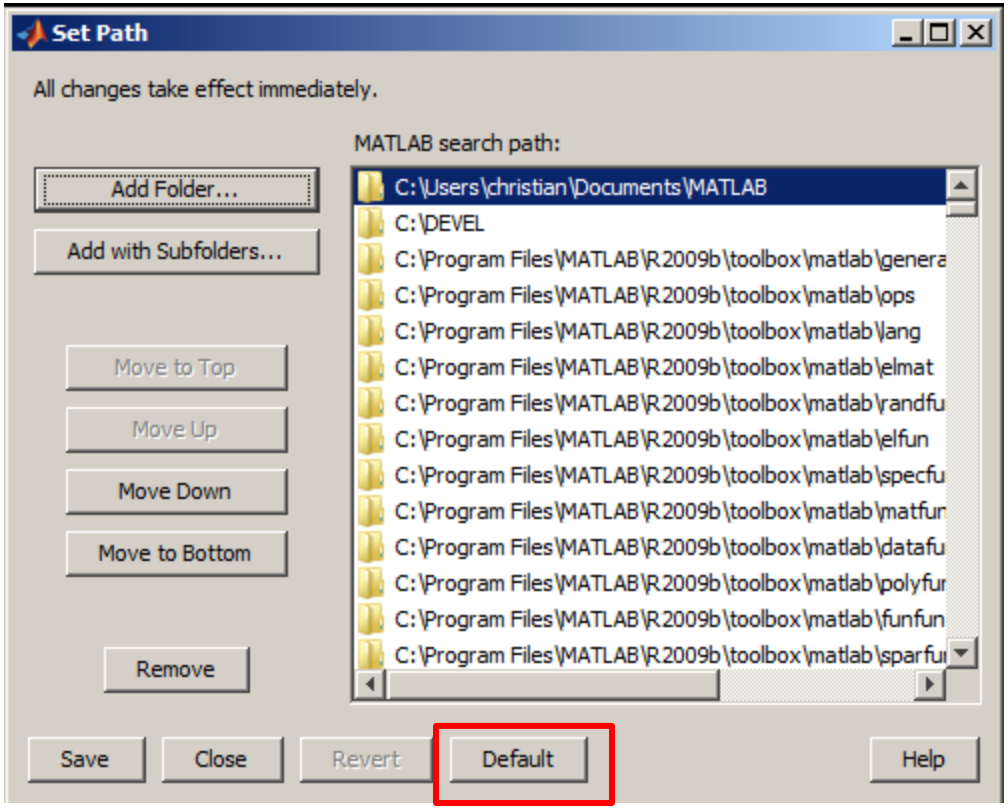
Rawr!

Clearing the Path



Swartz Center for Computational Neuroscience

Clearing the Path



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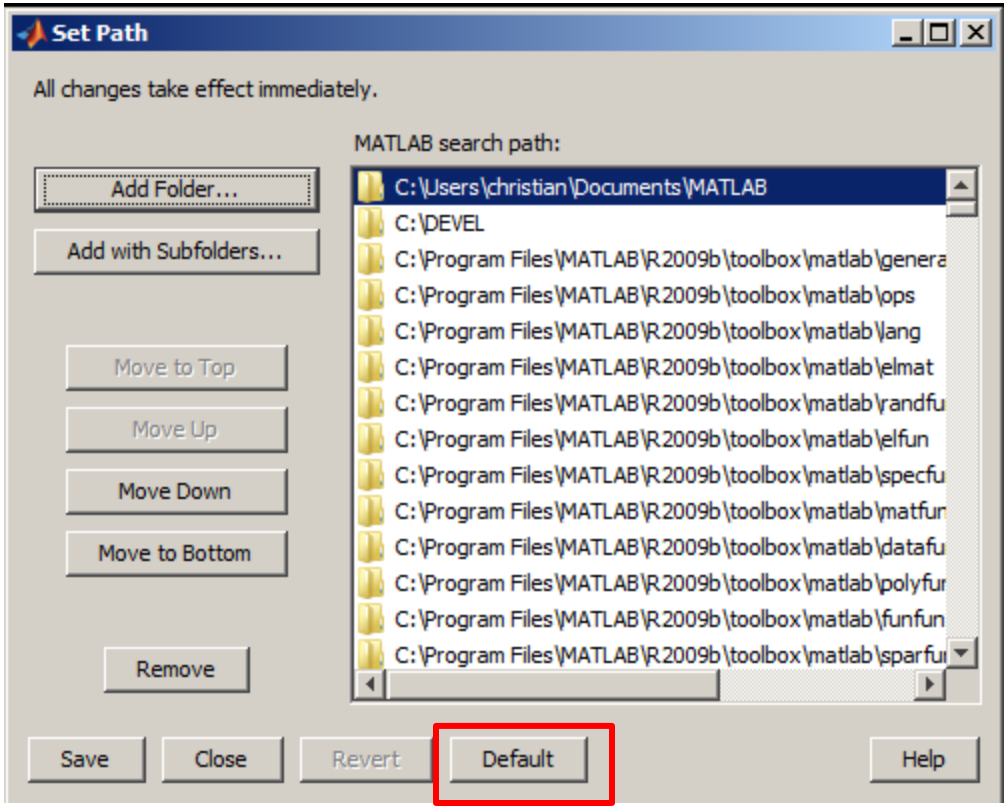

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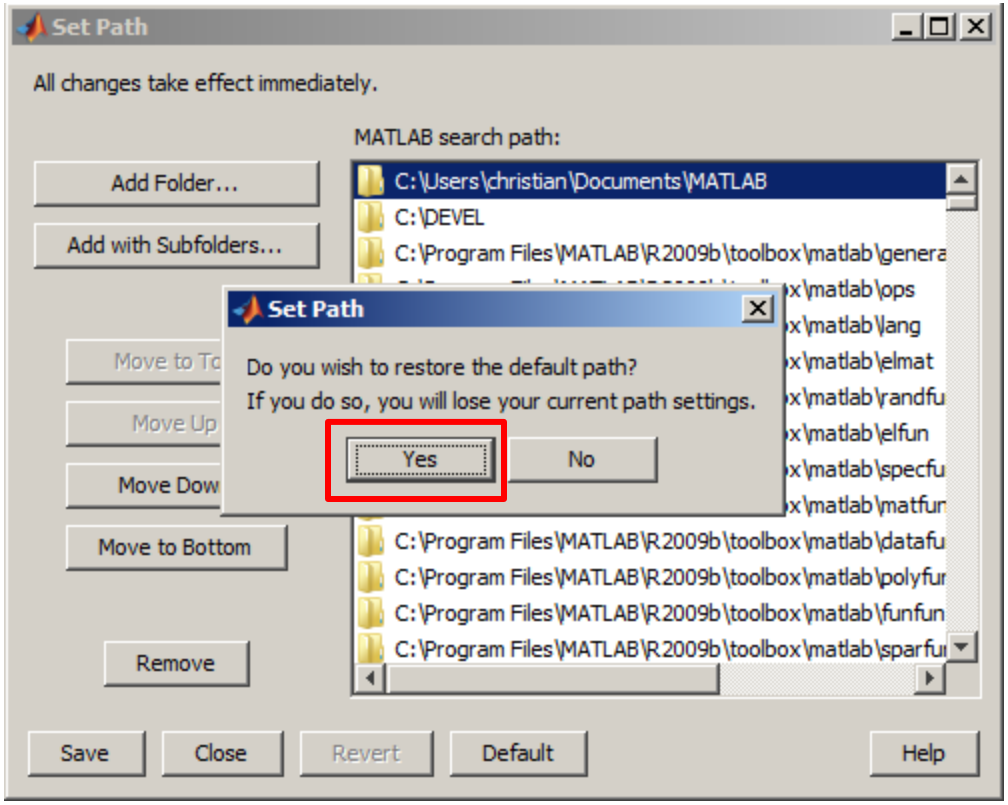

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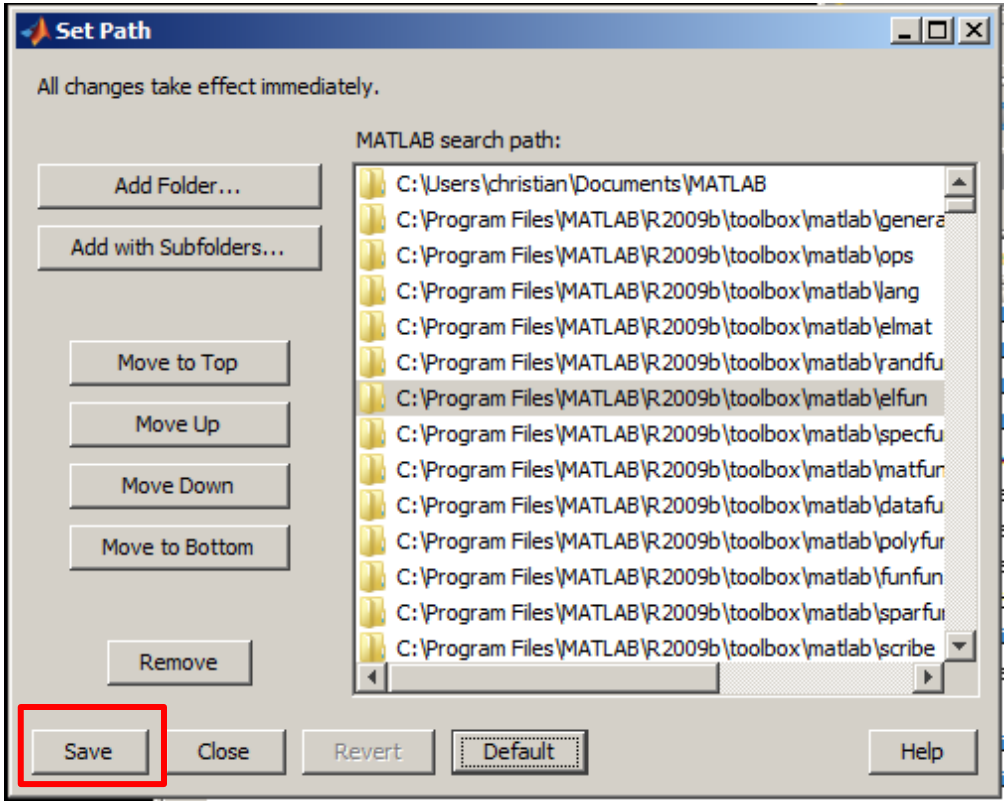
Clearing the Path



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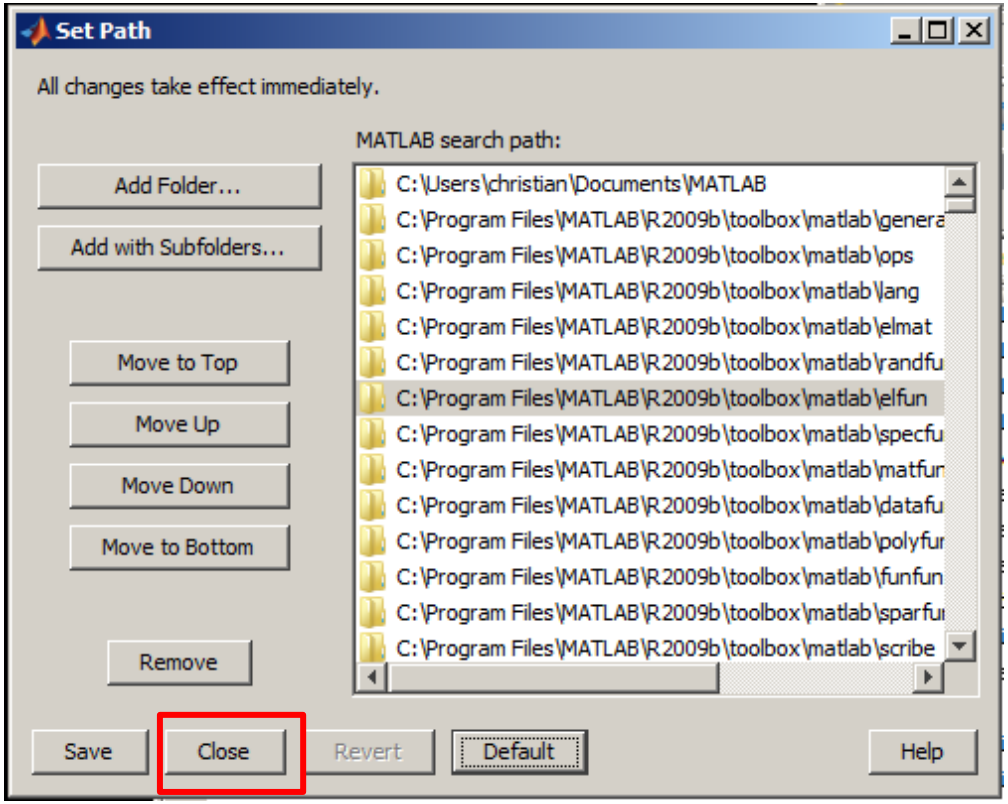
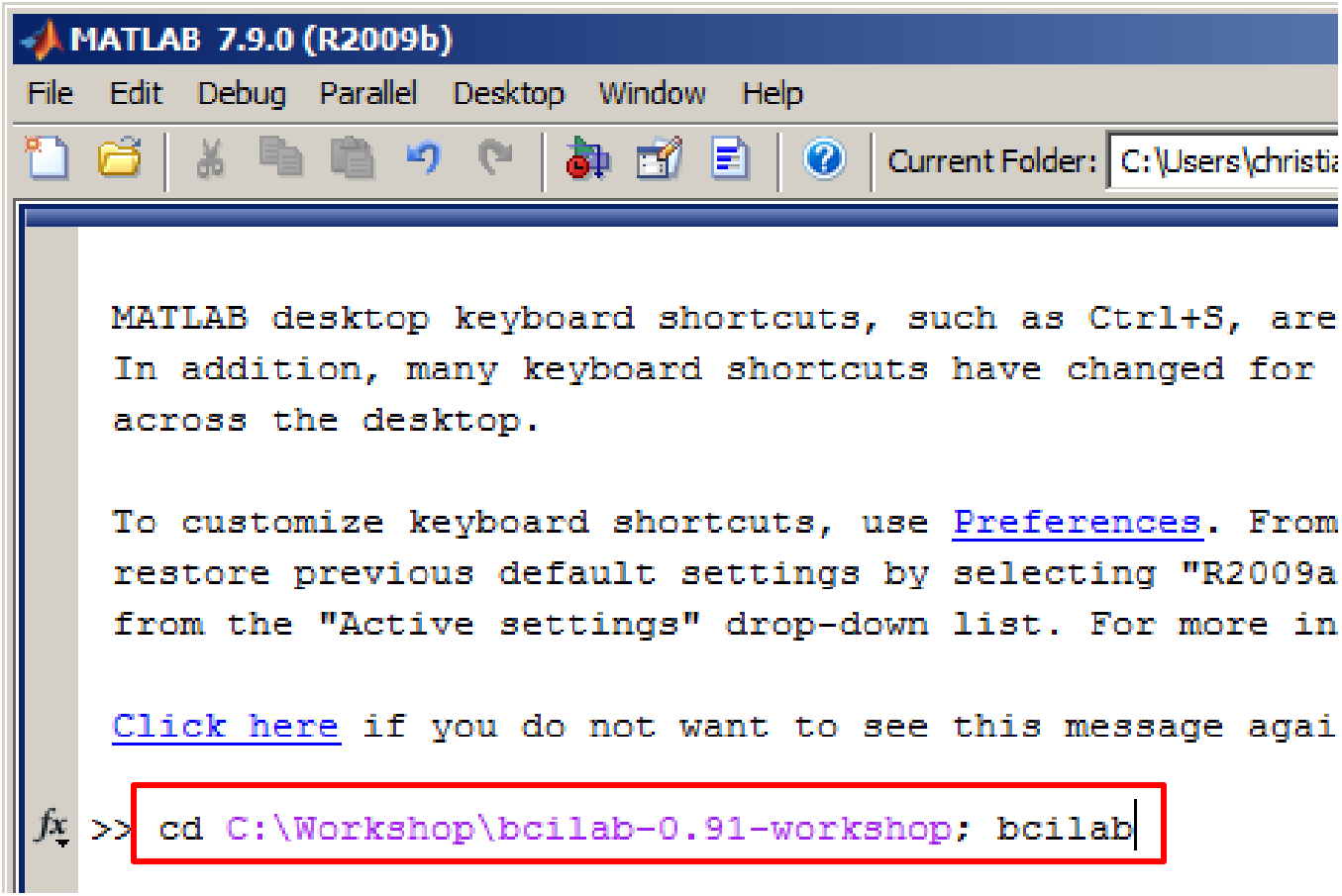
Clearing the Path



