RELACS —
a modular software platform for closed-loop experiments

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bpcn benda

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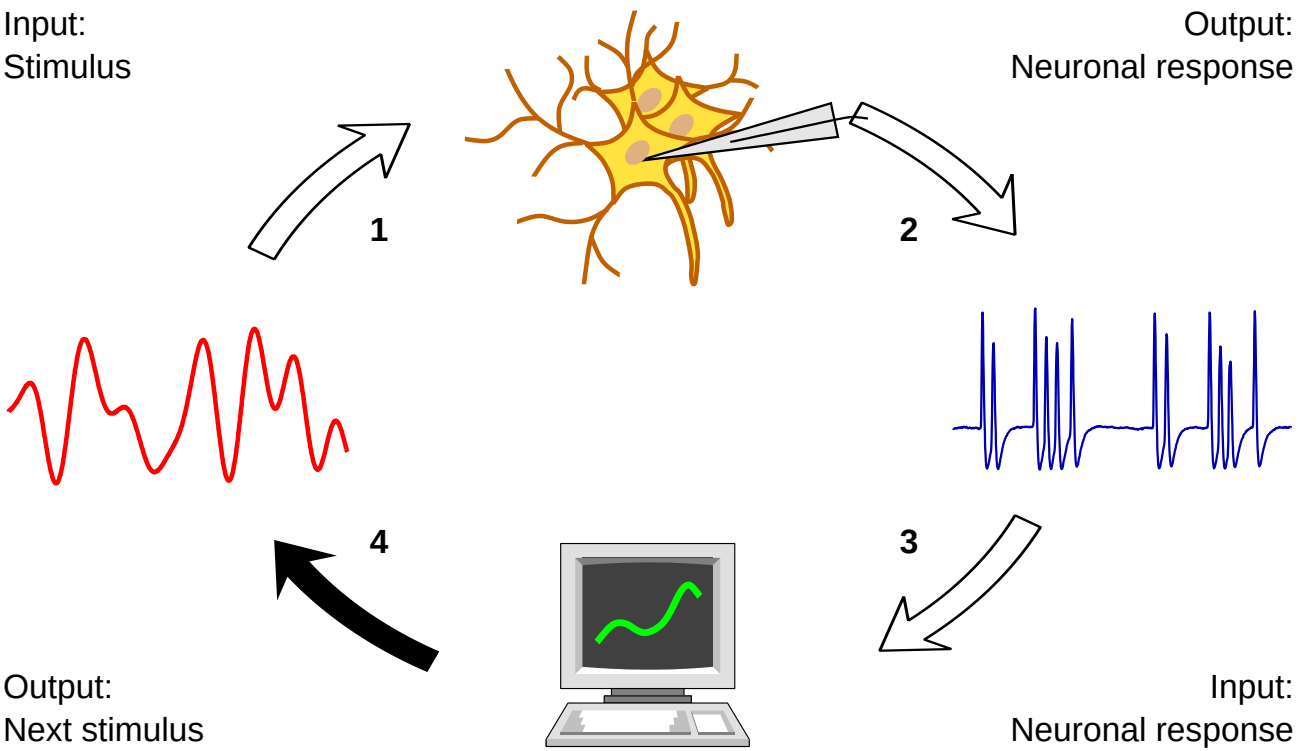
3. The data are analyzed offline
4. The stimuli and the protocol are modified
5. A new set of recordings is made

