Signal processing and data analysis in Matlab

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Outline

1. Introduction to Pandora

2. Analyzing voltage trace data
   - Loading a membrane voltage trace
   - Analyzing a membrane voltage trace

3. Database analysis with Pandora
   - Creating a database from arbitrary data
   - Creating a database from analysis of traces
   - Multivariate analysis with database objects

4. Conclusion

Why should I use a Matlab toolbox?

Use it if:

1. You are already using Matlab
2. Python and other environments are too complex or unsustainable in your lab

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Seriously, why would anyone still use Matlab?

1. If you're just starting in computational neuroscience, probably the best option is using Python (Jupyter notebooks, etc)
2. However, even though Python and its modules have improved considerably, they still require a bit of maintenance
3. Matlab still has its audience in non-programmer, scientist communities (e.g. experimentalists)
4. Also many researchers can't quit Matlab because of inherited legacy code

Main features of the Pandora toolbox

Has several independent, major features—not limited one type of data or analysis:

1. Extracting electrophysiological properties from intracellular recordings
   - Can **find spikes** from a membrane voltage trace using multiple methods
   - Frequency **filtering** of data (lowpass, bandpass, highpass)
   - **Finding bursts** and analyzing their properties
   - You can **add any other custom measurement** yourself
   - Made to **process large number of files** and produce uniform database output

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2. Analysis of model or experimental data using a *Dataframe*-like objects
   - Creating a database from tabular data for **querying** and **plotting**.
   - Putting results from analysis of voltage traces of multiple models into a database.
   - Advanced operations with a database: **statistics, multivariate analysis**, etc.

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3. Improved plotting functions
   - Matlab's plotting functions are augmented
   - Can **stack subplots** that share same axes
   - **Control spacing** between subplots
   - Render plots based on export size to produce **publication-quality figures**

Newer features of the Pandora toolbox

1. Simple model simulation and parameter fitting
   - Can simulate simple neuronal structures such as single **ion channels and passive membrane**
   - Useful for fitting responses from **voltage and current clamp protocols**
   - For instance, you can **compensate for series resistance artifacts**
   - Used in Gunay et al (2015) *PLOS Comp Bio* Gunay et al (2015) PLOS Comp Bio and packaged separately as param-fitter

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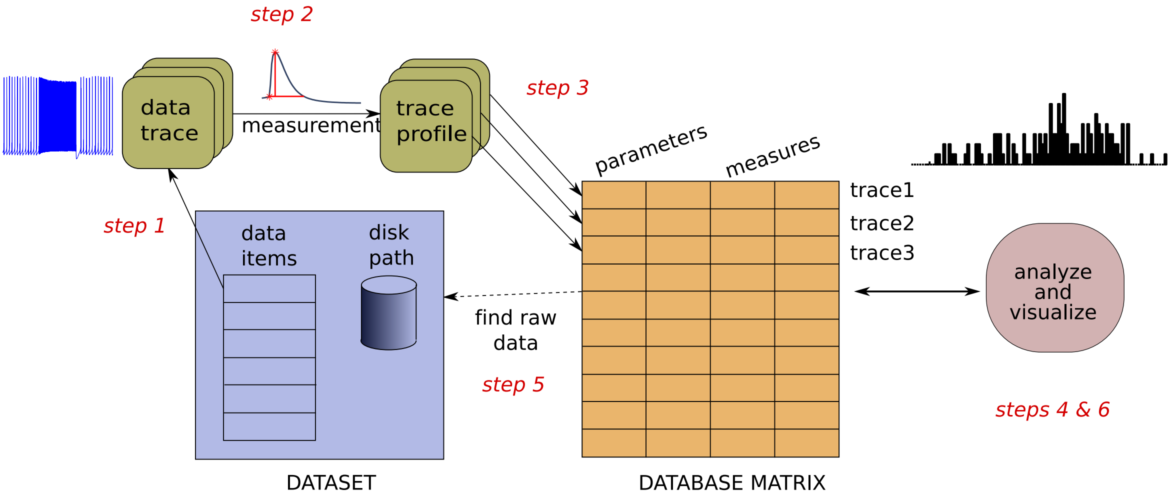
   - Used in Gunay et al (2015) *PLOS Comp Bio* Gunay et al (2015) PLOS Comp Bio and packaged separately as param-fitter
2. Model simulation parameter optimization
   - Uses the GODLIKE toolbox that can run **multiple optimization algorithms** (multi-objective evolutionary algorithms, swarm, ...)
   - Can **control running simulations** by calling an external simulator like Neuron, GENESIS, etc)
   - Experimental feature used in Gunay et al (2019) *eNeuro* and published on Github