Starting the Toolbox

- Type: cd C:\your\path\to\bcilab; bcilab



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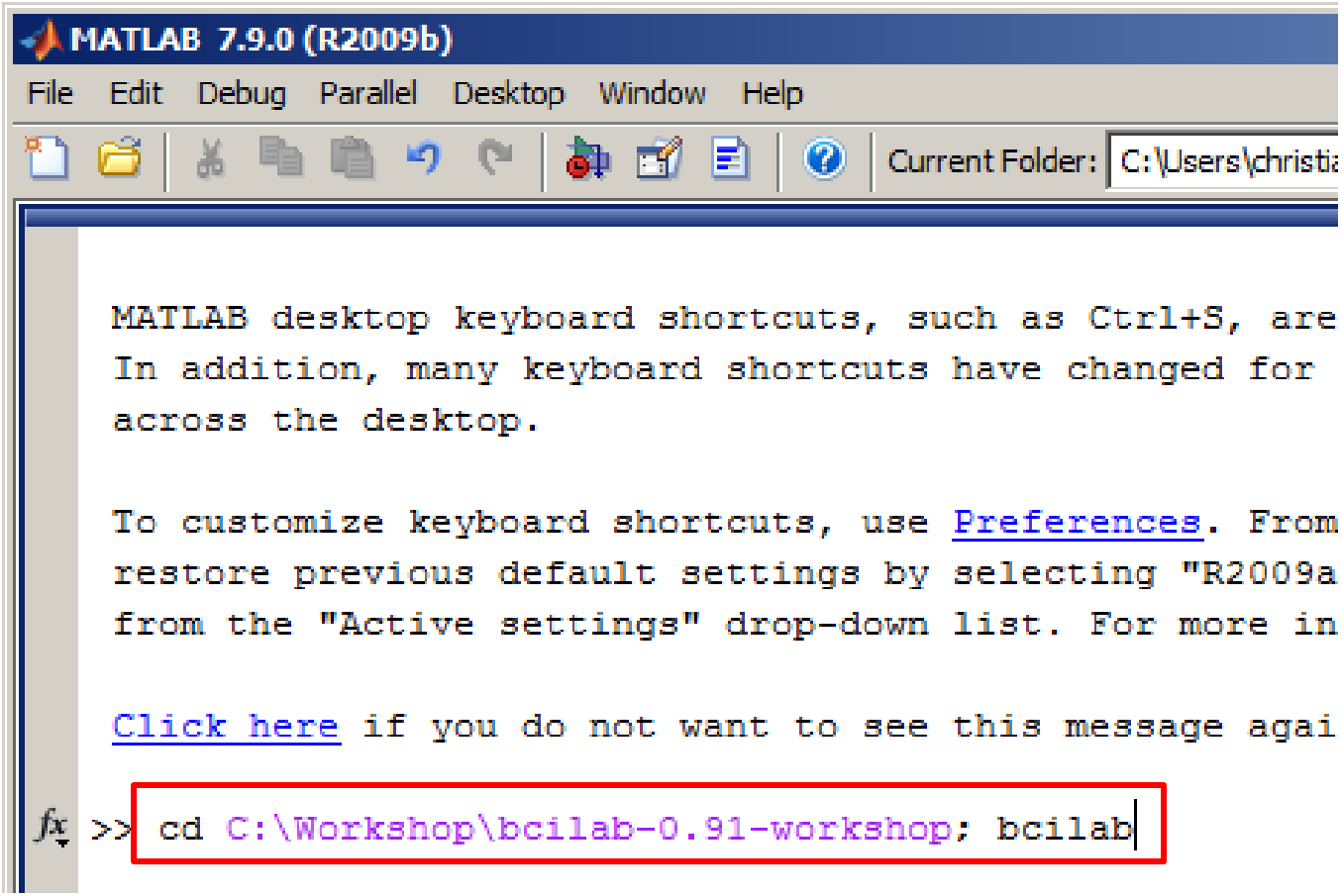
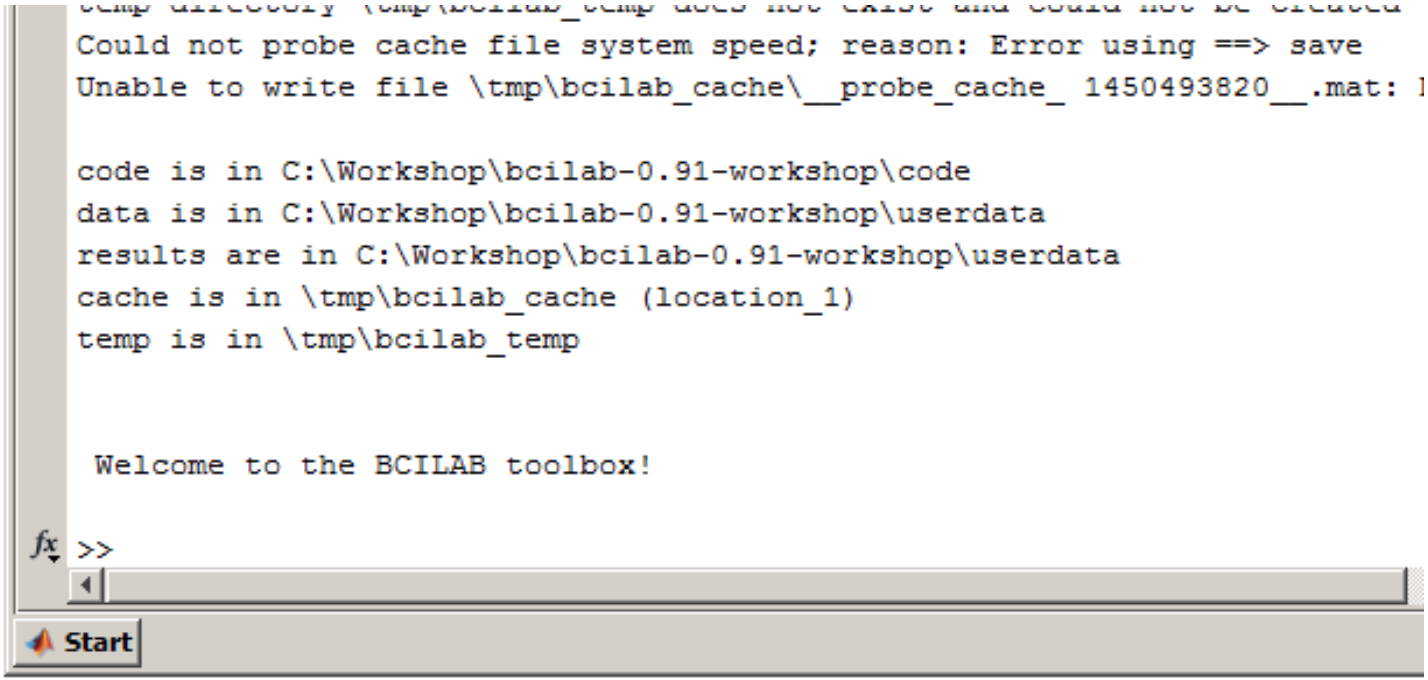


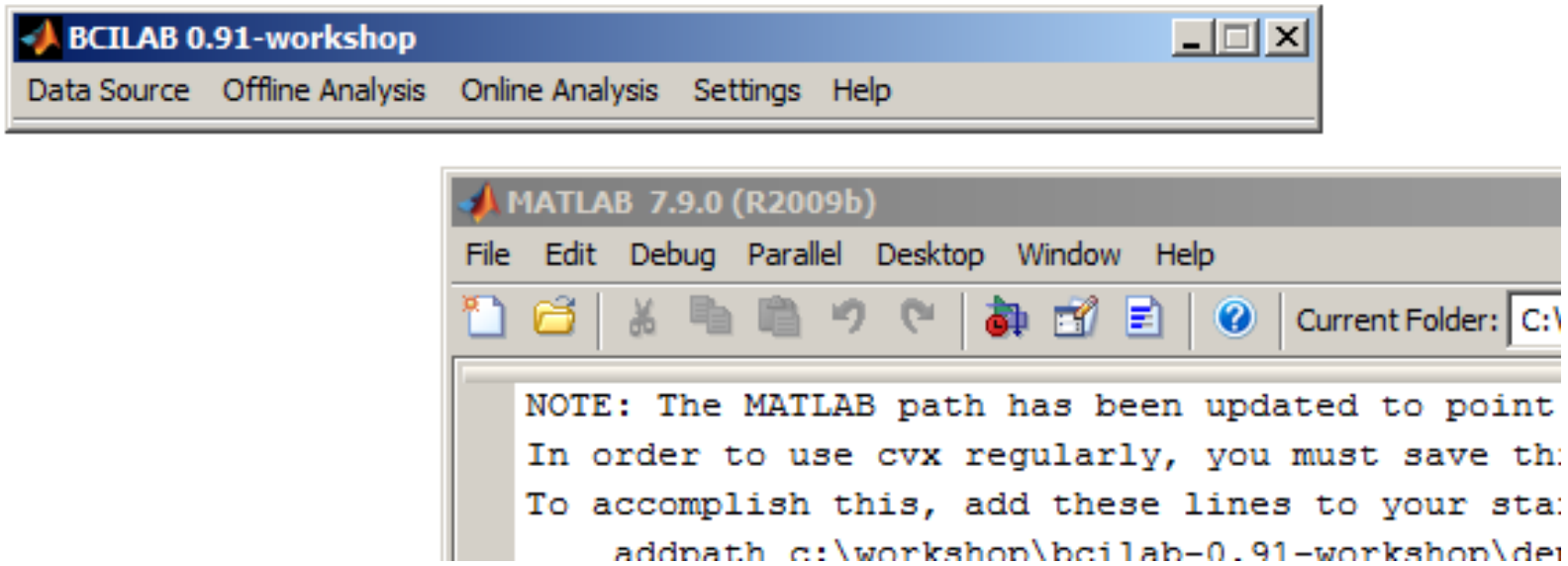
Starting the Toolbox

- You should see the welcome message



Starting the Toolbox

- … and the main menu

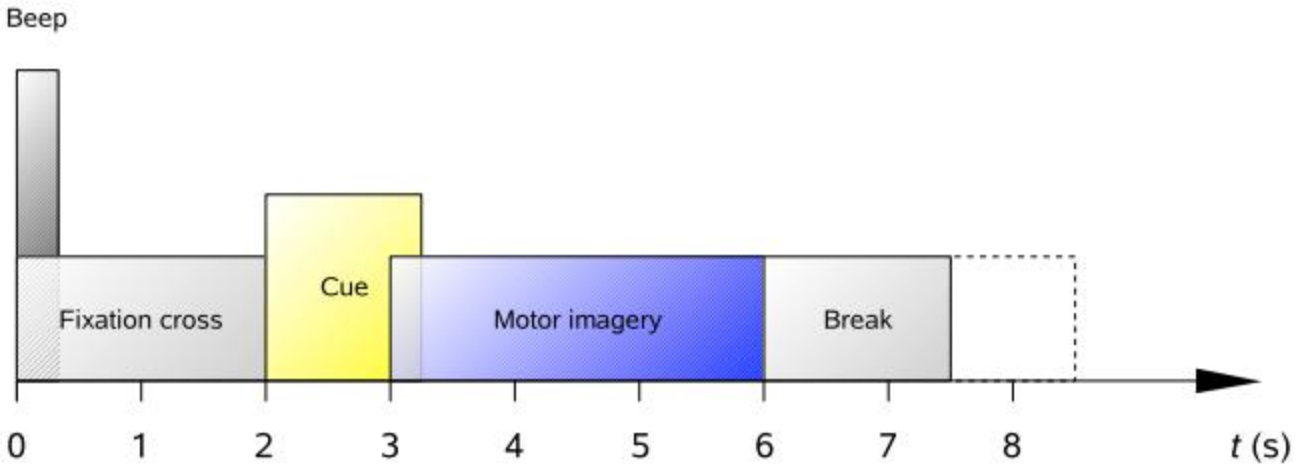


The Data

- Recorded at the famous BCI Lab in Graz, Austria
- Part of the BCI competition IV ("dataset 2a")
- More info: http://www.bbci.de/competition/iv/desc_2a.pdf
- Contains imagined movements of 4 classes:
  - Left hand
  - Right hand
  - Feet
  - Tongue
- 2 Training sets, 2 evaluation sets

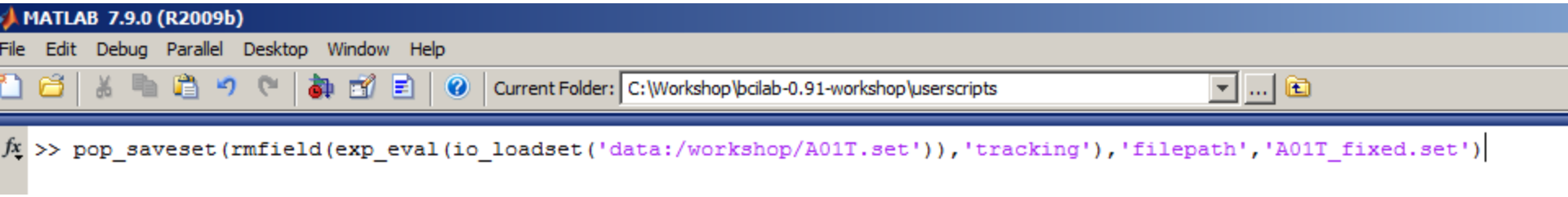
The Data

- Timing overview



Fixing the Data ☺

- Execute the following line:



- You can copy & paste this from the .pdf:

```
pop_saveset(rmfield(exp_eval(io_loadset('data:/workshop/A01T.set')),'tracking'),'filepath','A01T_fixed.set')
```

Fixing the Data ☺

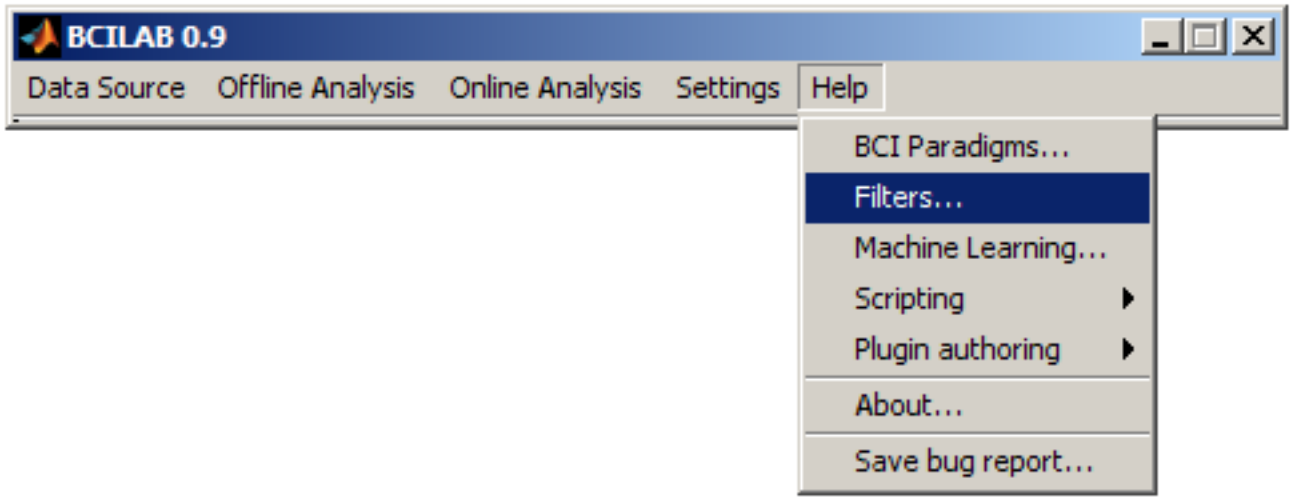
- … and the same for the three other data sets:

```
pop_saveset(rmfield(exp_eval(io_loadset('data:/workshop/A01E.set')),'tracking'),'filepath','A01E_fixed.set')

pop_saveset(rmfield(exp_eval(io_loadset('data:/workshop/A03T.set')),'tracking'),'filepath','A03T_fixed.set')

pop_saveset(rmfield(exp_eval(io_loadset('data:/workshop/A03E.set')),'tracking'),'filepath','A03E_fixed.set')
```

Getting help (if needed)



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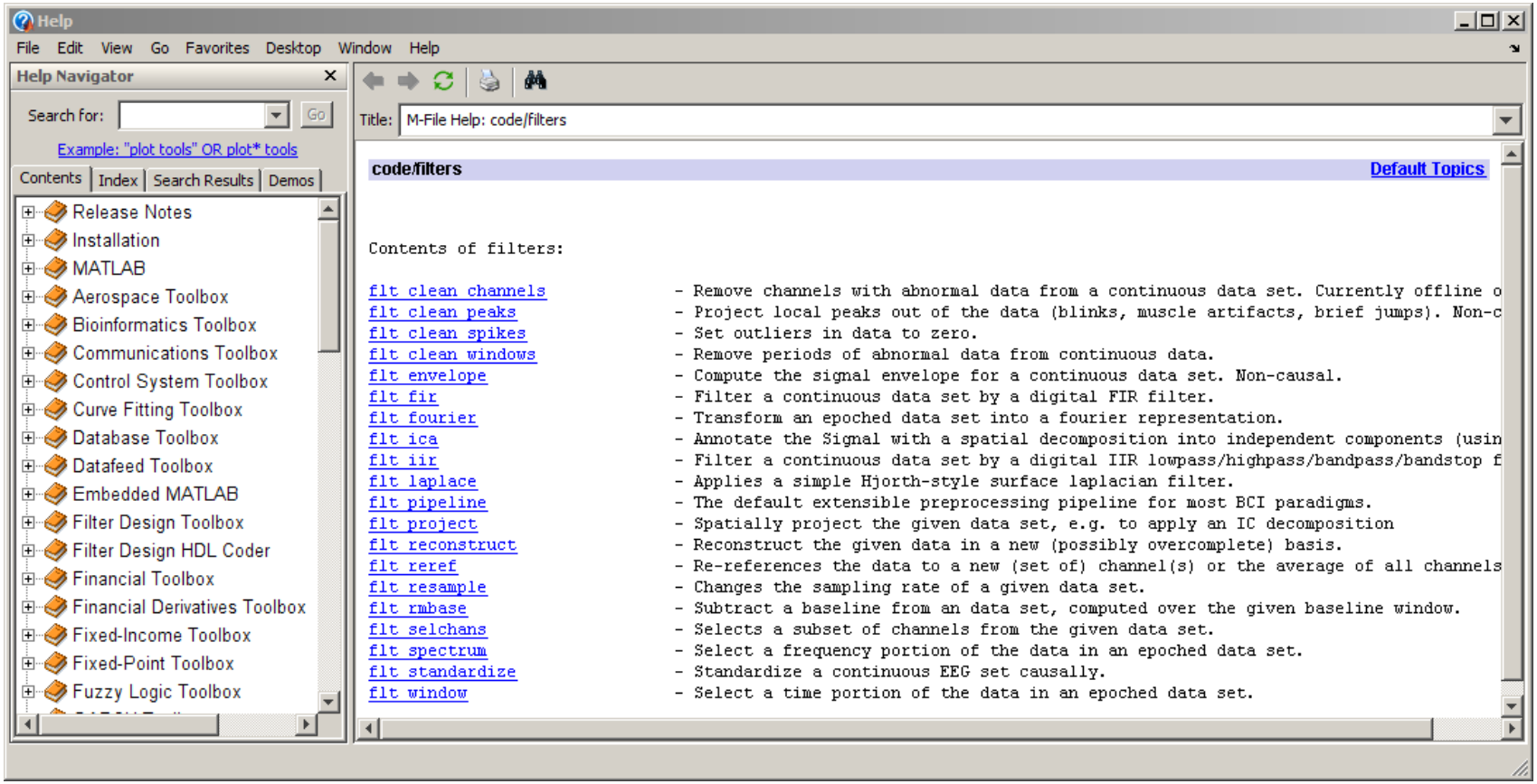

