RELACS - a Modular Platform for Closed-Loop and Dynamic Clamp Experiments

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1 Introduction

relacs
... enjoy your recordings

RELACS ("**R**elaxed **EL**ectrophysiological data **A**cquisition, Control, and **S**timulation") is a fully customizable software platform for data acquisition, online analysis, and stimulus generation specifically designed for electrophysiological recordings. The main design goals are (i) **closed loop** recordings on both the stimulus time-scale ($> 10\,\text{ms}$) and the sampling time-scale ($< 1\,\text{ms}$), i.e. **dynamic clamp**, (ii) a hardware independent **modular** design, and (iii) automatic annotation of the data with **metadata**.

2 Free Software

RELACS is free and open software published under the GPL to foster development and exchange of innovative experimental protocols and analysis techniques.

RELACS is independent of any specific hardware manufacturer.

RELACS is programmed in C++ (more then 120 000 lines of code, using multithreaded Qt for the GUI, and runs on Linux.

Data recorded with RELACS are published in 13 scientific papers in journals like Neuron, Nature, Neuroscience, Journal of Neurosciene, Journal of Neurophysiology, etc.

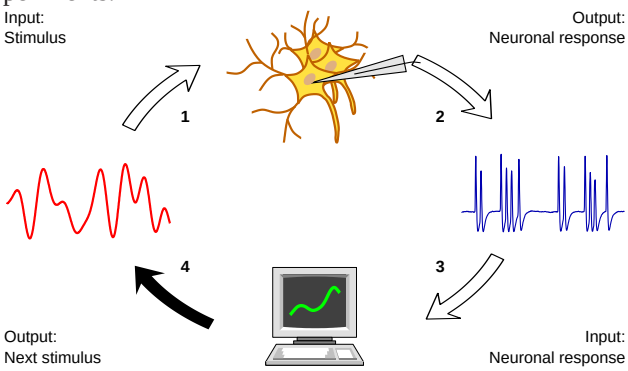
For more information and downloads visit
www.relacs.net

3 Closed Loop

In a closed-loop experiment

1. a stimulus is presented,
2. the resulting response
3. is analyzed immediately, and
4. properties of the next stimulus (mean intensity, standard deviation, spectral content...) are adjusted as needed.

RELACS is designed as a framework for closed-loop experiments.



The closed-loop approach is beneficial on many levels, even for traditional experimental paradigms:

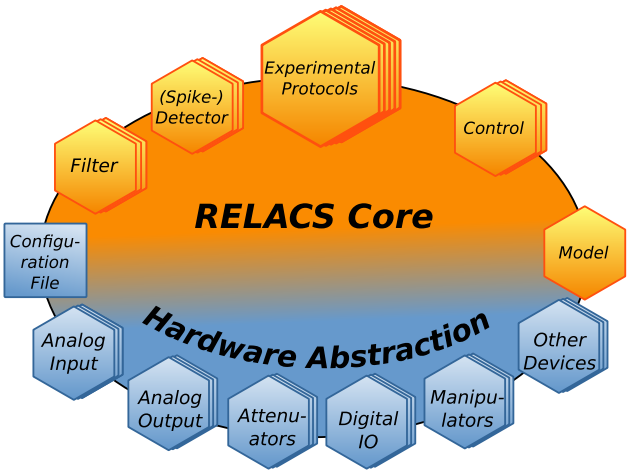
- Processed results are displayed immediately in addition to the raw voltage traces and thus give the experimenter valuable quantitative information about the recorded cell during a running experiment. For example, quality of the spike detection, sensitivity or input resistance of the cell, heart rate, etc.
- Probing the neuron with stimuli that are outside its dynamic range can be avoided and thus the yield of a recording is maximized.
- Advancing of individual electrodes can be automated, such that the chance to get a dual recording is increased.

Closed-loop experiments, however, also offer new experimental designs:

- Automated and possibly optimal search for a neuron's receptive field.
- Search for stimuli that drive a neuron in an "optimal" way (firing rate, coding quality, mutual information).
- Find sets of stimulus parameter that result in the same response (iso-response method).

See our review "From response to stimulus: adaptive sampling in sensory physiology" for more details (Benda et al. 2007, Current Opinion in Neurobiology 17(4): 430-436).

4 Modular Design and Hardware Independence



The central building blocks of RELACS are the "Experimental Protocols". These are freely programmable C++ plugins that

- take recorded and preanalyzed data
- perform analysis & display results
- generate next stimulus

Hardware of different manufacturers is integrated by

- device plugins and
- a configuration file

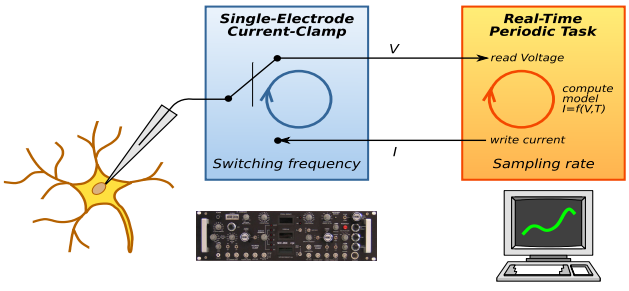
into RELACS, providing a hardware independent interface for

- filter and detectors,
- control modules, and
- experimental protocols.