Closed-Loop Experiments

1. Present a stimulus
2. Record the response
3. Immediately analyze and visualize the data
4. Generate the next stimulus



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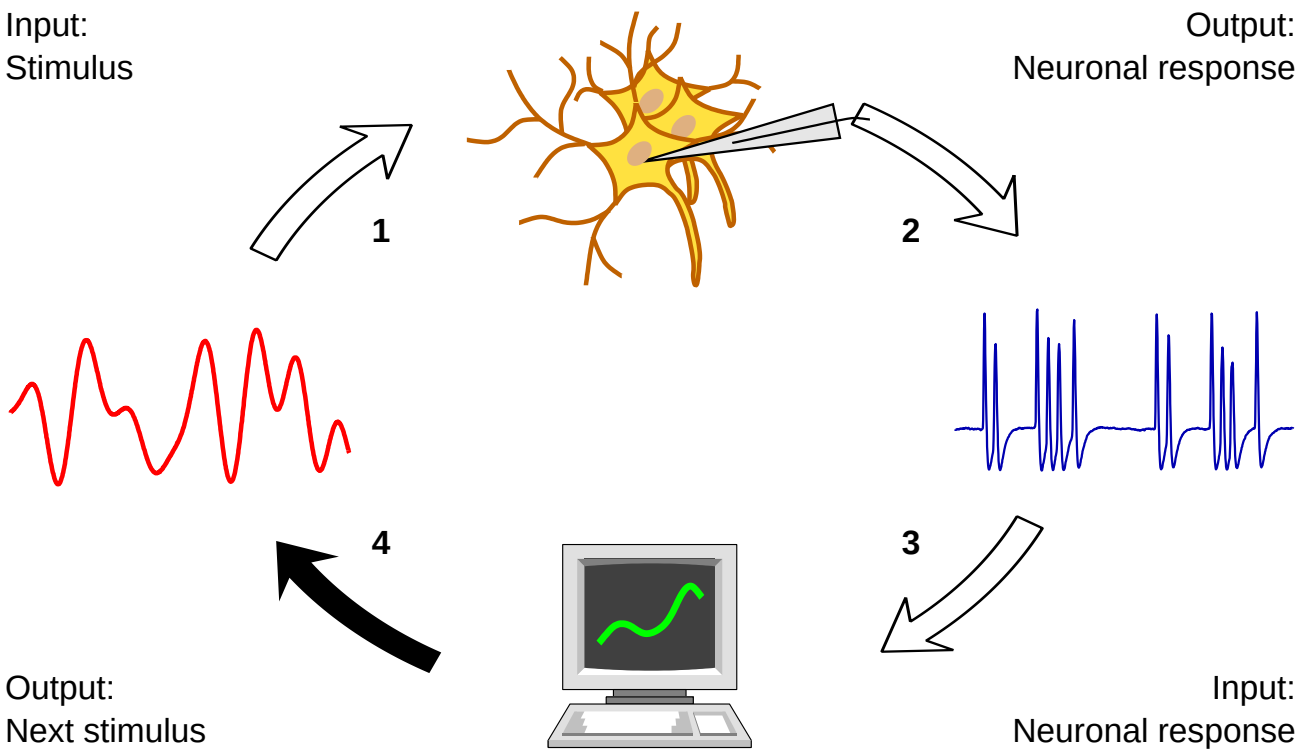
Closed-Loop Experiments

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

- considerably speed up this traditional approach
- offer novel experimental possibilities



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Simple Closed-Loop Experiments

- Online visualization of processed data:
  - General infos, e.g. quality of spike detection, sensitivity of the cell, temperature, condition of animal, ...
  - Specific results, e.g. spike raster, firing rates, spike-triggered averages, ...

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  $\Rightarrow$ Speeds up manual closed-loop
- Set stimuli relative to the neuron's dynamic range
- Automatically control motorized electrodes
- ...