Pandora is originally described in Günay et al. (2009) *Neuroinformatics*; and documentation can be found on Github and Mathworks File Exchange pages.

The basic Pandora workflow



step 2

data
trace

measurement

trace
profile

step 3

parameters

measures

trace1

trace2

trace3

step 1

data
items

disk
path

find raw
data

step 5

analyze
and
visualize

steps 4 & 6

DATASET

DATABASE MATRIX

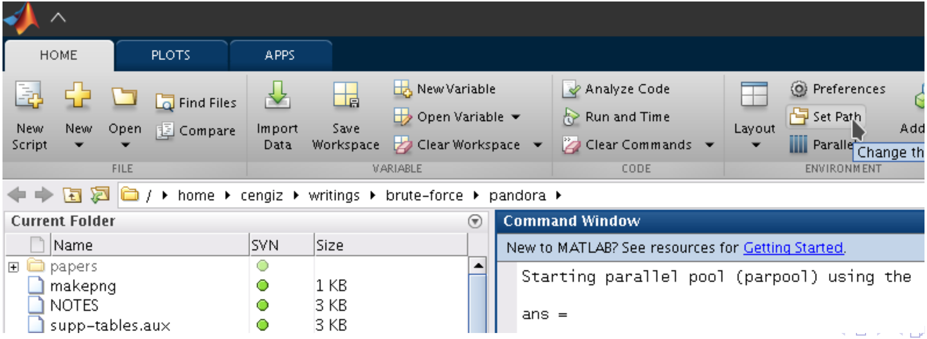
Installing the Pandora toolbox

Download from:

- Mathworks File Exchange (see below if you don't want to create an account)

Installation: Follow instructions on Github

- Extract ZIP
- Add **classes** and **functions** folders to the Matlab search path:



/ ▸ home ▸ cengiz ▸ writings ▸ brute-force ▸ pandora ▸

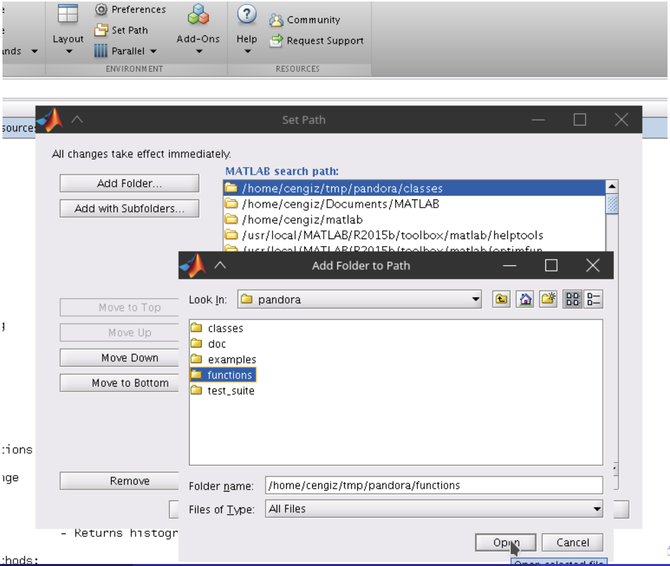
Name	SVN	Size
papers	●	
makepng	●	1 KB
NOTES	●	3 KB
supp-tables.aux	●	3 KB

New to MATLAB? See resources for Getting Started.

```
Starting parallel pool (parpool) using the

ans =
```

Matlab path should look like this



All changes take effect immediately.