Therefore, experimental protocols

- can be used on all the different experimental setups in your lab without any modifications
- can be shared with other labs

5 Dynamic Clamp

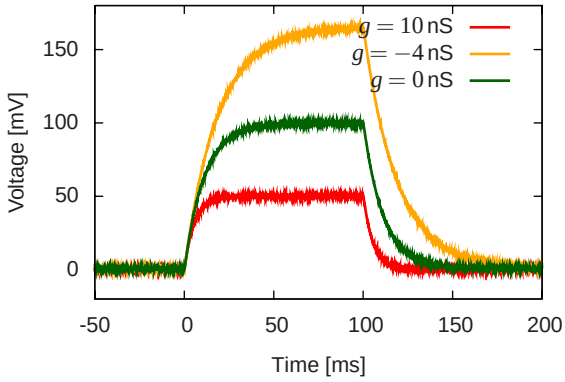


The dynamic clamp is a closed-loop experiment on a per sample basis where each sampled value of the cell's membrane potential is used to compute a current that is injected back into the cell. RELACS supports software dynamic clamp, i.e. no additional hardware is needed, that is implemented as an RTAI real time Linux kernel module.

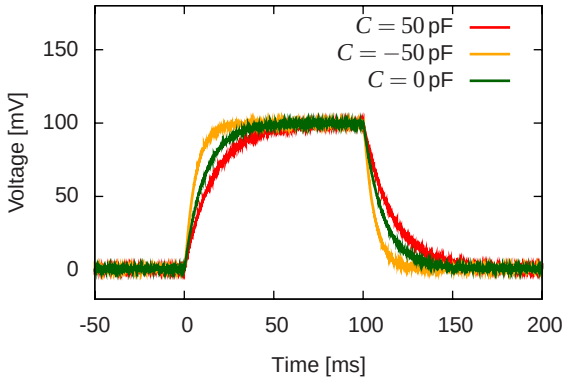
For using the full potential of discontinuous current-clamp amplifiers for the dynamic clamp we are synchronizing the switching cycle of an npi SEC amplifier with the software loop (in collaboration with H. R. Polder, npi electronic GmbH, Tamm, Germany).

The examples show measurements on a passive cell model with input resistance of 100 MΩ and "membrane" capacitance of 100 pF. A 1 nA current pulse of 100 ms duration was injected via current clamp into this cell.

Dynamic clamp model: $I = -gV$



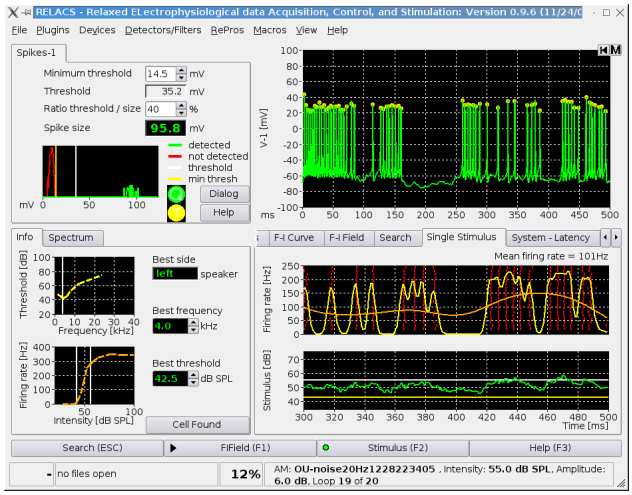
Dynamic clamp model: $I = -C\dot{V}$

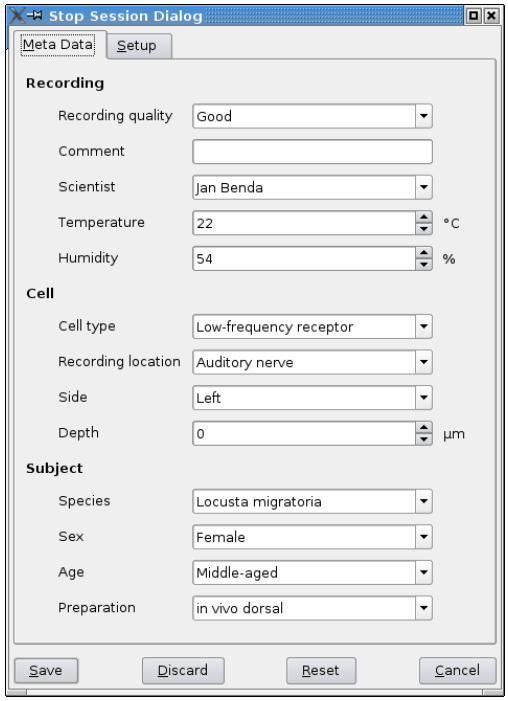


6 Graphical User Interface

- top right:
  raw voltage trace (green)
  with detected spikes (yellow)
- top left:
  spike detector
- bottom right:
  an experimental protocol

- bottom left:
  infos about the cell





7 Metadata

Metadata (“data about data”) is needed for

- data analysis
- data management
- data sharing.

Upon completion of a recording, RELACS immediately forces the experimenter to provide this important information through a freely configurable dialog. In addition, for each recording all configuration files, log files, and settings of the experimental protocols are automatically saved as well.

We are currently working on a XML-based standard for metadata, so that various recording, storing, and analysis programs are able to understand your data (supported by the German Neuroinformatics Node, www.g-node.org).

In particular, metadata recorded by RELACS can be automatically stored in LabLog soon (see Poster #T27-6B by Jan Grewe).