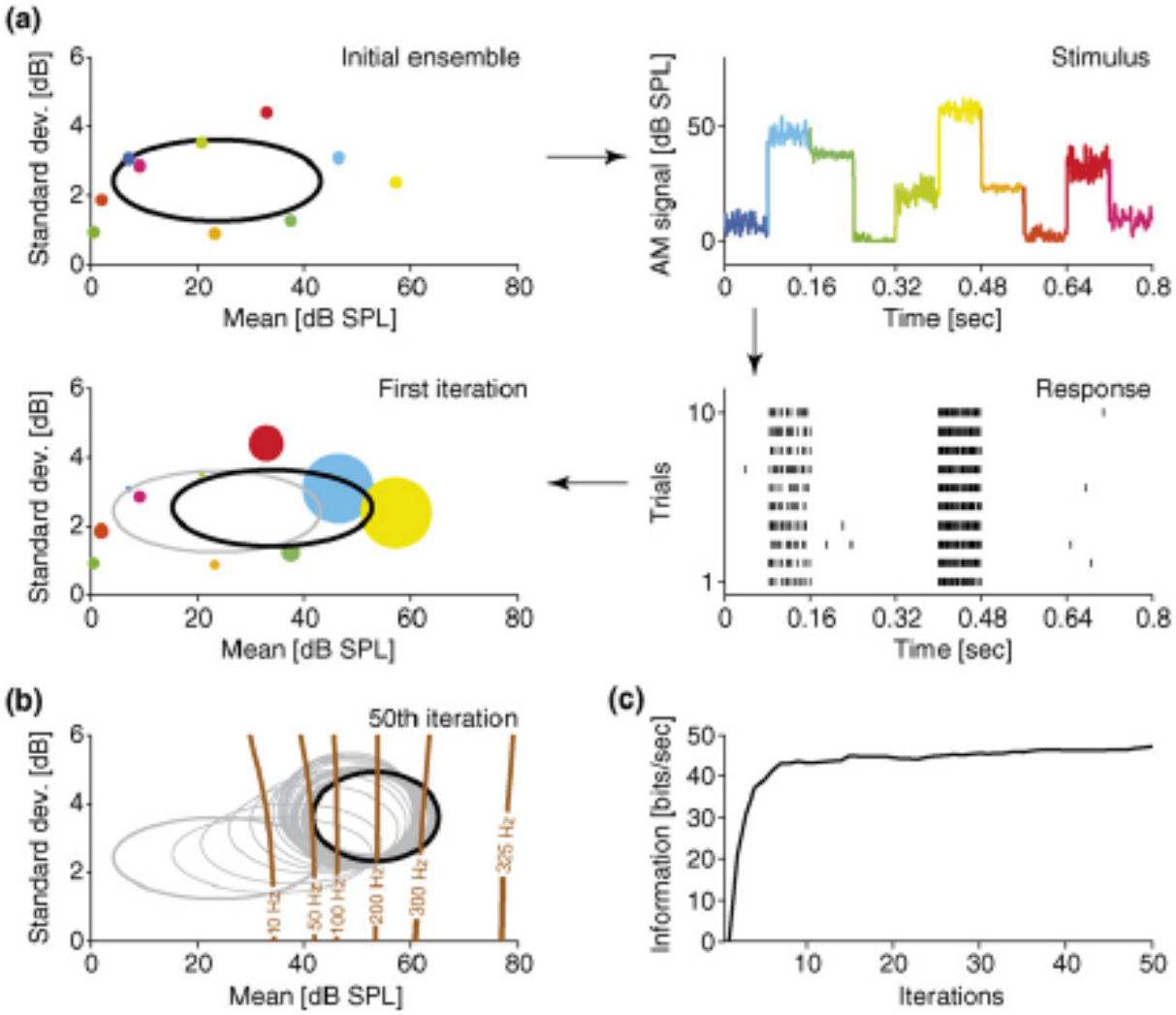
Advanced Closed-Loop Experiments

New experimental designs are possible:

- Optimal search for a neuron's receptive field.
- Search for stimuli that drive a neuron in an "optimal" way.
- Find set's of stimulus parameter that result in the same response (iso-response method).
- ...

Benda et al. (2007): "From response to stimulus: adaptive sampling in sensory physiology." *Curr. Opin. Neurobiol.* **17**: 430–436.

Example: Optimal Stimulus Ensembles



Machens et al. (2005) *Neuron* **17**: 47–56.

