

Göttingen, 1997

New tools for data acquisition and analysis in multichannel recordings

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1 Introduction

Chemically, electrically and temporally features of neural systems are modeled as specific temporal spike patterns of neural activation sites. Traditionally, wave packets of this information have been investigated by single cell electrophysiological recordings. However, it is impossible to define precise stimulus patterns from the response of a single neuron cell. Newer signals flow from the surface to the brain via the natural network of the cortex fibers. The transmission carried out by the axons and the resulting branching of neural stimuli should be based on a global and population wide. We want to investigate more precise multi-channel recordings in a multi-electrode array (MEA). This makes it possible to record simultaneously the responses of many neuron cells to one defined neural stimuli.

2 Hardware

2.1 Mechanical Part

The recording array used was the Utah Intracranial Electrode Array (UIEA) developed at the Dept. of Biomechanical Engineering, University of Utah. It consists of a $12 \times 12 \times 0.12$ mm data interconnectable square grid substrate with 100 conducting μm square needles. Each needle is electrically isolated from the others and carries from a 0.05 mm hole to a square tip along 0.13 mm length. The tip of each electrode is coated with platinum over gold, with the rest of the array electrode covered with polyimide (Fig. 1).



Figure 1: SEM-micrograph of the MEA

Each electrode is connected through its own leadwire to a 100 pin connector. External traces mounted across from 60 of these connectors were wired and led to a data acquisition board (DAQ). The digital signals are further processed as a LabView-based PC-acquisition system.

Three 100- μm diameter optical fibers were attached from the end and narrowed, guiding red, blue and green light through a microscope objective. The MEA was placed directly into the animal's skull using a stereotaxic coordinate. Light stimulation was done with a modified optical system and is directed from below onto the preparation area (Fig. 2).

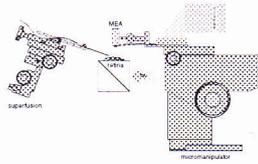


Figure 2: Schematic diagram of the experimental setup and MEA.

2.2 Electrical Part

The electrical hardware part used in the system consists of the 16-bit Analog-to-Digital (A/D) converter, personal computer (200 MHz Pentium-Pro, 128 MB RAM, 4GB HD) and a special DSP-based design of H. Urbschat.

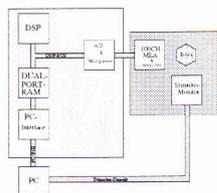


Figure 3: Schematic diagram of hardware.

2.2.1 DSP-board

In order to reduce noise, the analog part of the DSP-board is implemented on a daughterboard and placed near the preparation by the researcher. This makes that changes are very flexible for different types of different animal models. One first prototype uses only 16 channels with 2000 samples and 12 bit resolution. The second generation board uses up to 64 channels with 2000 samples. Since data acquisition is done continuously with high rate (up to 4000) of raw data for 100 channels a fast DataPort-RAM is used as interface between DSP and PC. The DSP (TMS320C49) can be reprogrammed via the DataPort-RAM with 64 kilobytes. The system samples continuous data until the hardware buffer. This data can be written on either raw or compressed format to a CD-Rewriter for later evaluation. The actual version of the DSP-board works on the IS685-System, the second version uses the more fast PC410-board (up to 64MB/s).

2.2.2 64-channel preamplifier

A commercial analogue 64-channel preamplifier (MEA 1000, Hoes & Müller, Reutlingen) is designed to amplify the extracellular signals (ca. 100 μV rms) with a gain of 2000. It uses widebandwidth, which operate in the frequency range 0.01-1000 Hz.

3 Operating-Software

The software package consists of two parts. The first part organizes the DSP-based data acquisition and optional data processing processes. Here, we have the procedure of acquiring new developed processing algorithms from the multi-channel computer to the DSP. The rest of the software package runs on the PC under Linux and Windows. In order to receive a serious data flow we had to modify the Linux-System, by adding a 1MB RAM cache set to a very high priority level. Besides we use in the first version some other processing algorithms on the DSP. The main part of the software runs on the PC (under Linux and Windows).

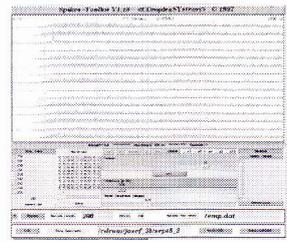


Figure 4: Screenshot of SynapseTool showing 16 channel FFT-analysis.

Fig. 4 shows the graphical user interface SynapseTool. The digitalized signals can be displayed either in multi channel mode (see Fig. 3) after recording of 16 single channel mode (see Fig. 5).

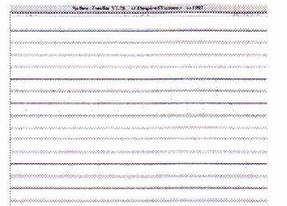


Figure 5: Screenshot: Single channel extracellular signal.