MATLAB search path:

```
/home/cengiz/tmp/pandora/classes
/home/cengiz/Documents/MATLAB
/home/cengiz/matlab
/usr/local/MATLAB/R2015b/toolbox/matlab/helptools
/usr/local/MATLAB/R2015b/toolbox/matlab/optimfun
```

Look In: pandora

```
classes
doc
examples
functions
test_suite
```

Folder name: /home/cengiz/tmp/pandora/functions

Files of Type: All Files

Testing the installation

In Matlab type:

```
>> help tests_db
```

Your installation is **successful** if you see:

```

tests_db - Construct a numeric database organized in a matrix format.

  Usage:
  obj = tests_db(test_results, col_names, row_names, id, props)
[and a lot more here]
...
```

Otherwise, it is **broken** if you see:

```
>> help tests_db
tests_db not found.
```

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Loading a membrane voltage trace

Pandora can read the file formats from:

1. Simulators:
   - Neuron, Genesis, others can be added
2. Data acquisition programs:
   - All NeuroShare-compatible acquisition devices (Alpha Omega, Cambridge Electronic Design, NeuroExplorer, Plexon, R.C. Electronics Inc., Tucker-Davis Technologies, and Cyberkinetics Inc., etc.)
3. Other:
   - Simple text file, CSV, Hierarchical data format (HDF5)

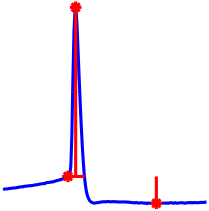
Tutorial demo on Github

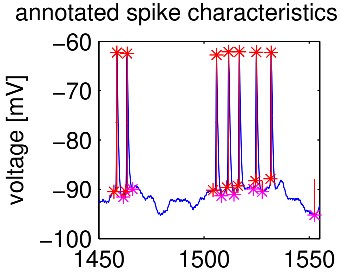
Analyzing a membrane voltage trace

By extracting electropysiological characteristics

- Measure spike shape and firing rate properties
- Measure sag, spike adaptation and current response properties
- Can be done repetitively for a large number of models
- Can be entered into a Matlab database

Tutorial demo on Github





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Database analysis in Pandora

What do we mean by database analysis?

- Labeling columns and rows of numerical matrices.
- Makes scripts more readable
- Labels propagate into plots and reports, reducing human errors.

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It's not new:

- R had similar concept of *Dataframe* earlier
- Python acquired Dataframes with the *pandas* package, around the same time as Pandora :)
- Matlab introduced the `table` command recently, with similar functionality
- Pandora still offers some benefits as an integrated environment

Creating a database from arbitrary data

Create a 2 × 2 database matrix:

	col1	col2
row1	1	2
row2	3	4

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With Matlab code:

```
>> db_obj =
        tests_db([1 2; 3 4],
                 {'col1', 'col2'},
                 {'row1', 'row2'}, 'a 2x2 DB')
```

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```

Can also import text files as database (e.g., Excel export).

Creating a database from analysis of traces

Using a dataset:

```
>> my_dataset_obj =
     my_dataset_class(’data/*.bin’, arguments...)
```

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```

Creating a database from analysis of traces

Using a dataset:

```
>> my_dataset_obj =
     my_dataset_class('data/*.bin', arguments...)
>> my_database_obj =
     param_tests_db(my_dataset_obj)
>> sorted_obj =
     sortrows(my_database_obj, 'AP_amplitude')
```

Database analysis: Querying

```
>> db_obj2 =
     db_obj(1:10, {'neuron_index', 'fire_rate'})
```

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>> db_obj2 =
     db_obj(1:10, {'neuron_index', 'fire_rate'})
>> db_obj2 =
     db_obj(db_obj(:, 'neuron_index') == 46, :)
```

Database analysis: Querying

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>> db_obj2 =
     db_obj(1:10, {’neuron_index’, ’fire_rate’})
>> db_obj2 =
     db_obj(db_obj(:, ’neuron_index’) == 46, :)
>> db_obj2 =
     db_obj(anyRows(db_obj(:, ’neuron_index’),
                    [46; 56; 12]), :)
```