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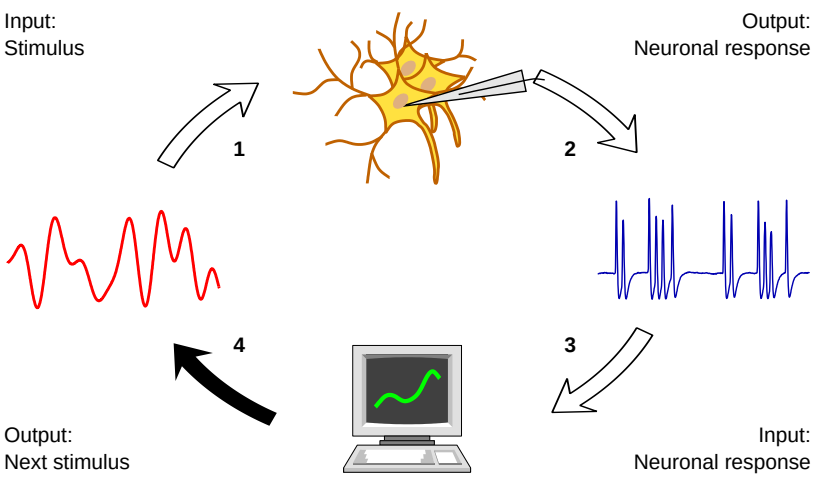
Closed-Loop Experiments

In *RELACS* the closed-loop cycle can be freely programmed as a C++ plugin (*"experimental protocol"*).

The experimental-protocol plugins

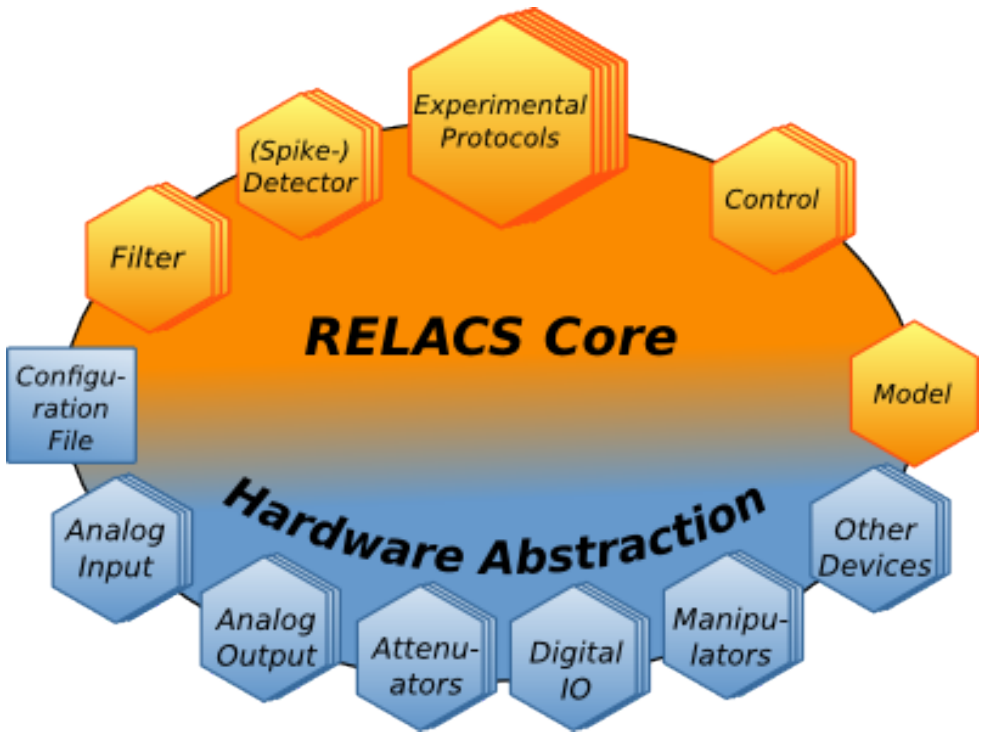
- take recorded and pre-analyzed data
- perform analysis & display results
- generate next stimulus