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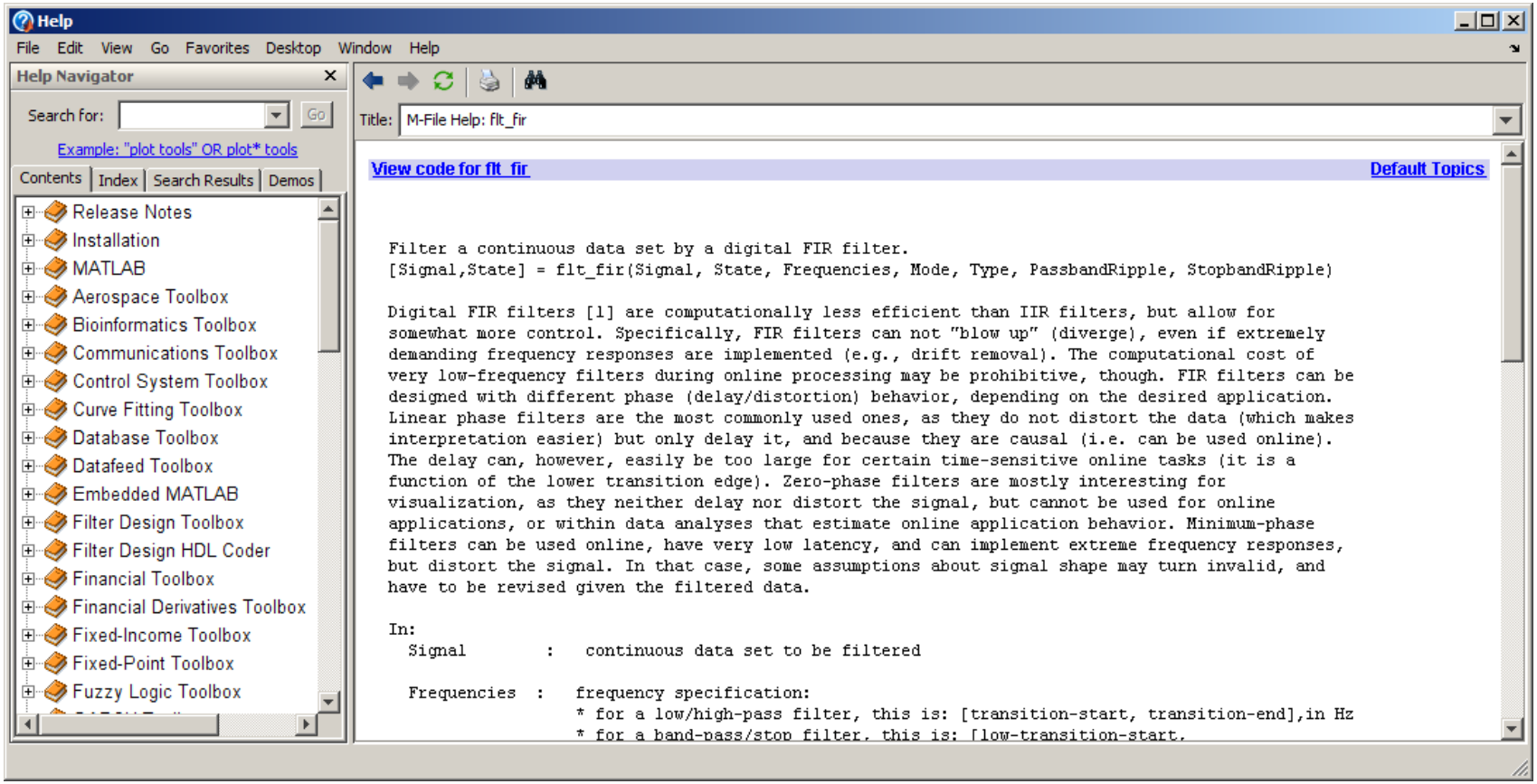
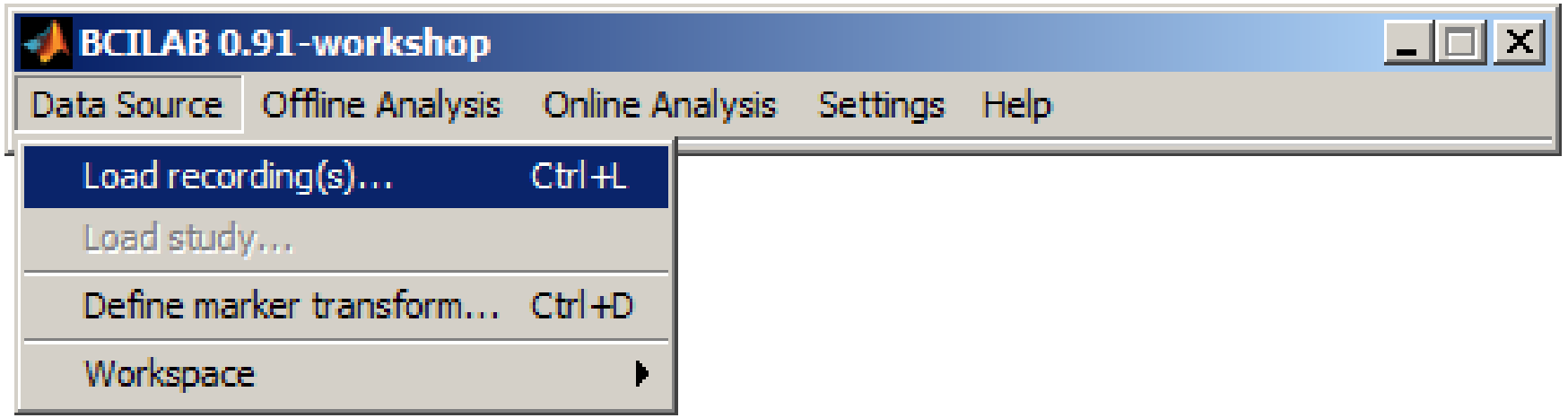


Loading the Data



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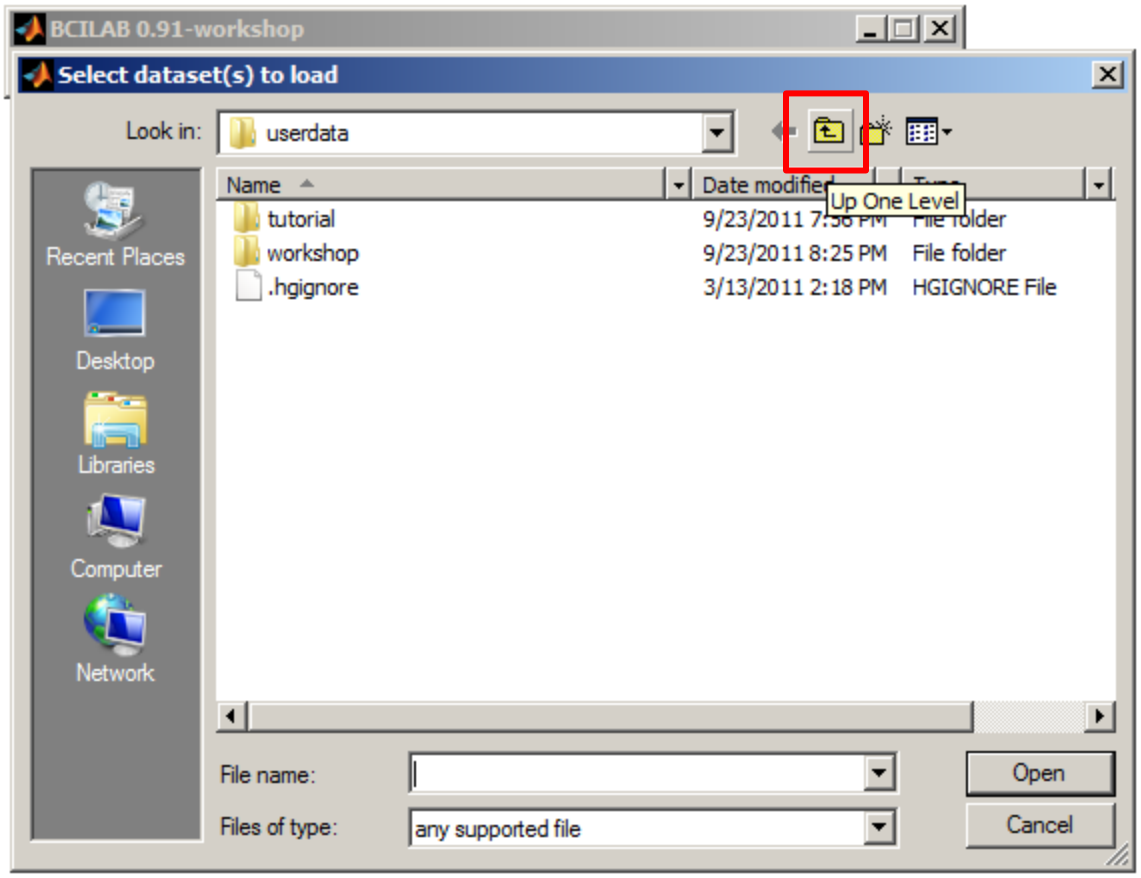
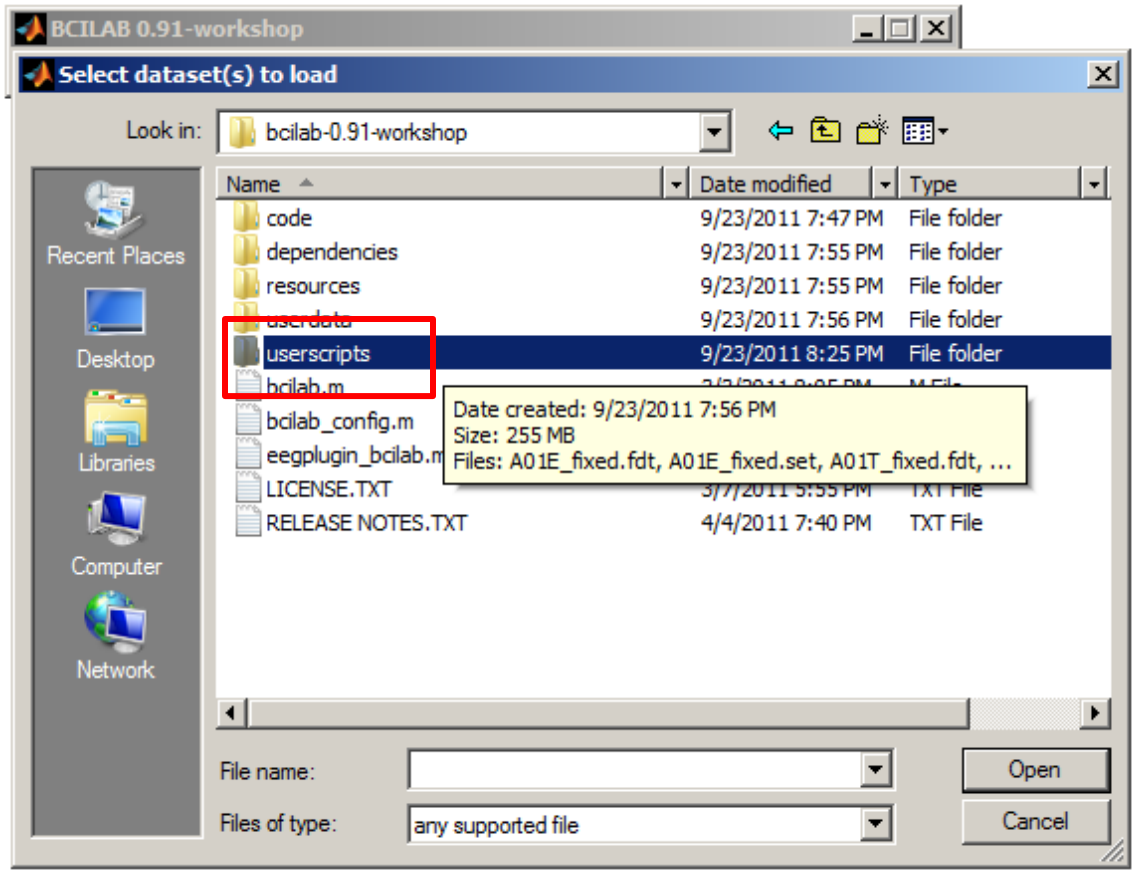
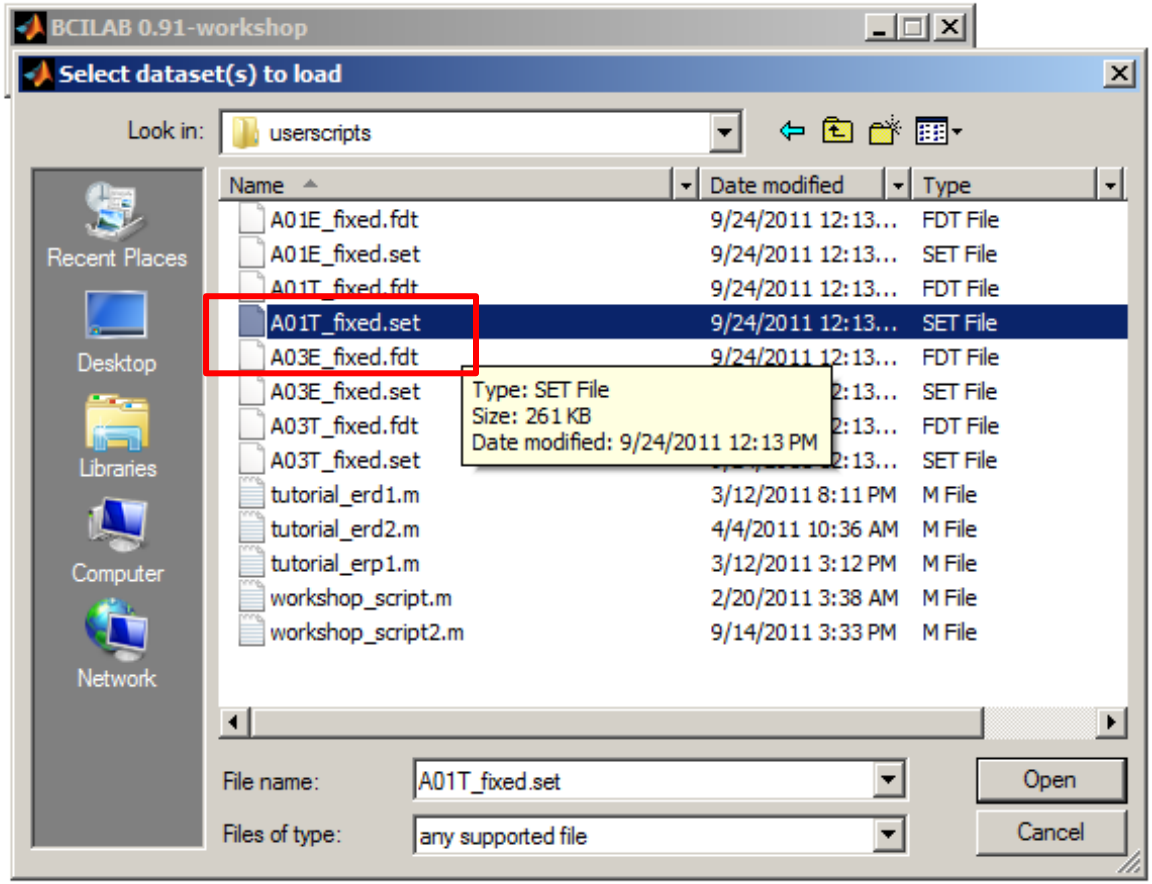


