Advances in the PANDORA Matlab Toolbox for neural database analysis

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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:

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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
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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**
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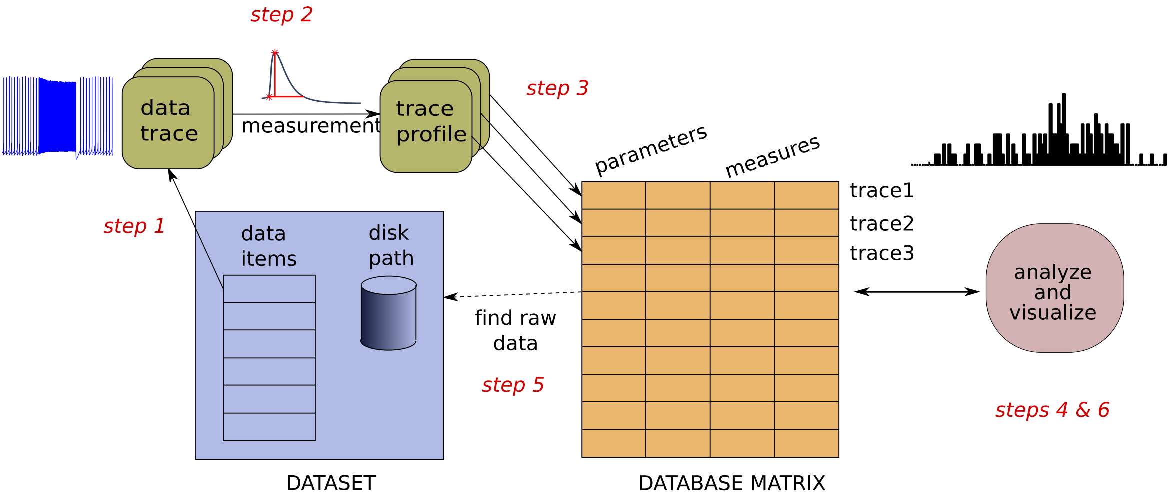
2. Model simulation parameter optimization
   - Uses the GODLIKE toolbox that can run **multiple optimization algorithms** (multi-objective evolutionary algorithms, swarm, ...)
   - Can **control running simulations** by calling an external simulator like Neuron, GENESIS, etc)
   - Experimental feature 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



Outline

Loading a membrane voltage trace

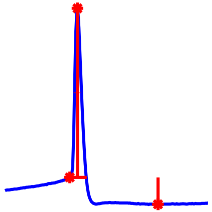
Pandora can read the file formats from:

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

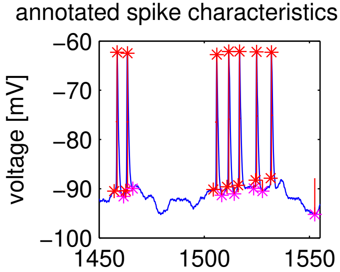
Analyzing a membrane voltage trace

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
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- Labels propagate into plots and reports, reducing human errors.

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:

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>> db_obj =
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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 =
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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_obj(db_obj(:, 'neuron_index') == 46, :)
>> db_obj2 =
     db_obj(anyRows(db_obj(:, 'neuron_index'),
                    [46; 56; 12]), :)
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                         [46; 56; 12]), :)
>> db_obj2 =
     db_obj(db_obj(:, 'neuron_index') ~= 46 &
              (db_obj(:, 'CIP') > 100 |
               db_obj(:, 'rate') <= 50 ), :)
```

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>> db_obj2 =
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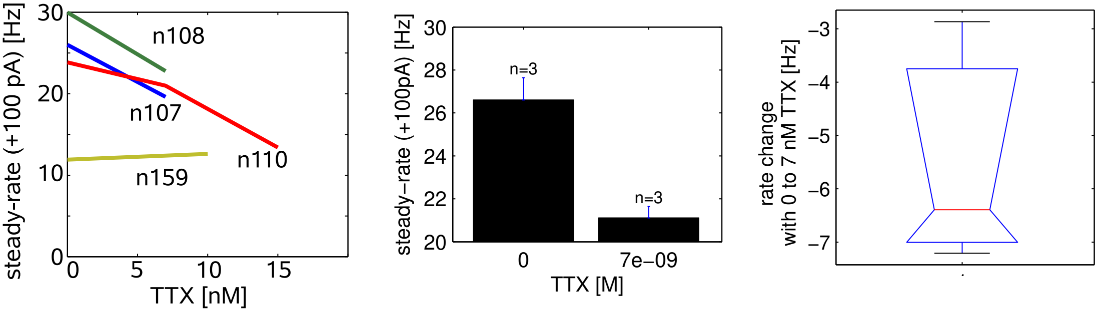
                    [46; 56; 12]), :)
>> db_obj2 =
     db_obj(db_obj(:, 'neuron_index') ~= 46 &
            (db_obj(:, 'CIP') > 100 |
             db_obj(:, 'rate') <= 50 ), :)
>> db_obj2 =
     model_db_obj(anyRows(model_db_obj(:, 'rate'),
                  neuron_db_obj(:, 'rate')), :)
```

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

Outline

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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