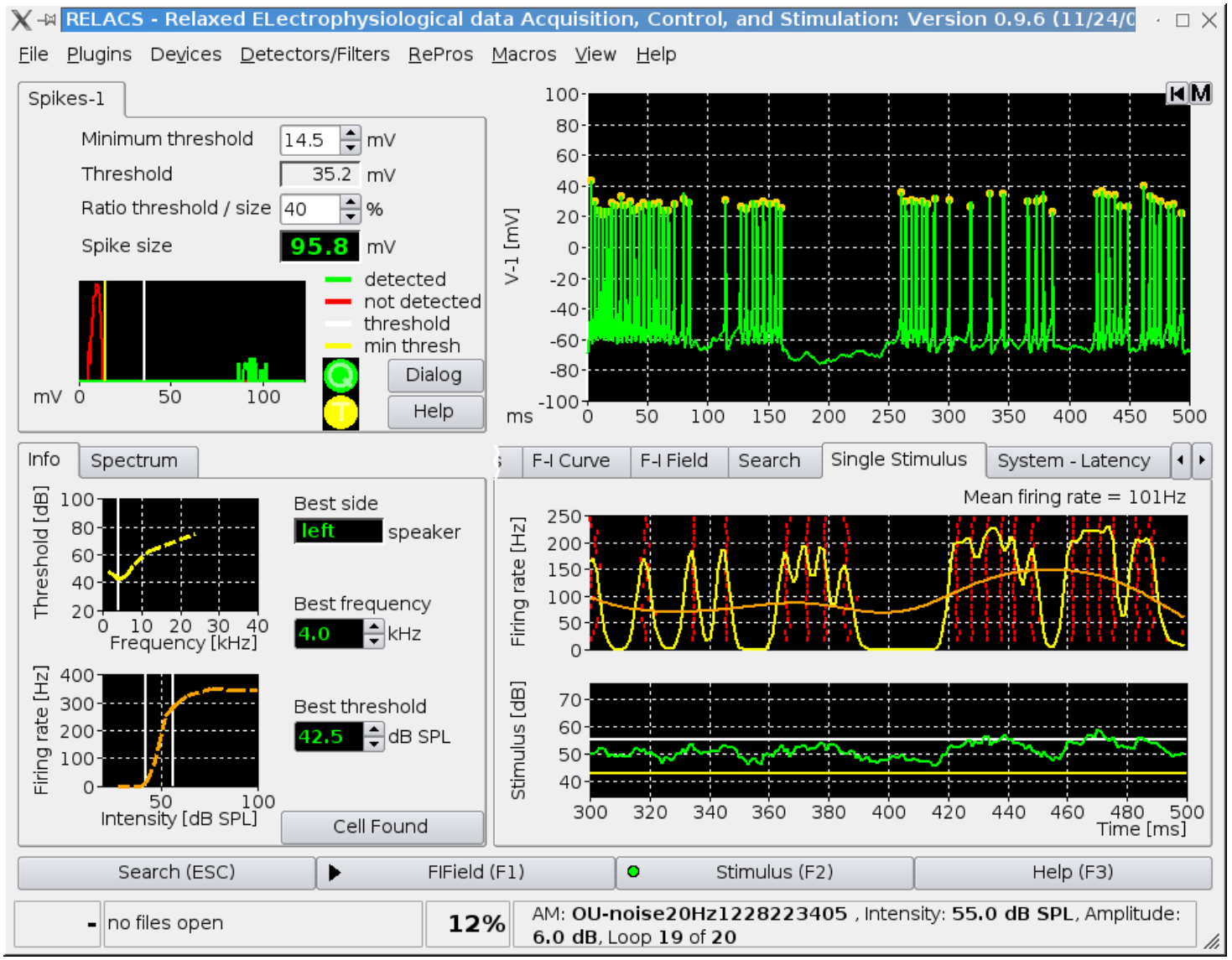
Modular Design

RELACS core with flexible C++ Plugins for

- hardware abstraction
- data pre-processsing (filter, spike detectors)
- passive and active control
- model



Screen Shot



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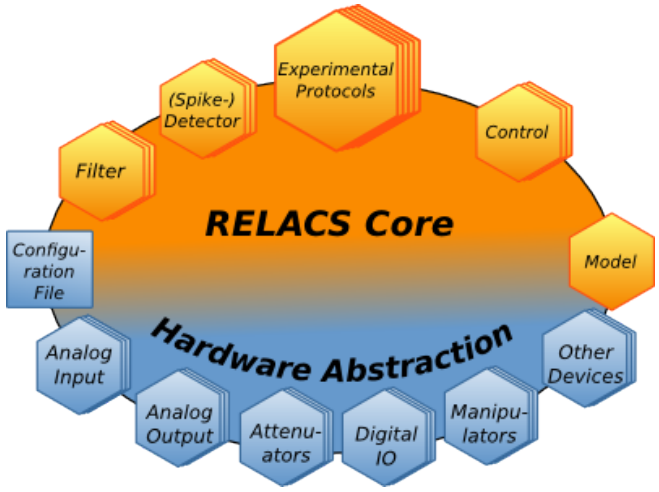
Hardware Independent Protocols

RELACS integrates all hardware components.