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>> db_obj2 =
     db_obj(1:10, {’neuron_index’, ’fire_rate’})
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     db_obj(db_obj(:, ’neuron_index’) == 46, :)
>> db_obj2 =
     db_obj(anyRows(db_obj(:, ’neuron_index’),
                    [46; 56; 12]), :)
>> db_obj2 =
     db_obj(db_obj(:, ’neuron_index’) ~= 46 &
            (db_obj(:, ’CIP’) > 100 |
             db_obj(:, ’rate’) <= 50 ), :)
```

Database analysis: Querying

```
>> db_obj2 =
     db_obj(1:10, {’neuron_index’, ’fire_rate’})
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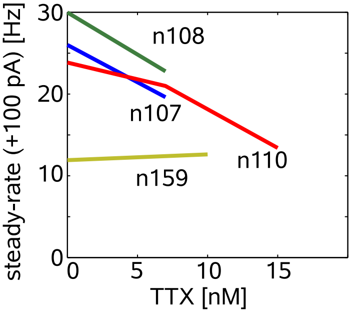
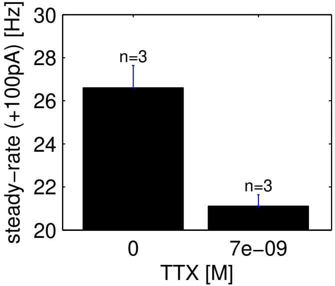
     db_obj(anyRows(db_obj(:, ’neuron_index’),
                    [46; 56; 12]), :)
>> db_obj2 =
     db_obj(db_obj(:, ’neuron_index’) ~= 46 &
            (db_obj(:, ’CIP’) > 100 |
             db_obj(:, ’rate’) <= 50 ), :)
>> db_obj2 =
     model_db_obj(anyRows(model_db_obj(:, ’rate’),
                  neuron_db_obj(:, ’rate’)), :)
```

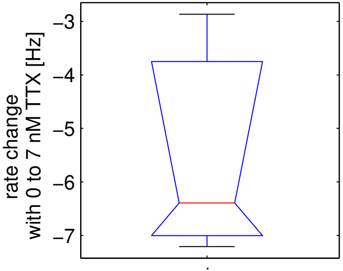
Tutorial demo on Github

Multivariate analysis with non-grid data

Tetrodotoxin block effects on firing rate of globus pallidus neurons with current injection







Multivariate analysis (I)

Sifting the database to find effects of parameters

Sample with 3 Neurons:

PicroTx	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
KynAcid	0.001	0.001	0.001	0.001	0.001	0.001
TTX	0	$7e-09$	0	$7e-09$	0	$7e-09$
Apamin	0	0	0	0	0	0
drug 4AP	0	0	0	0	0	0
NeuronId	107	107	108	108	110	110
D100pA steady rate	25.9982	19.6056	29.9673	22.7628	23.8443	20.9744

Focus on changes with TTX:

	Page 1		Page 2		Page 3	
TTX	0	$7e-09$	0	$7e-09$	0	$7e-09$
D100pA steady rate	25.9982	19.6056	29.9673	22.7628	23.8443	20.9744
RowIndex	1	2	3	4	5	6

Multivariate analysis (II)

Processing database contents

Change in rate (Δ) between successive TTX levels:

d1_2	−6.3926	−7.2045	−2.8699
PageIndex	1	2	3

Regrouping to find average values for each TTX level:

	Page 1			Page 2		
TTX	0	0	0	$7e-09$	$7e-09$	$7e-09$
D100pA steady rate	25.9982	29.9673	23.8443	19.6056	22.7628	20.9744
RowIndex	1	3	5	2	4	6

DEMO

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Try it out and share your feedback

How to access Pandora:

- Main publication: Günay et al. (2009) *Neuroinformatics*
- Downloads and documentation on Github and Mathworks File Exchange pages

How to give feedback/ask questions:

- Open issues and "star" project on Github
- Also looking for developers to improve it
- Email: cgunay AT ggc.edu
- Fill our survey please!

Credits goes to:

- Supervisors who supported development, Dieter Jaeger and Astrid Prinz, from Emory Univ.
- Several other contributors, see full list at our Github page
- Cite our paper above and the RRID if you use Pandora, and send us a message!

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