Loading the Data

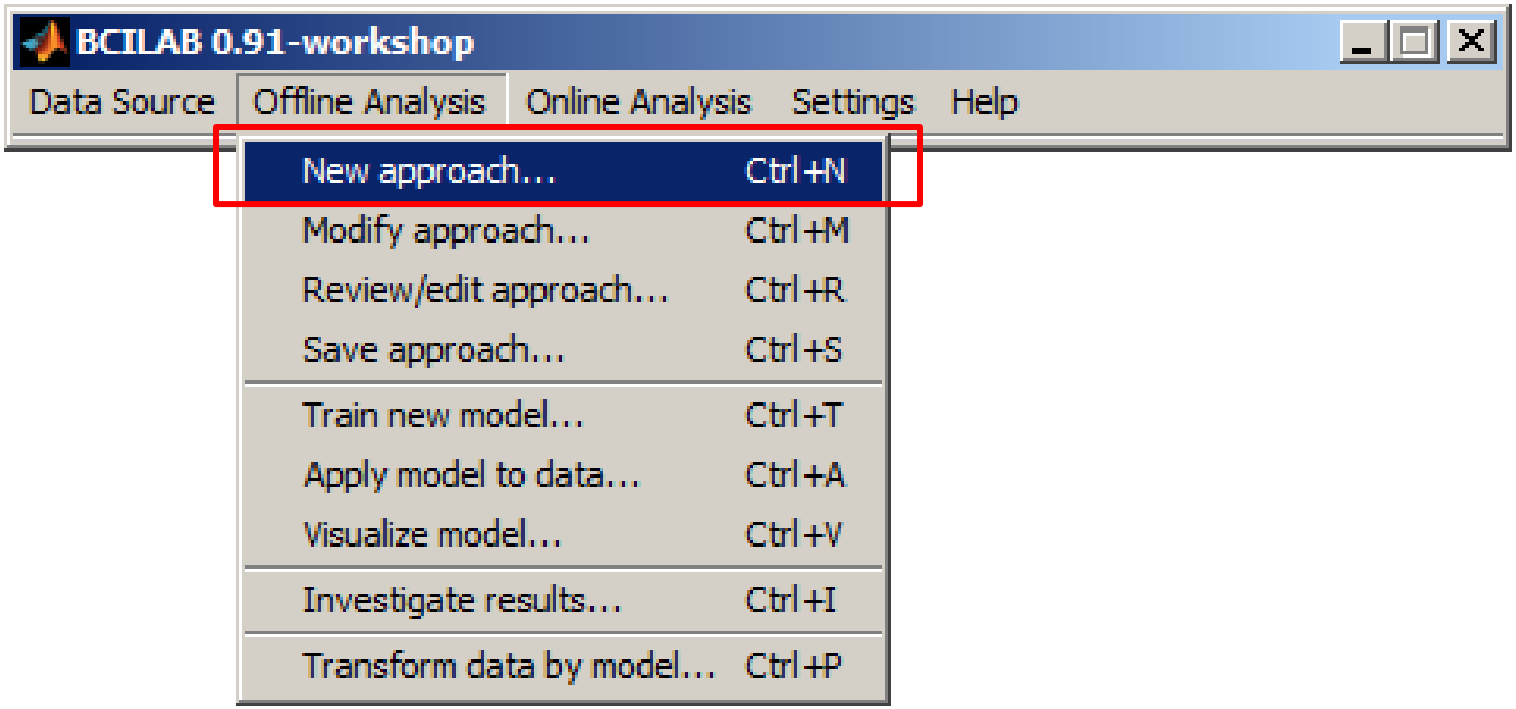


Loading the Data

- Please load A01T_fixed.set (training set #1)

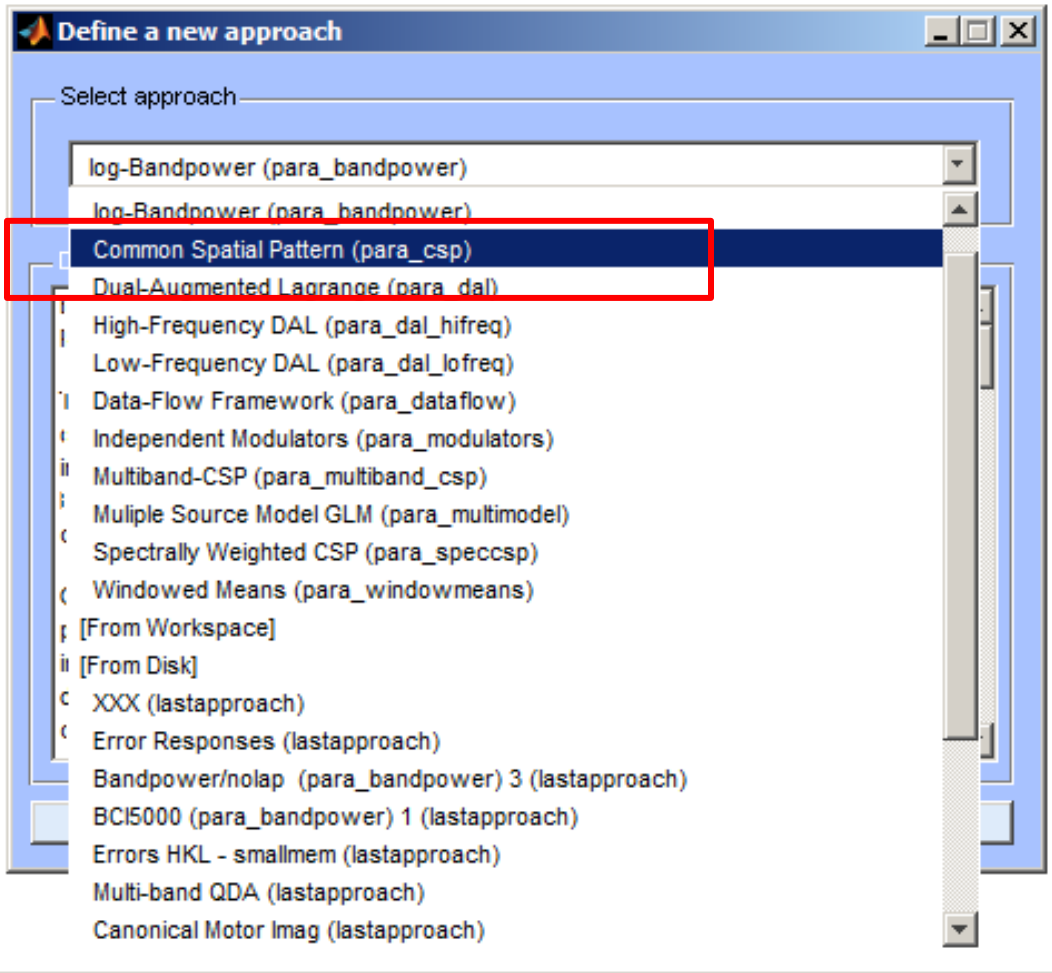


Defining a new Approach

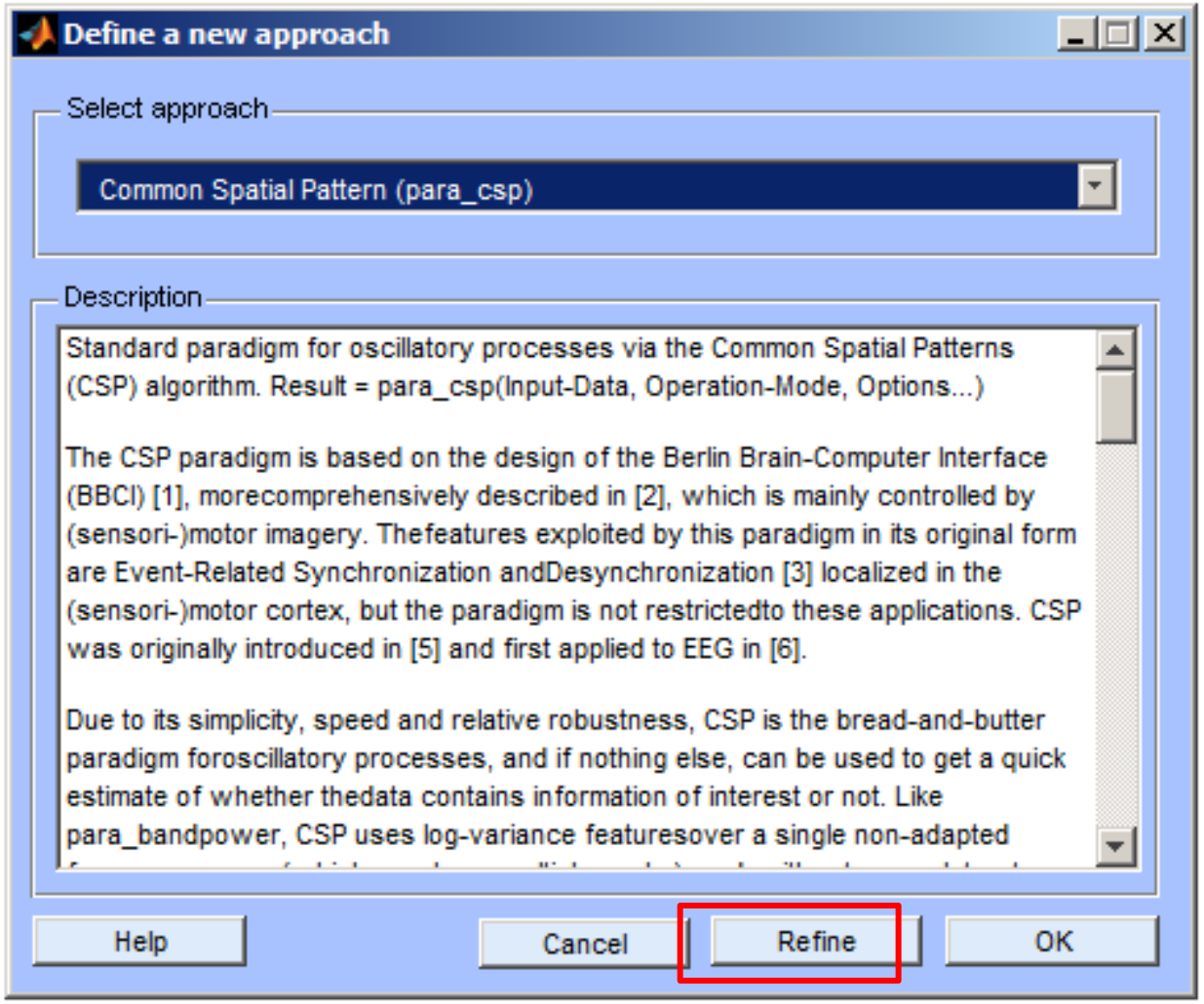


Defining a new Approach

- Let's start with Common Spatial Patterns:

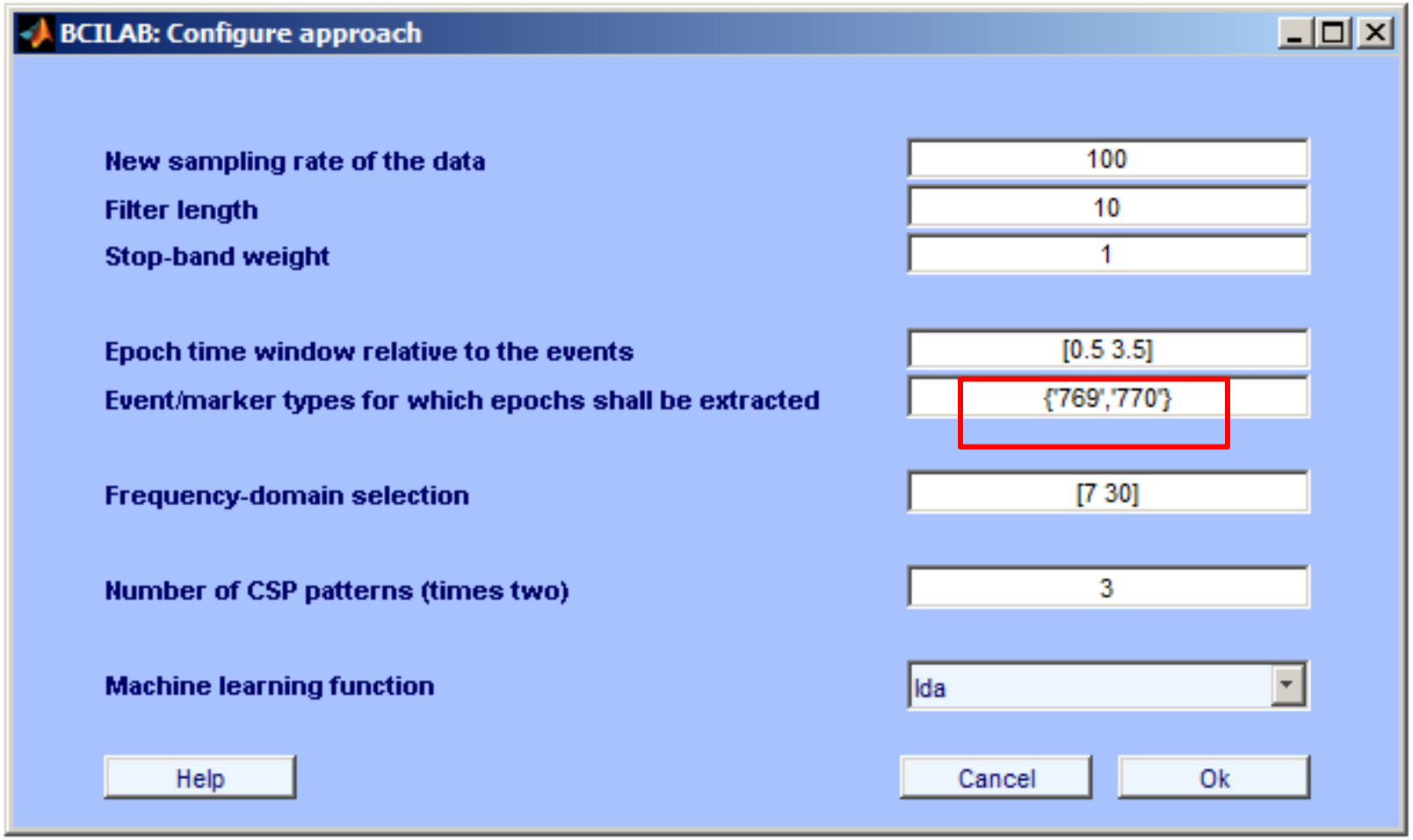


Defining a new Approach

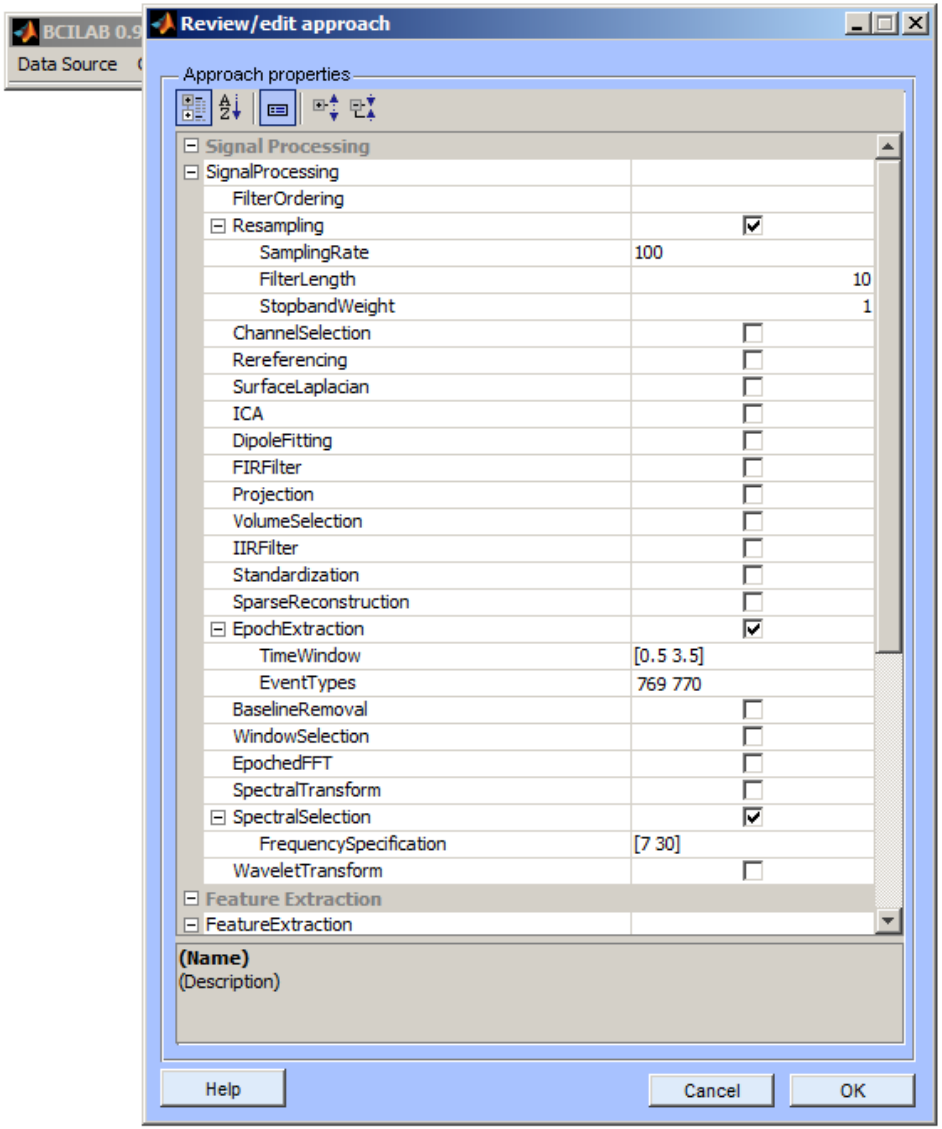


Adapting an Approach

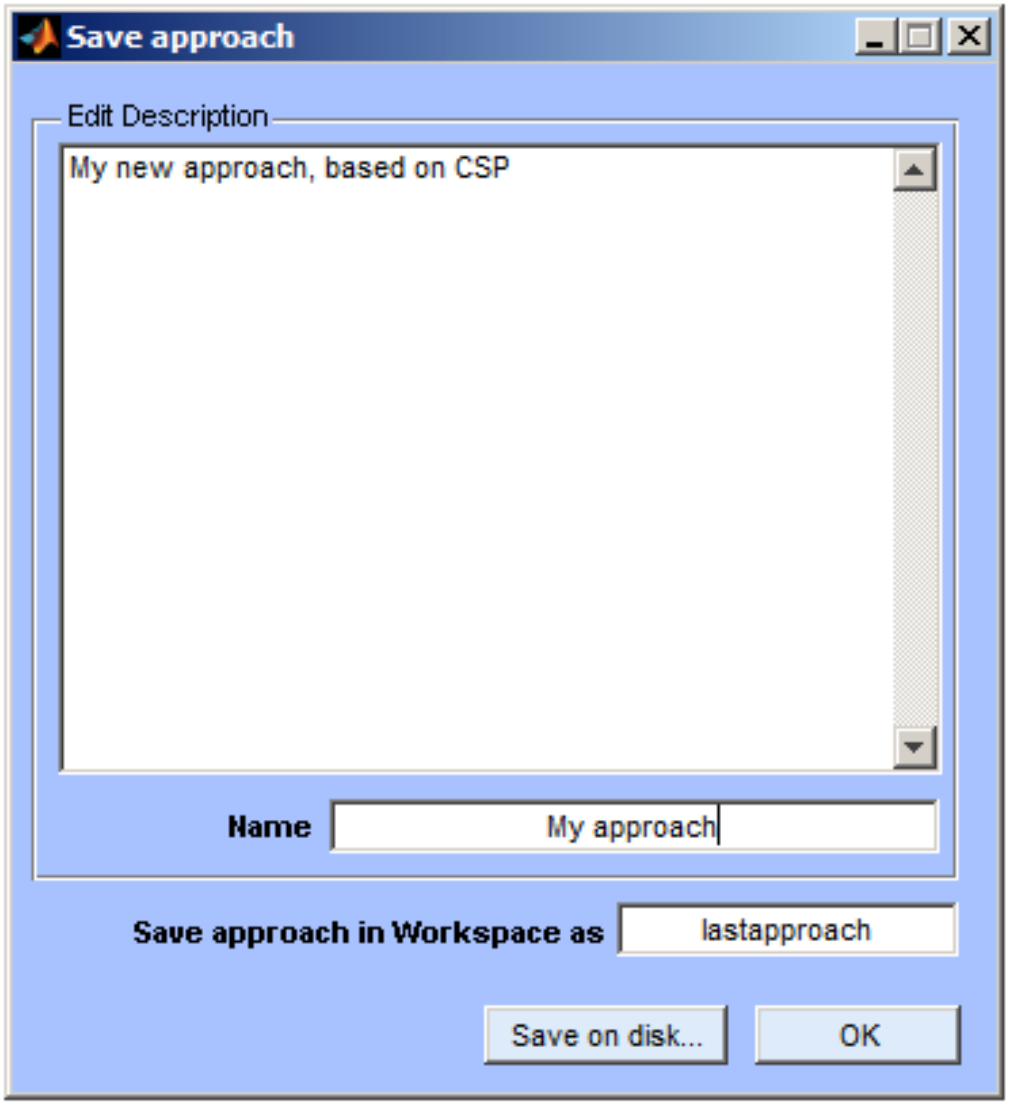
- Marker names are {‘769’,’770’} in this set:



Further Editing an Approach

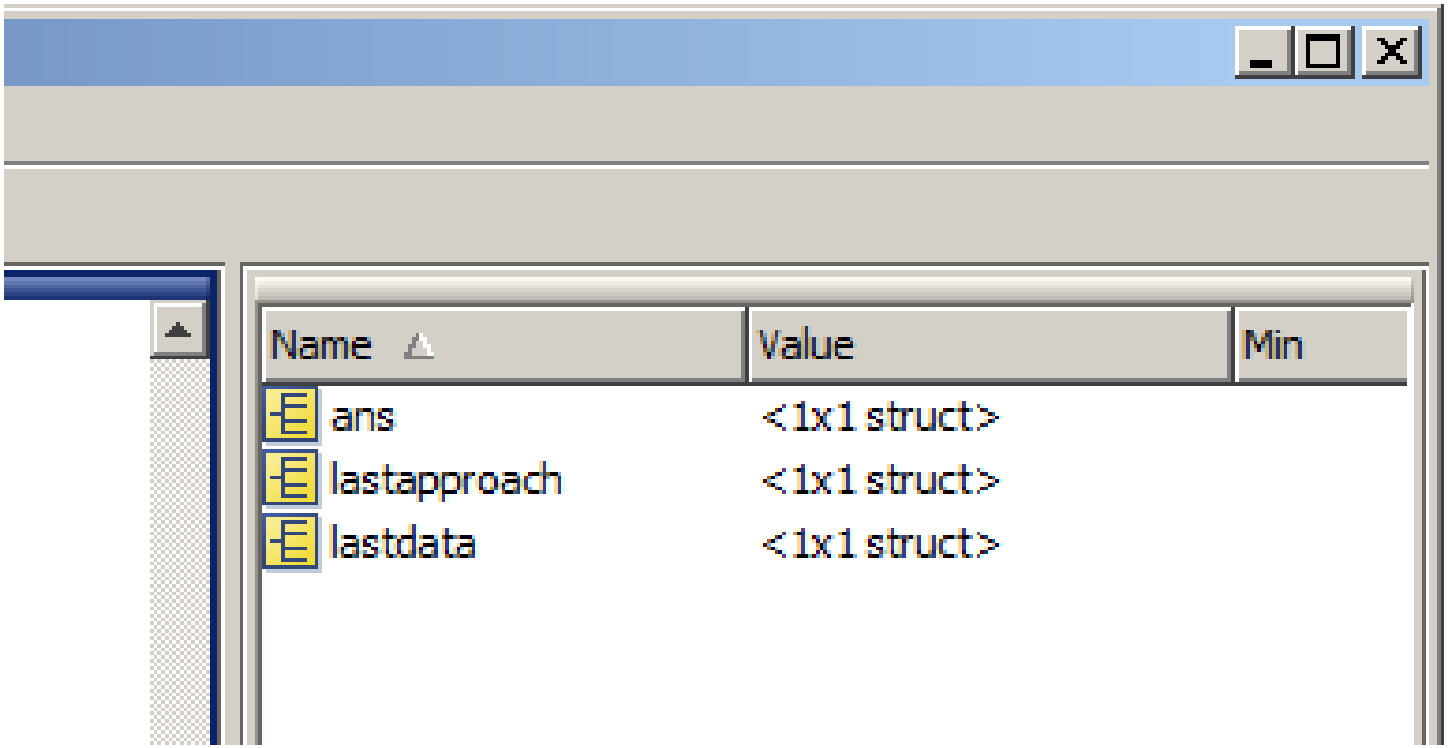


Saving the Approach

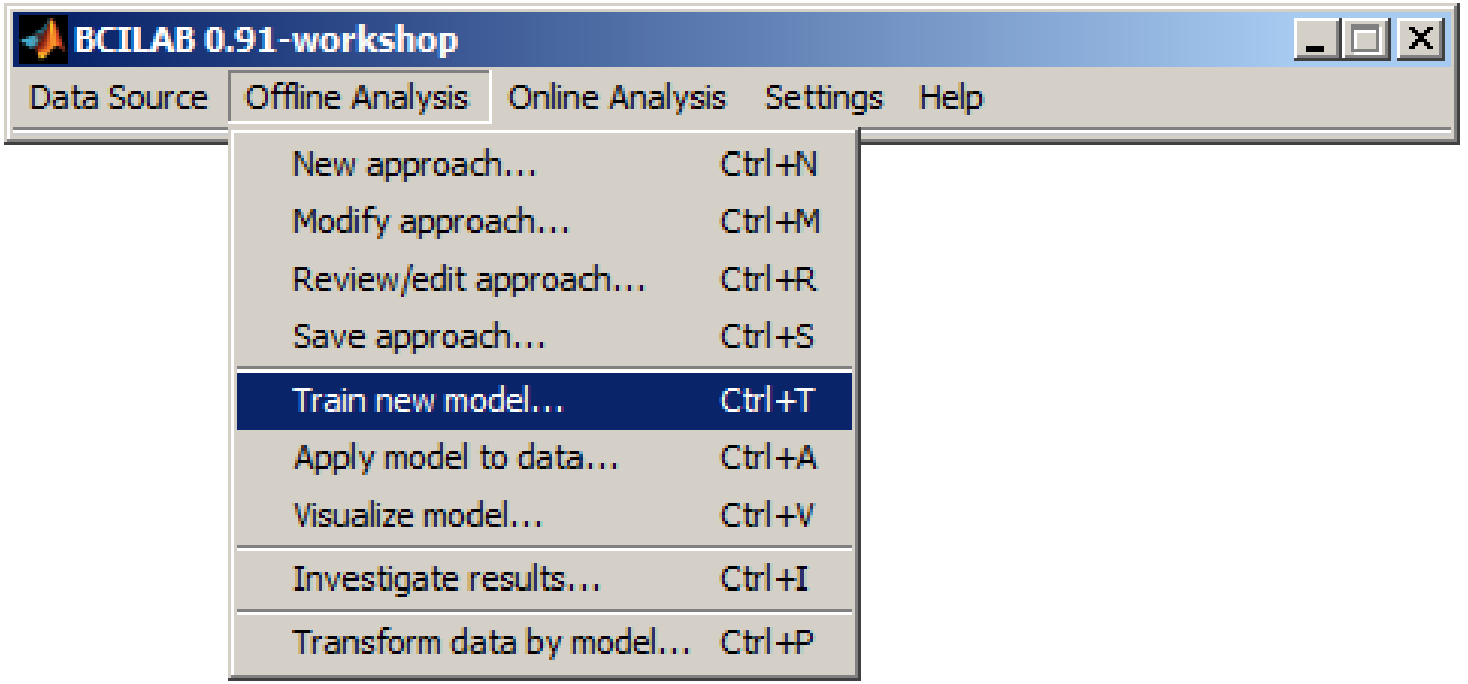


See also: MATLAB's Workspace

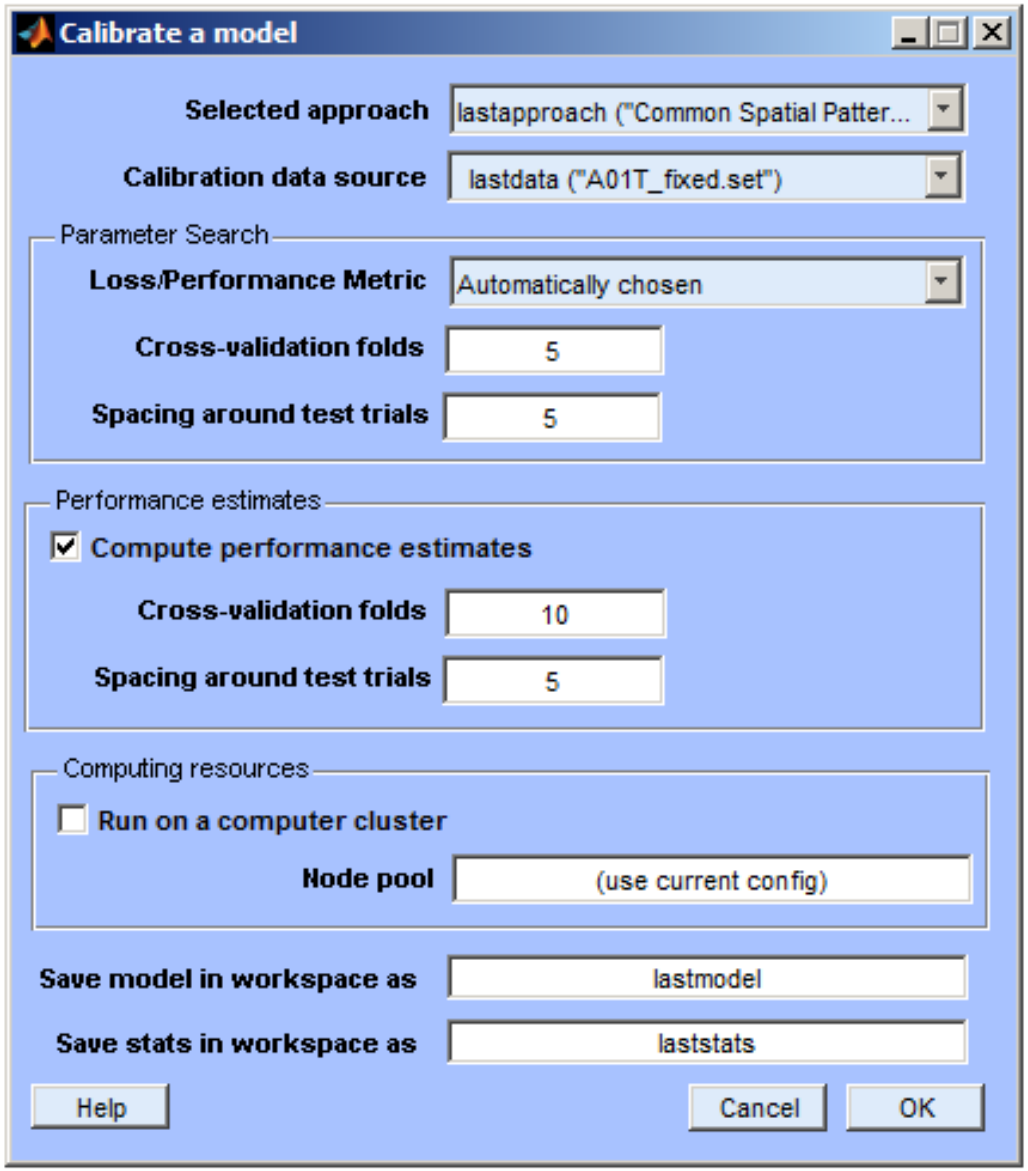
- Can be enabled via "Desktop" menu



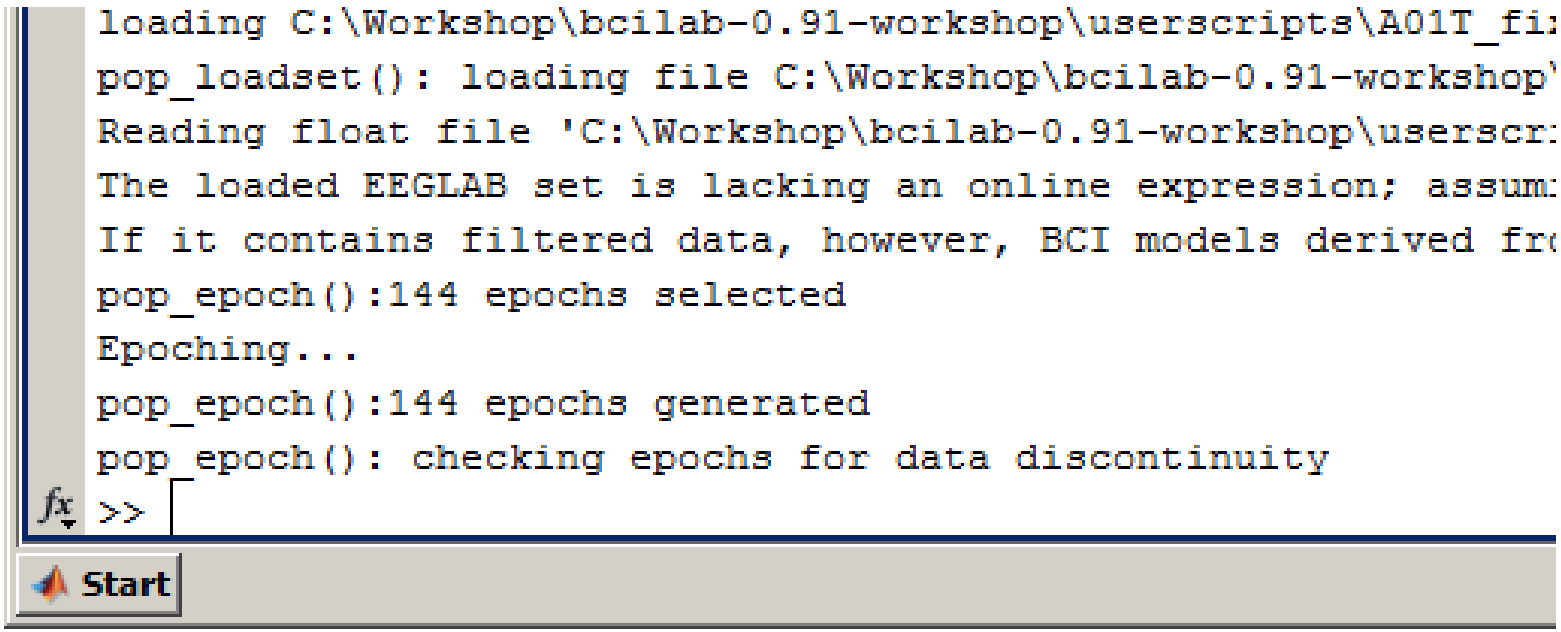
Now Hitting the Data…



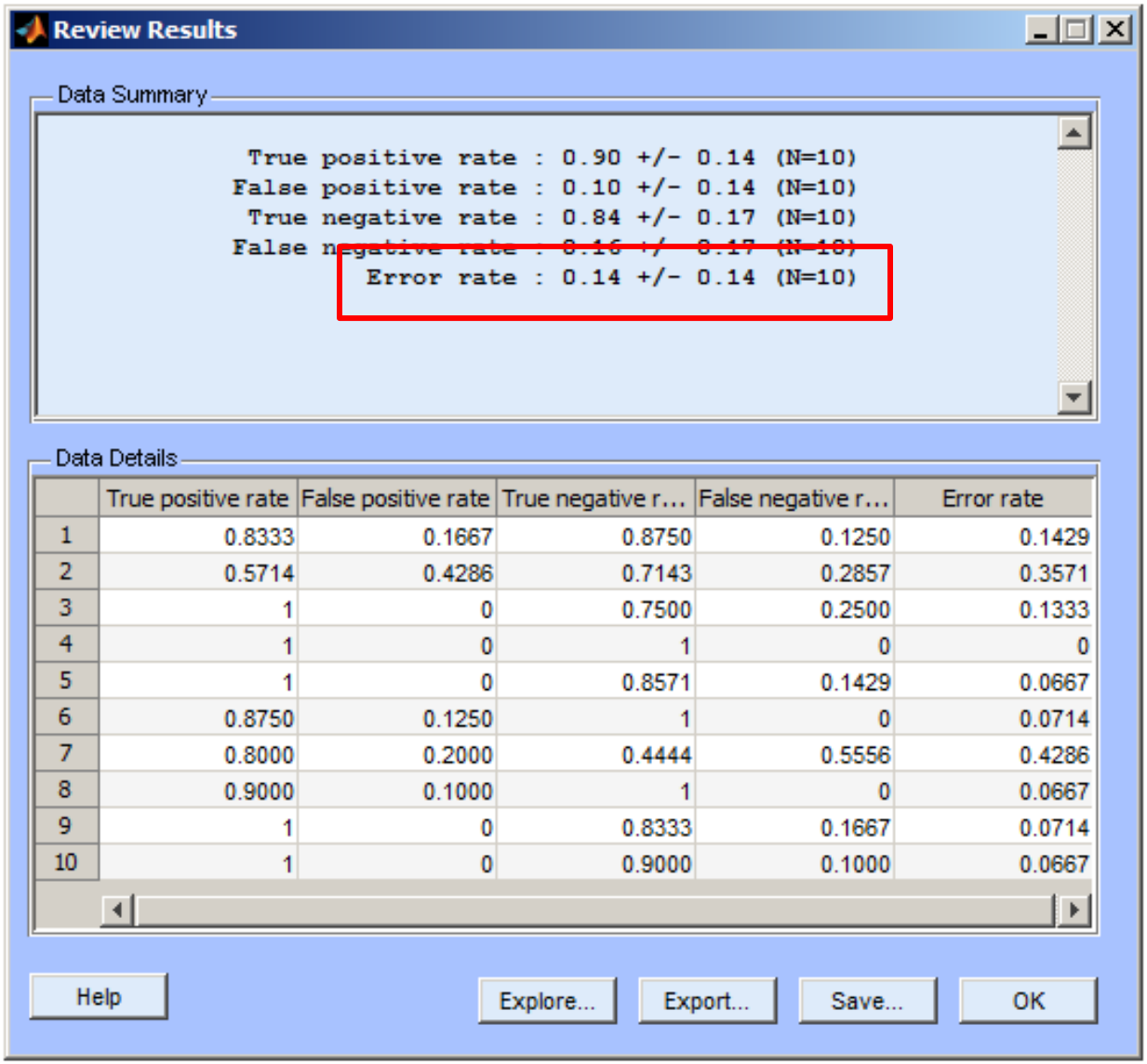
Now Hitting the Data…



Watching the Computation…

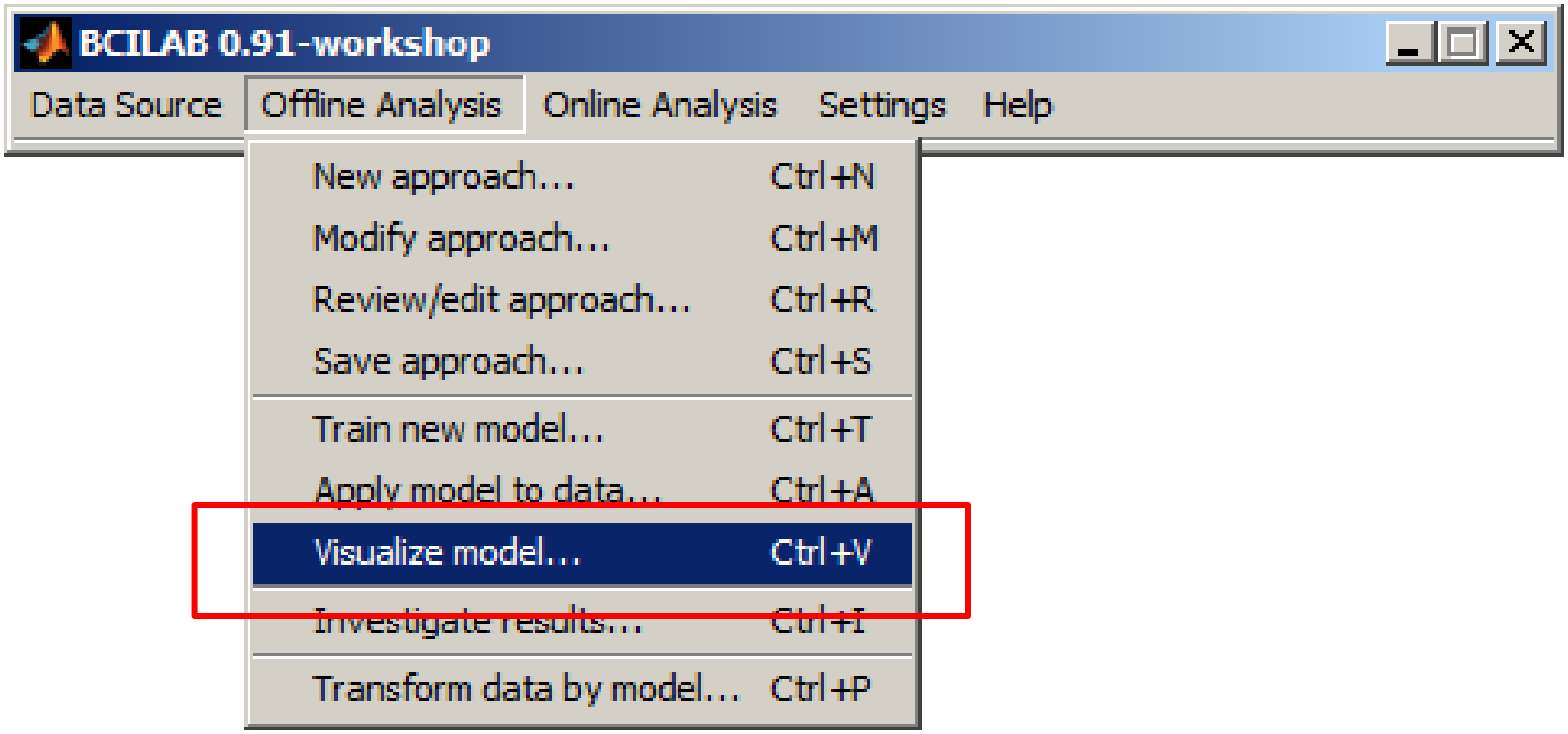


Cross-validation Results:



	True positive rate	False positive rate	True negative r...	False negative r...	Error rate
1	0.8333	0.1667	0.8750	0.1250	0.1429
2	0.5714	0.4286	0.7143	0.2857	0.3571
3	1	0	0.7500	0.2500	0.1333
4	1	0	1	0	0
5	1	0	0.8571	0.1429	0.0667
6	0.8750	0.1250	1	0	0.0714
7	0.8000	0.2000	0.4444	0.5556	0.4286
8	0.9000	0.1000	1	0	0.0667
9	1	0	0.8333	0.1667	0.0714
10	1	0	0.9000	0.1000	0.0667

Visualizing a Trained Model



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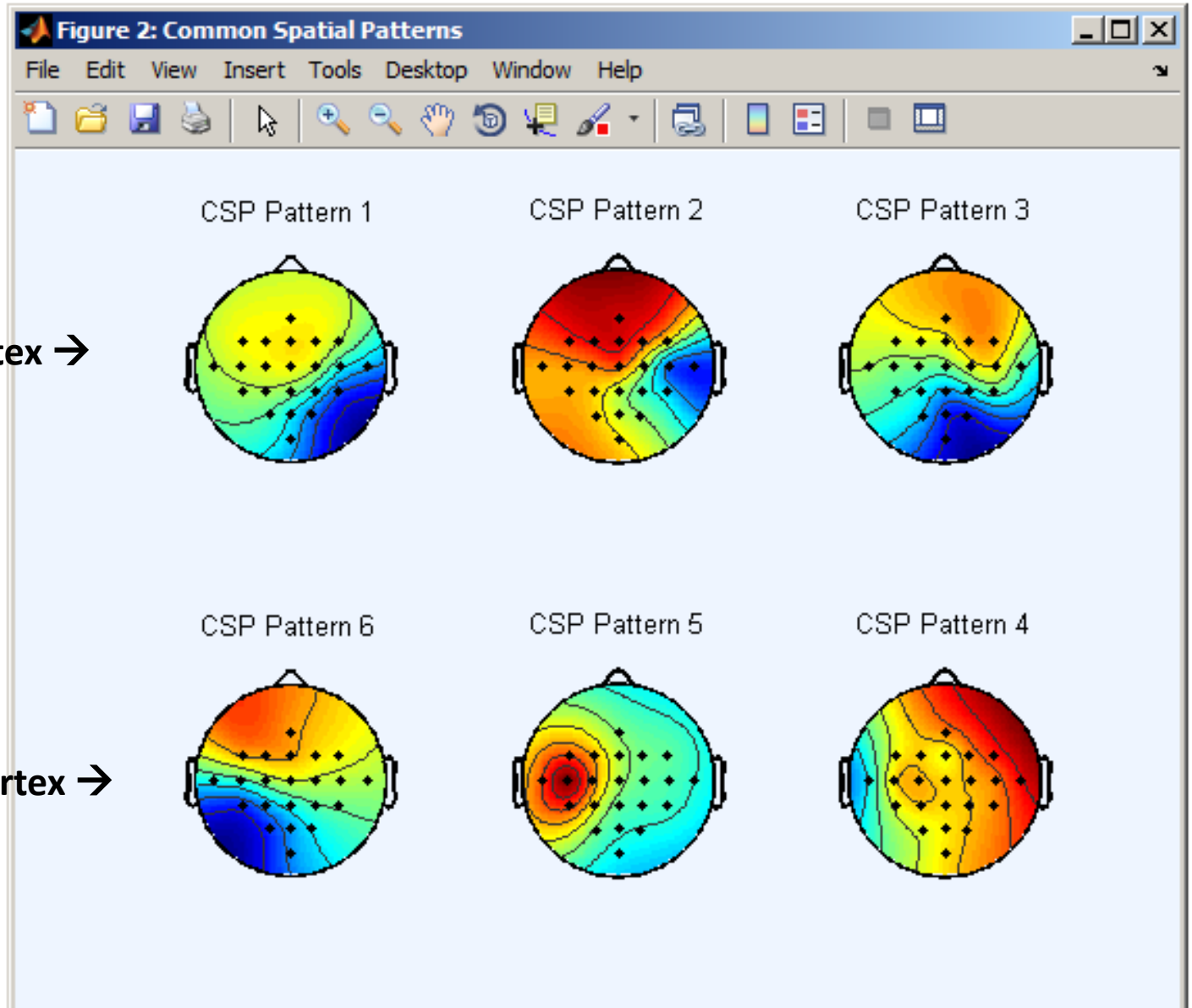
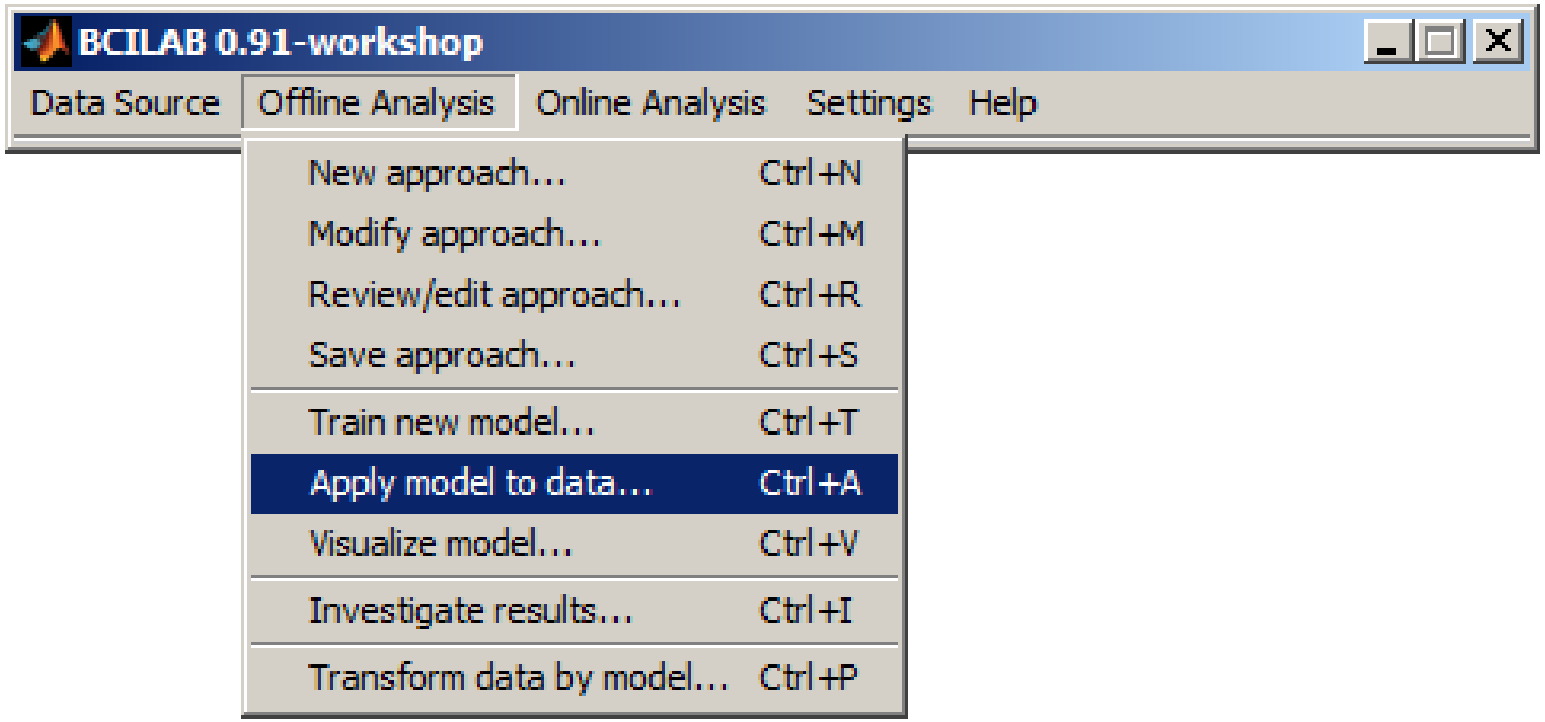