Experimental protocols for *RELACS*

- are implemented independently of specific hardware
- can be used on all the different experimental setups in your lab without any modifications
- can be shared with other labs



Experimental Protocol Example

```
int Example::main( void ) {
  // some initialization ...
  OutData signal;
  signal.setTrace( "LeftSpeaker" );
  signal.sineWave( frequency, duration, amplitude );
  SampleDataD rate( 0.0, duration, 0.001 );
  for ( int counter=0; counter<Repeats; counter++ ) {
    write( signal );
    sleep( duration + pause );
    EventData spikes( events( SpikeEvents[0] ),
                      events( SpikeEvents[0] ).signalTime(),
                      events( SpikeEvents[0] ).signalTime() + duration );
    double meanrate = spikes.rate( 0.3*duration, duration );
    spikes.addRate( rate, counter, GaussKernel( sigma ) );
    P.clear();
    P.plot( rate, 1000.0, Plot::Yellow, 2, Plot::Solid );
    P.draw();
    if ( meanrate < targetrate ) {
      amplitude *= 2.0;
      signal.sineWave( frequency, duration, amplitude );
    }
  }
}
```

Why C++

- well structured (object oriented)
- platform independent
- efficient and controllable memory usage
- very fast

C++ Library for Data Analysis

Data structures (classes, container):

- *Array* — Basic 1-D vector
- *SampleData* — 1-D data vector with regularly sampled time axis
- *Map* — Sequence of $x|y$ data pairs

Algorithms:

- basic statistics (moments, quartiles, histogram)
- power spectra, coherence, transfer function
- linear fits
- non-linear fits (Simplex, Levenberg-Marquardt)

C++ Library for Data Analysis

Data structures (classes, container):

- *EventData* — Spikes and other point process data
- *EventList* — Multi-trial spike trains

Algorithms:

- firing rates (mean, PSTH binned/kernel, 1/ISI)
- CV, Fano factor, ISI correlation
- vector strength, reliability, jitter
- mutual information (lower and upper bound)

Free and Open Source Software

RELACS is open source and free software distributed under the GNU General Public License (GPL).

- No hassle with licenses of commercial software.
- Add whatever new feature you need directly to the program.
- Share the program and your specific experimental protocols with your collaborators.
- Know what the data-analysis algorithms are doing!

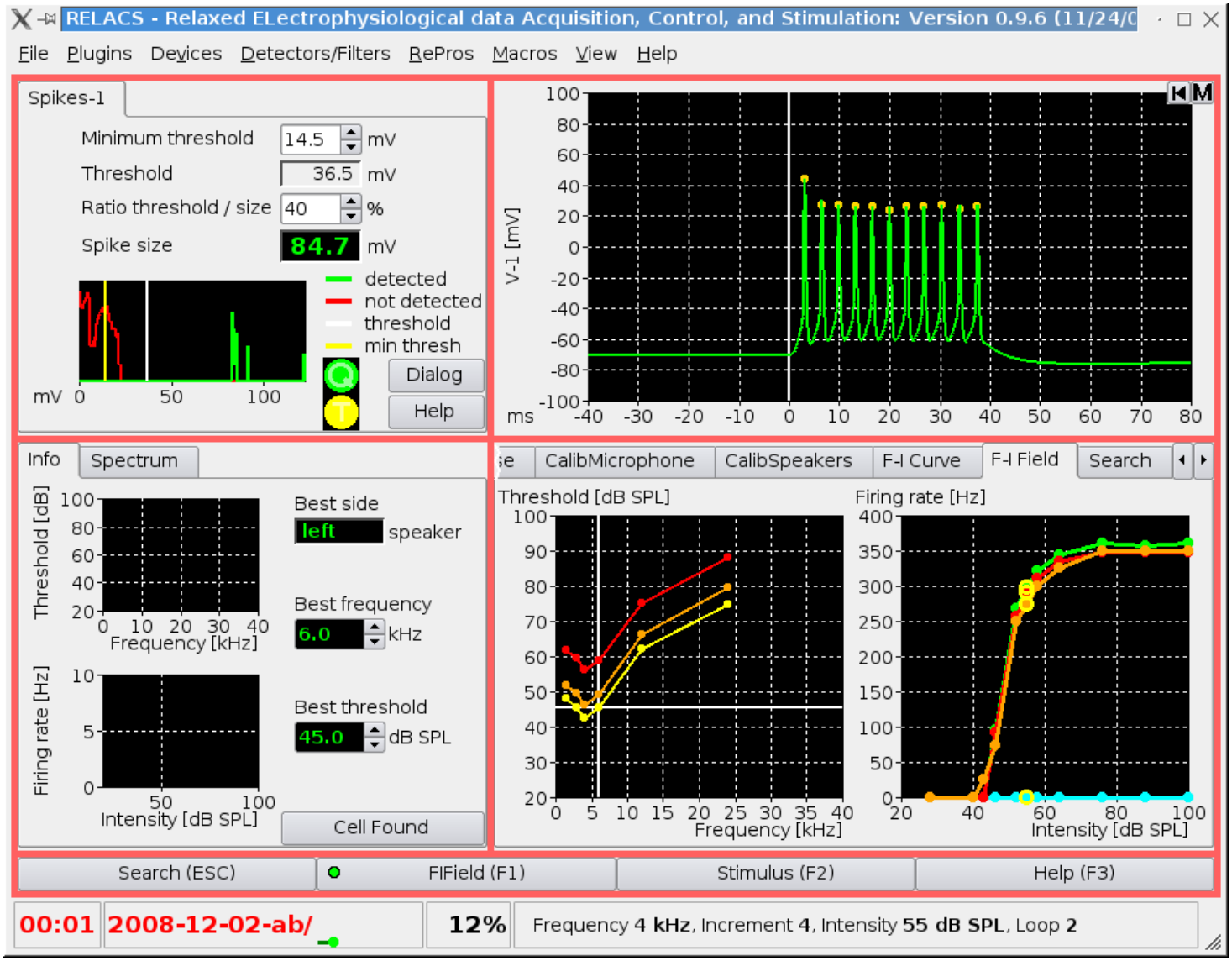
Meta-data

Meta-data (“data about data”) describe the context of the raw data.

Meta-data are important for:

- Data management
- Data retrieving
- Data analysis
- Data sharing

Meta-Data Acquisition by RELACS



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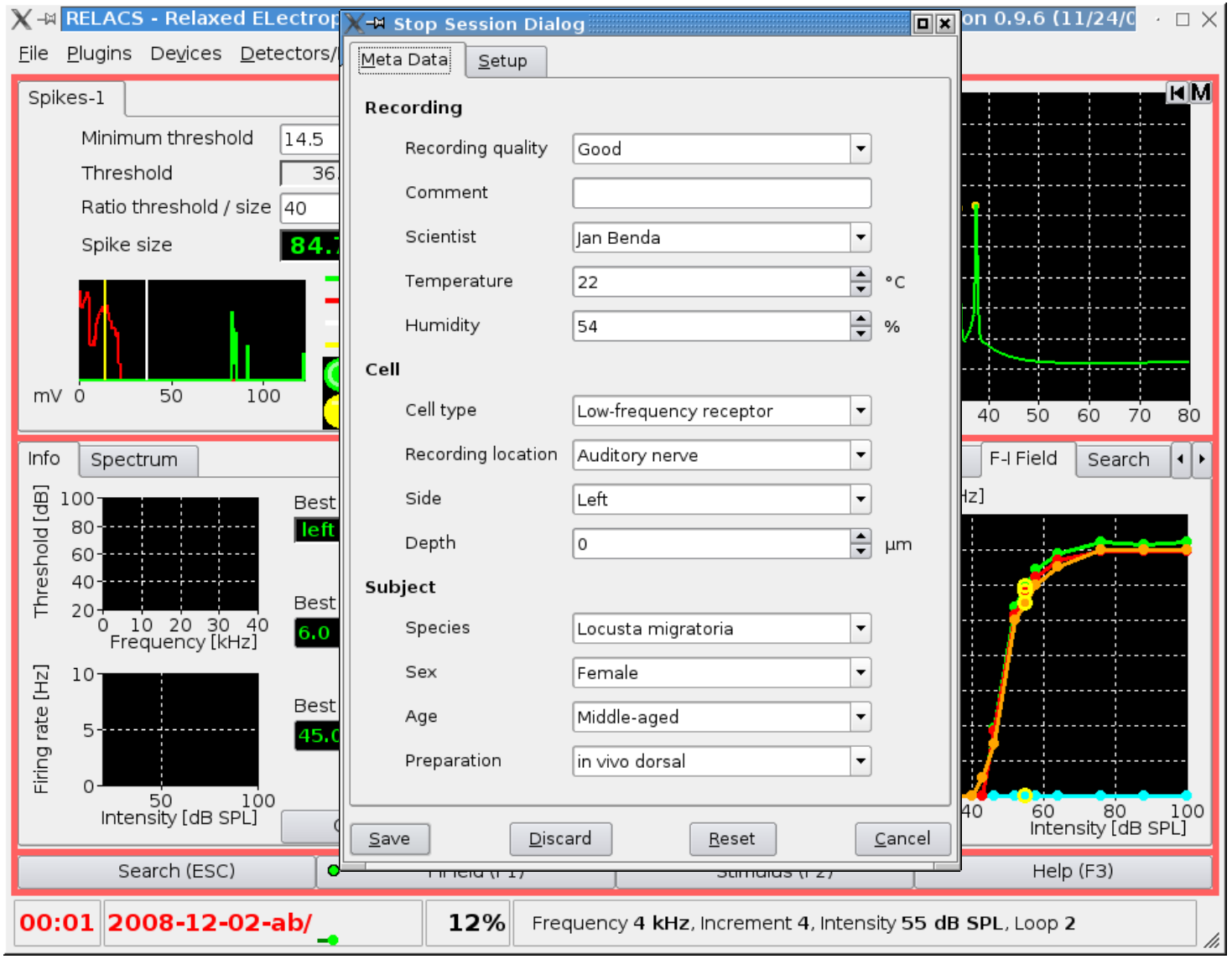

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Meta-Data Acquisition by RELACS

RELACS records many meta-data:

- General infos about the experiment (from the dialog)
- Main characteristics of the recorded cell
- All *RELACS*-controlled hardware settings (e.g. sampling rate)
- All settings and version numbers of the experimental protocols

The Meta-Data Problem

Name-value (+unit) pairs for:

- Stimuli
- Experimental settings
- Cell, preparation, experimental subject
- Hardware properties
- Analysis parameter
- etc.

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But:

- What name to choose?
- What does it mean?
- How to share meta-data?

A Proposal

We need some kind of standard!

- flexible and extensible
- downloadable and parseable for seamless integration in software

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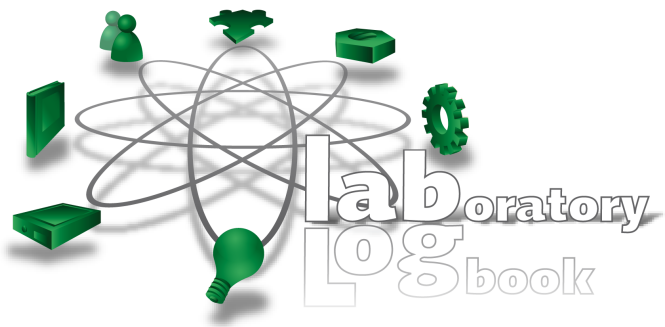

In collaboration with G-node and LabLog by Jan Grewe (lablog.sourceforge.net)

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... enjoy your recordings

- → Closed-loop experiments
- → Hardware independent
- → Data analysis libraries
- → Meta-data storage
- → Simulation mode
- → Dynamic clamp
- → Open source, GPL, Linux
- → ∼ 120 000 lines of C++ code

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www.relacs.net