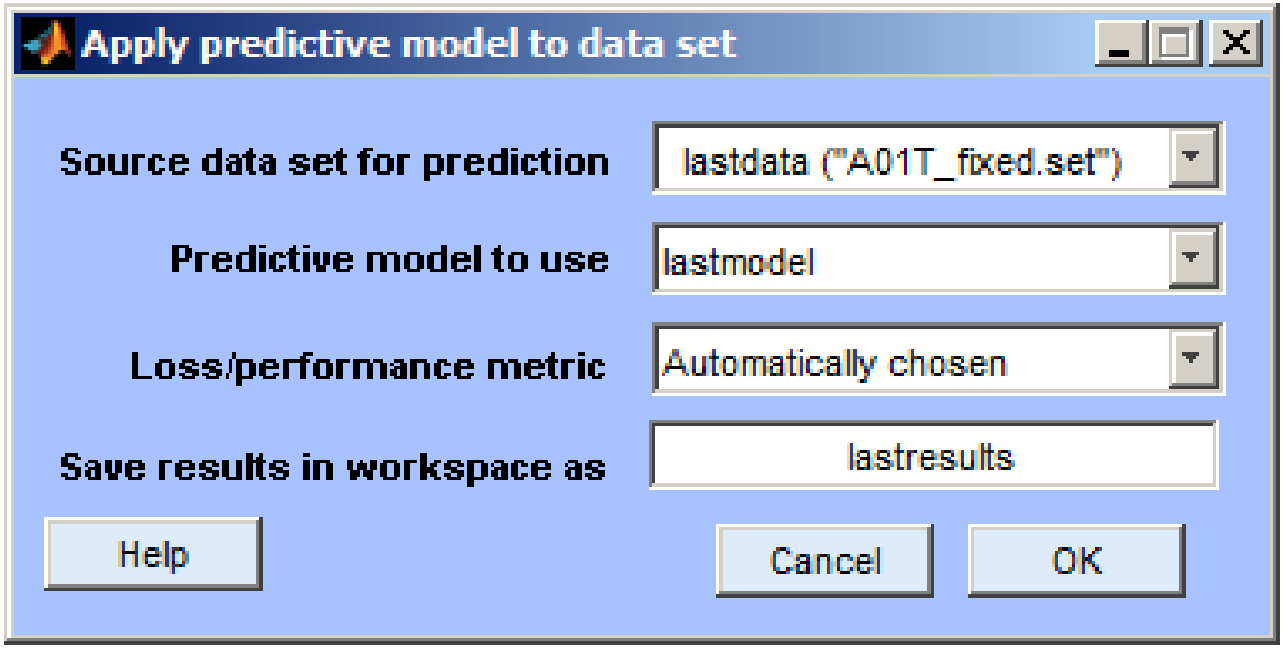
Left hand motor cortex →

Right hand motor cortex →

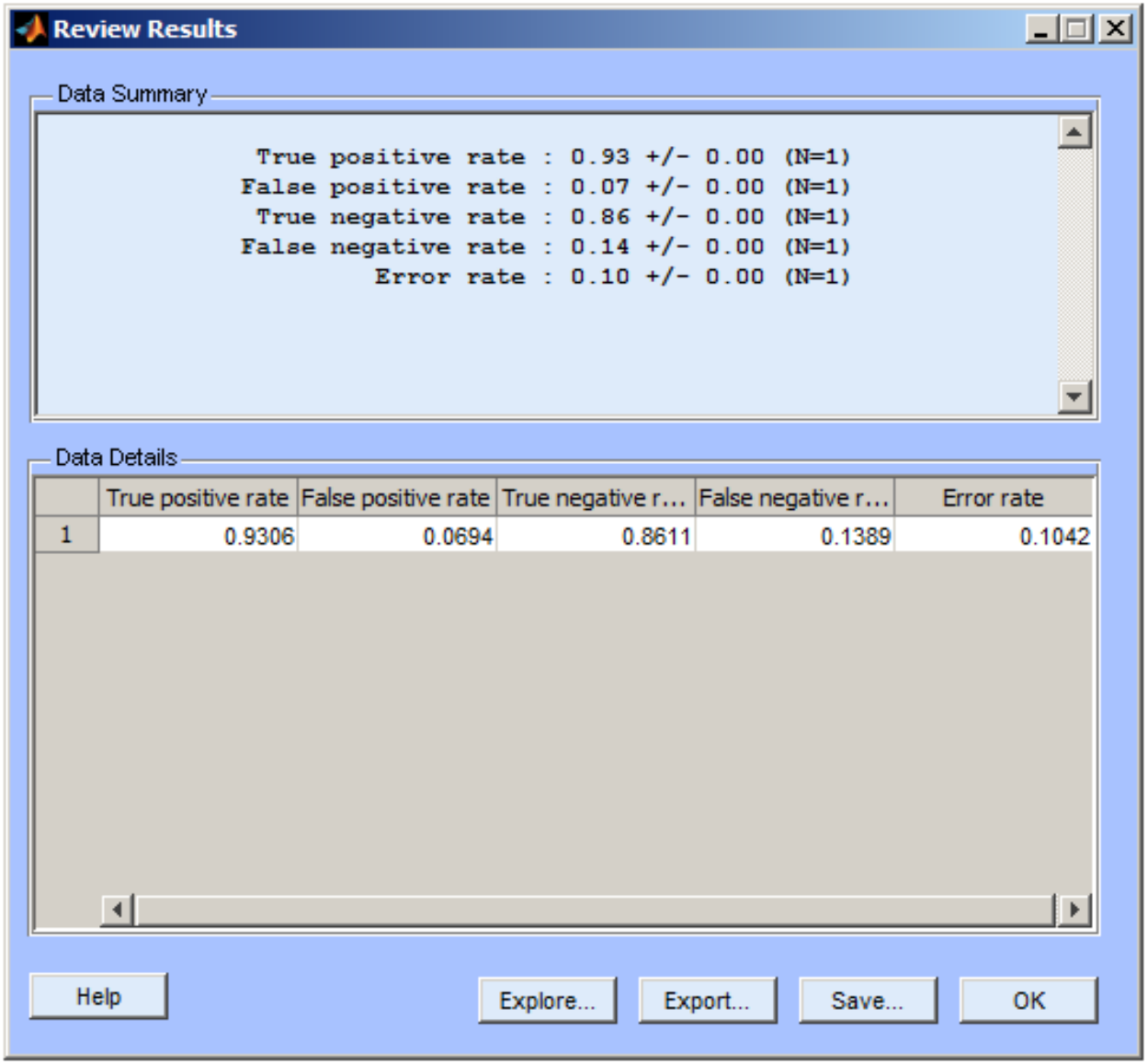
Applying a Model to New Data



Applying a Model to New Data

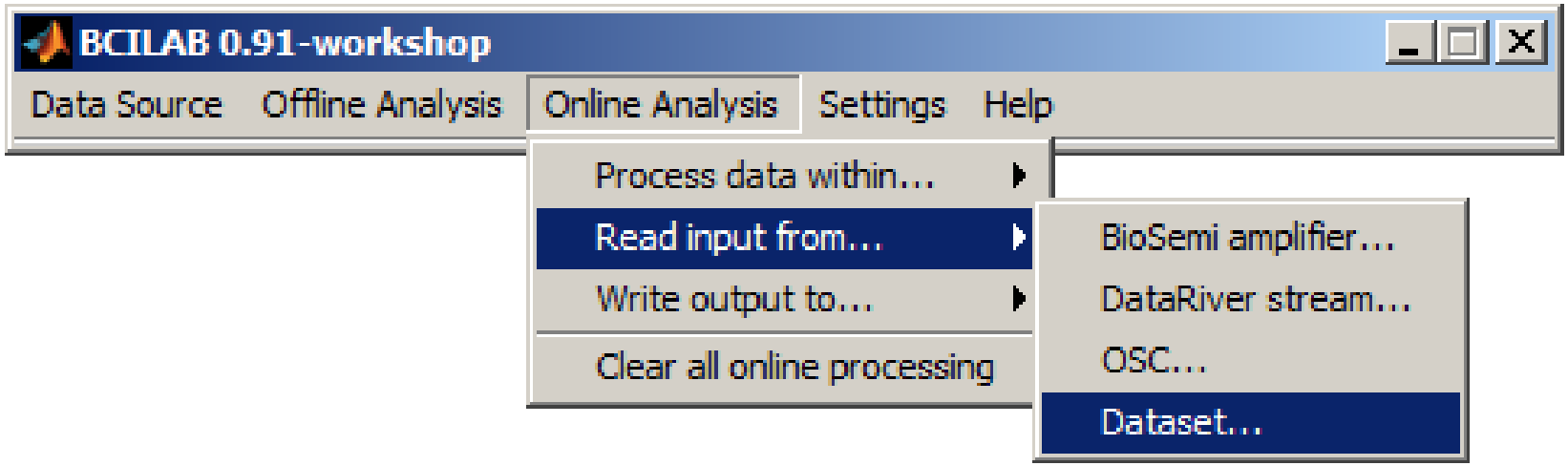


Results: Training-Set Error



Online Processing

- For lack of EEG hardware, play back a data set in real time:

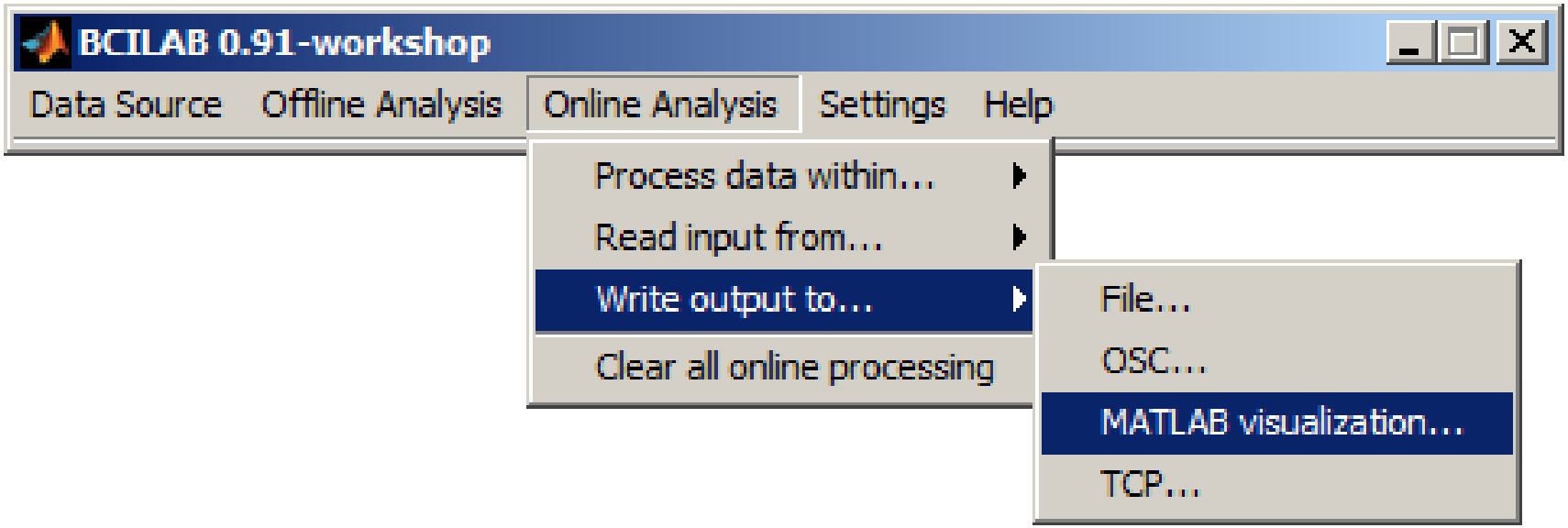


Online Processing

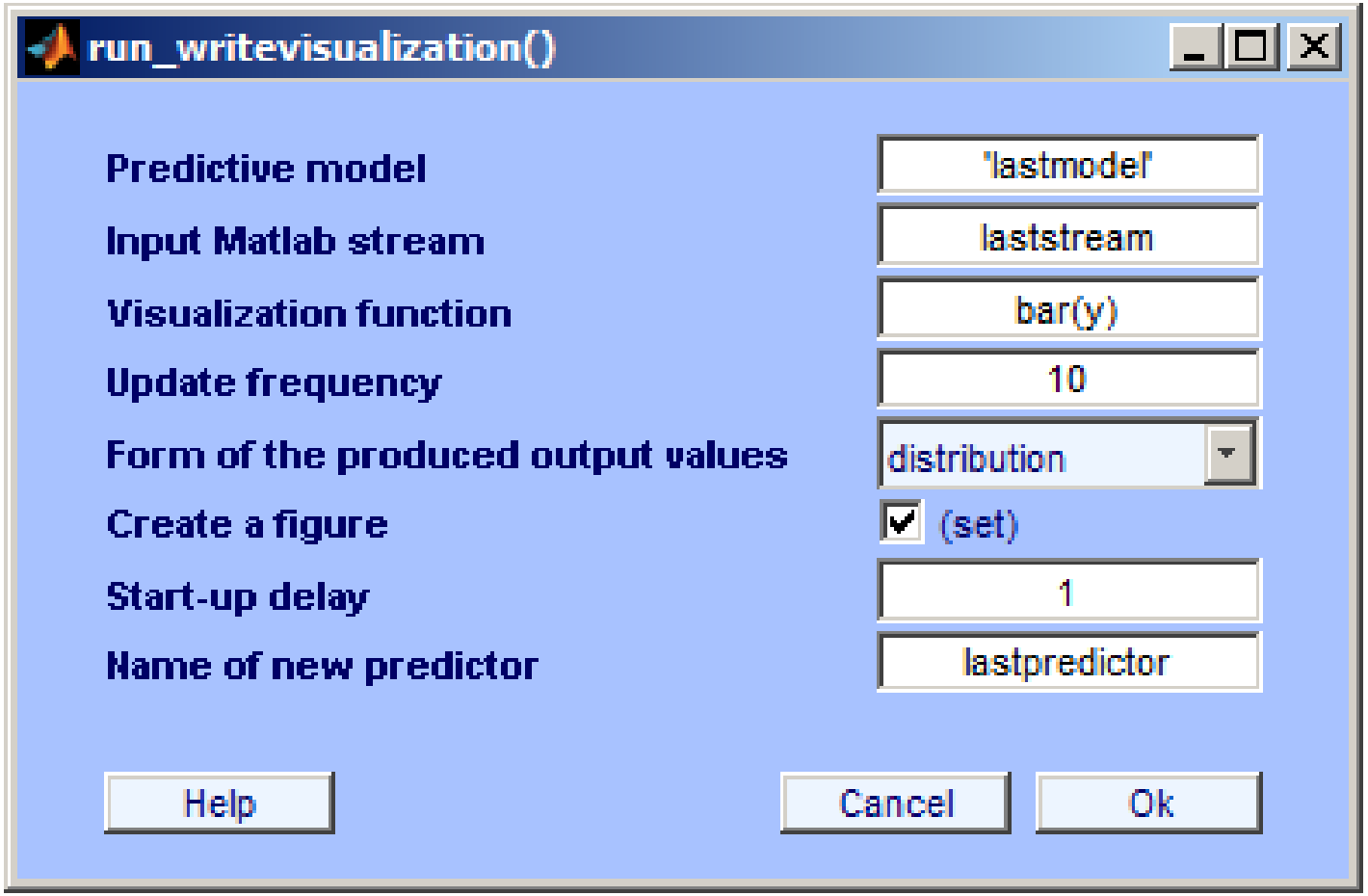
- For lack of EEG hardware, play back a data set in real time:

Online Processing

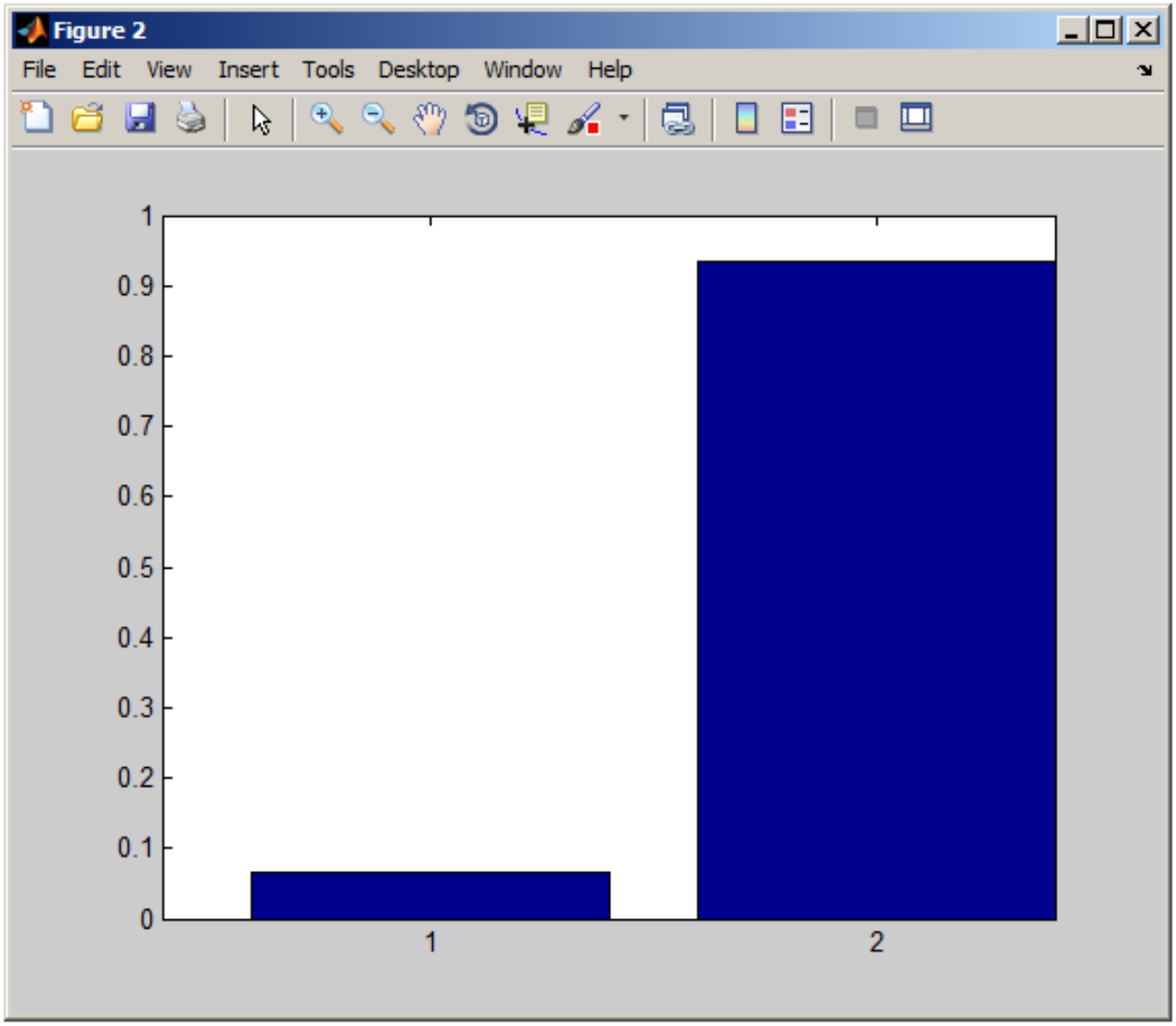
- Choosing a destination for outputs:



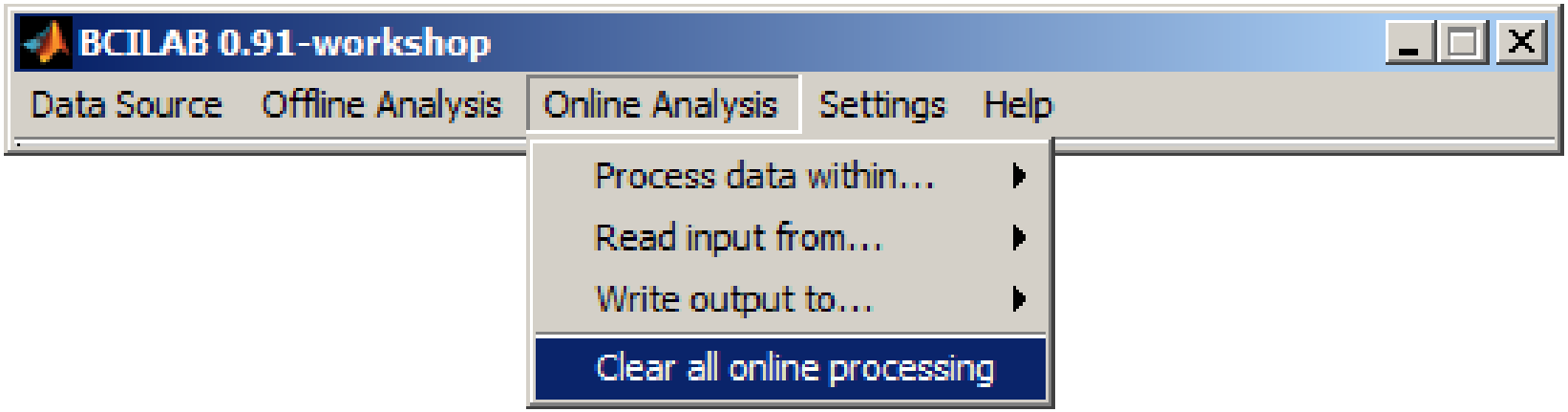
Setting up a Visualization



Real-time Class Probabilities



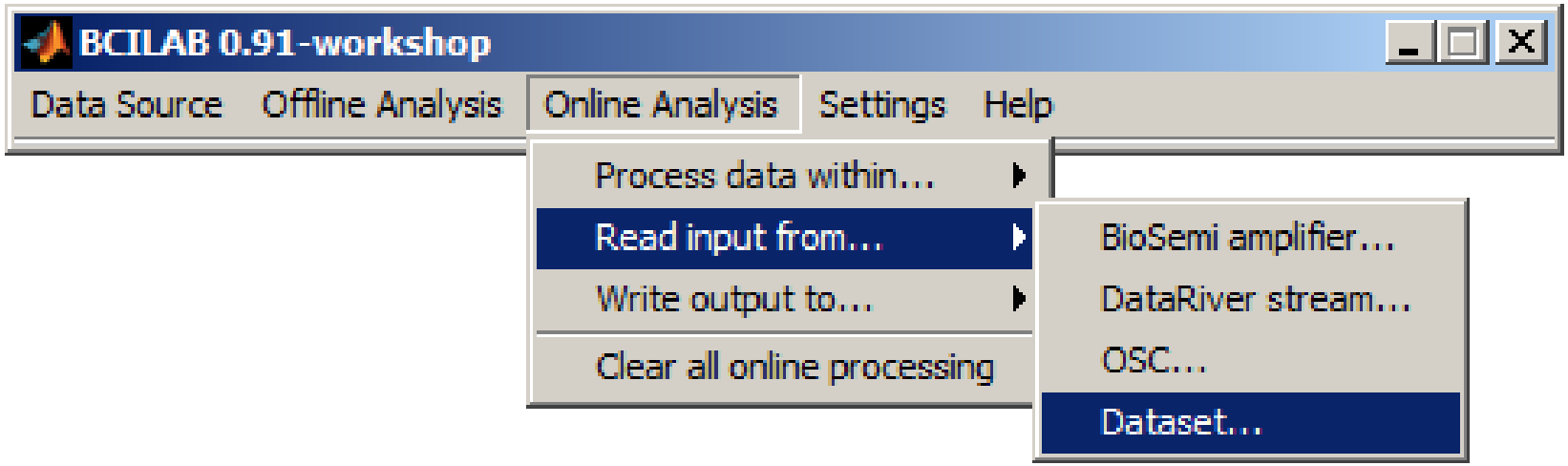
Clearing the Online Processes



Fancier Visualization

Online Processing

- For lack of EEG hardware, play back a data set in real time:

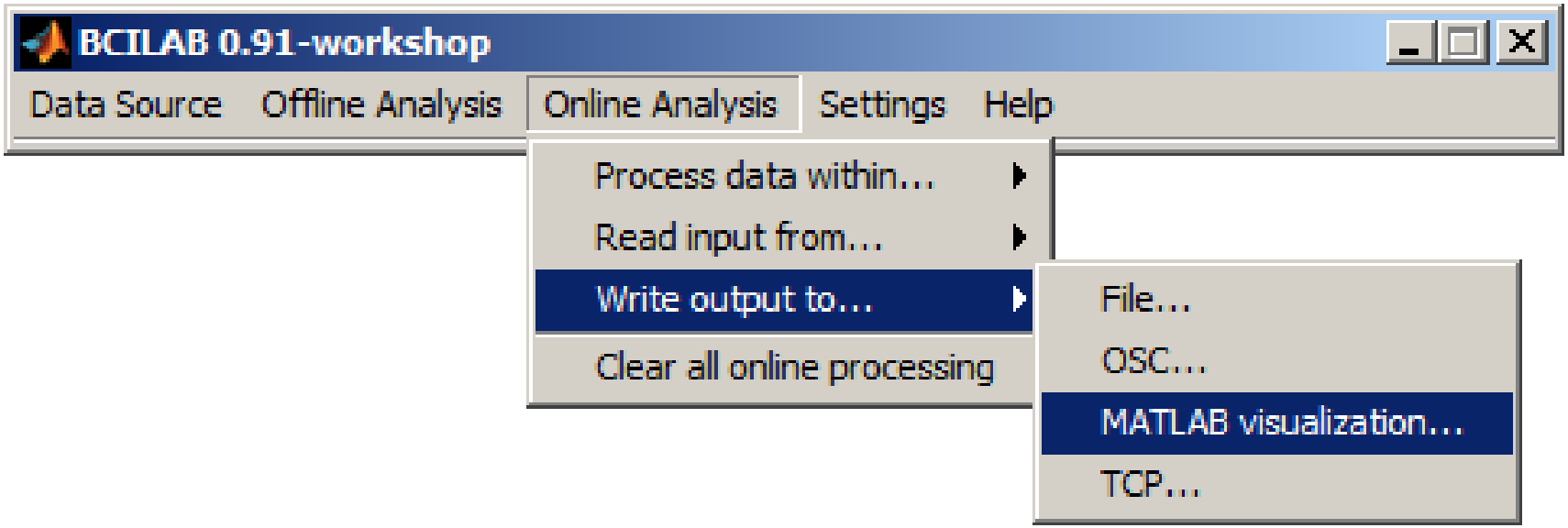


Online Processing

- For lack of EEG hardware, play back a data set in real time:

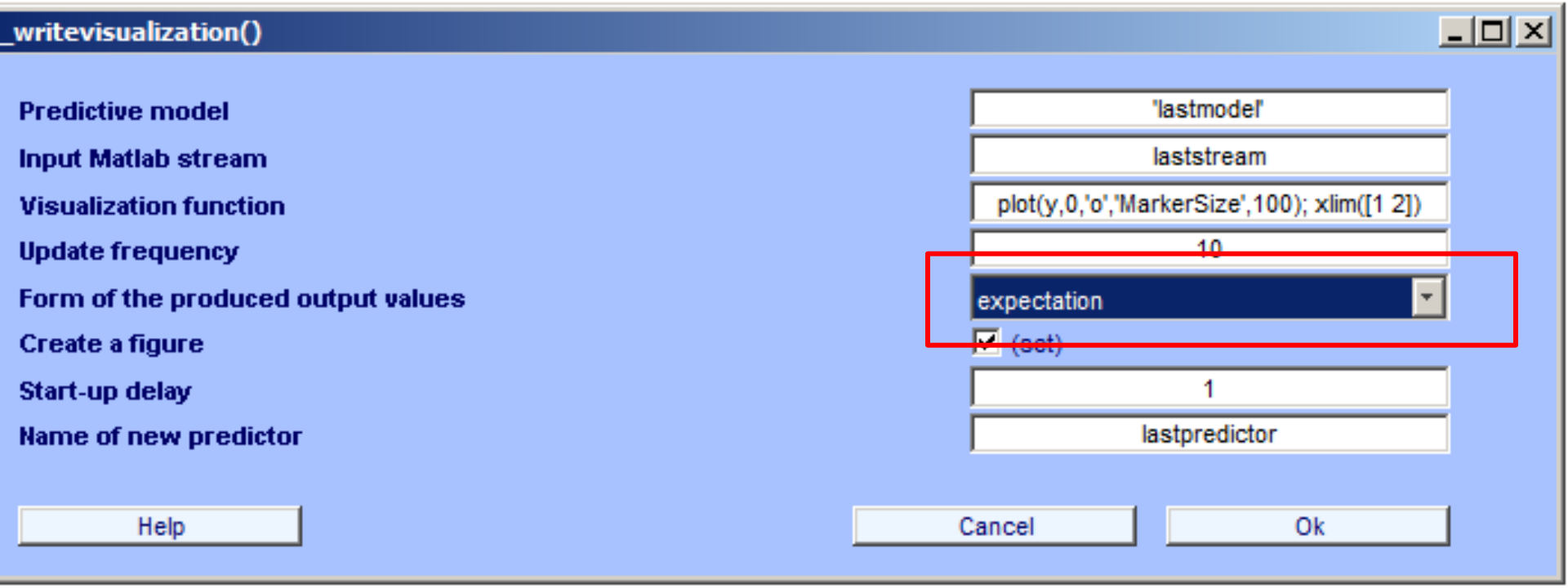
Online Processing

- Choosing a destination for outputs:



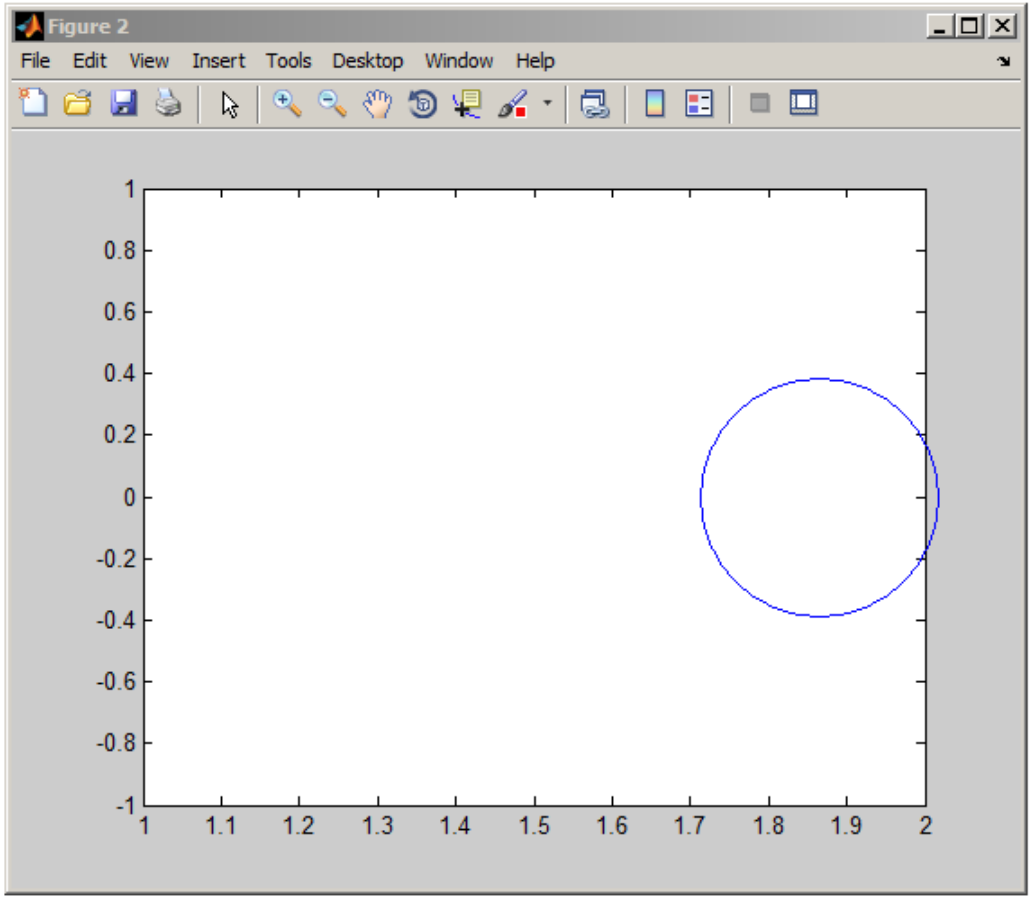
Setting up a Visualization

- The command is:
  plot(y,0,'o','MarkerSize',100); xlim([1 2])

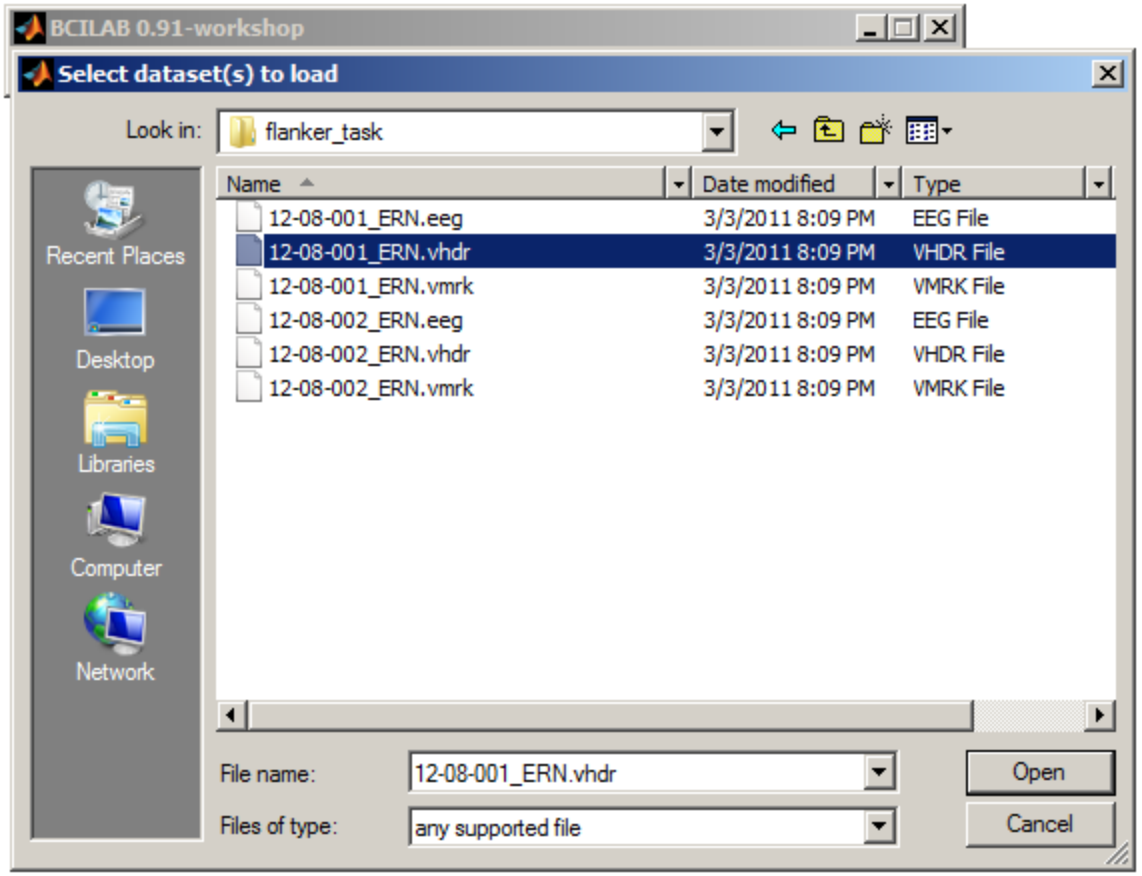


Real-time Class Probabilities

- The sphere indicates the imagined movement side



Looking at ERP Data



Setting up

- Markers: {{'S101','S102'},{'S201','S202'}}
- Time Windows: [0.25 0.3;0.3 0.35;0.35 0.4; 0.4 0.45;0.45 0.5;0.5 0.55;0.55 0.6]
- Freq flt: [0.1 15]
- Epoch: [0 0.8]