The tool allows to view the data on different scales and to mark arbitrary data ranges or time course lines. The location of the electrodes of the MEA in the different channels is distinguished by an color-coding, which can be assigned individually. FFT spectra can be calculated for all channels, helping to detect periodic wave patterns for the different electrodes of the electrode preparation and the data evaluation. Several data recording modes (continuous and manual) are implemented. Algorithms for signal detection, FFT and statistical comparison analysis (Fig. 7) are already implemented.

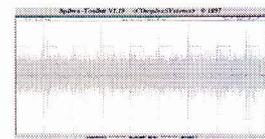


Figure 6: Screenshot: Multi channel extracellular signal.

3.1 Analysis tools

To search for values in the data, a color-coded color key automatically generated using a graphical editor. The monitor indicates the similarity between the patterns and different data ranges using predicted color-coding. The detected colors are marked with small red squares at the bottom of the display area (Fig. 8).

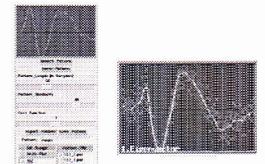


Figure 8: Screenshot of a 16 channel extracellular signal. The red lines represent the detected signals, provided from a threshold in the signal. The green traces represent the recordings of the different electrodes.

Figure 7: Screenshot: SynapseTool with a graphical editor. It is possible to define a template search pattern, which can be compared with the extracellular recordings.

For results see Power No. 210, color information representation by a small network of ganglion cells in the turtle cortex.

1 Introduction

Chromatic, spatial, and temporal features of visual objects are encoded as spatio-temporal pulse patterns of retinal ganglion cells. Traditionally, some aspects of this transformation have been investigated by single cell electrophysiological techniques. However it is impossible to deduce certain stimulus features from the response of a single ganglion cell.

Sensory signals pass from the retina to the brain via the narrow bottleneck of the optic nerve. The computations carried out by the brain and the resulting decoding of visual stimuli feature must be based on a ganglion cell population code. We started to investigate vertebrate image encoding using a multi-electrode array (MEA). This makes it possible to record simultaneously the responses of many ganglion cells to well defined visual stimuli.

2 Hardware

2.1 Mechanical Part

The recording array used was, the UTAH INTRACORTICAL ELECTRODE ARRAY (UIEA) developed at the Dept. of Bioengineering, University of Utah. It consists of a $4.2 \times 4.2 \times 0.12$ mm thick monocrystalline square grid substrate with 100 conductive (p^+) silicon needles. Each needle is electrically isolated from the others and tapers from a 0.08 mm base to a sharp tip along its 1.5 mm length. The tip of each electrode is coated with platinum over gold, with the rest of the shank electrically insulated with polyimide (Fig.1).

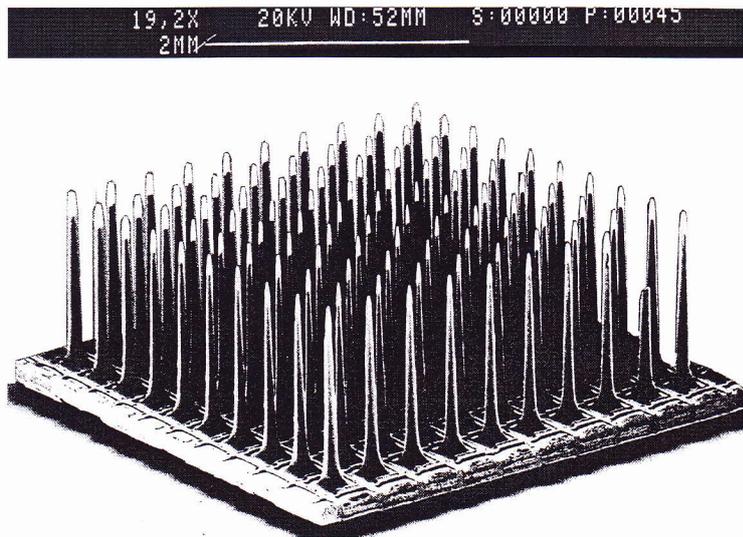


Figure 1: REM-micrograph of the MEA

Each electrode is connected through its own leadwire to a 100 pin connector. Extracellularly recorded signals from 60 of these electrodes were selected and fed to a 60-channel amplifier and A/D-converter. The digitized signal is further processed on a Linux-operated PC, as explained below.

Turtle (*Pseudemys scripta*) retinas were isolated from the eye, and mounted, ganglion cell side up, in a superfusion chamber within a Faraday cage. The MEA was slightly driven into the ganglion cell layer using a micromanipulator. Light stimulation was done with a standard optical system and is directed from below onto the photoreceptor layer (Fig.2).

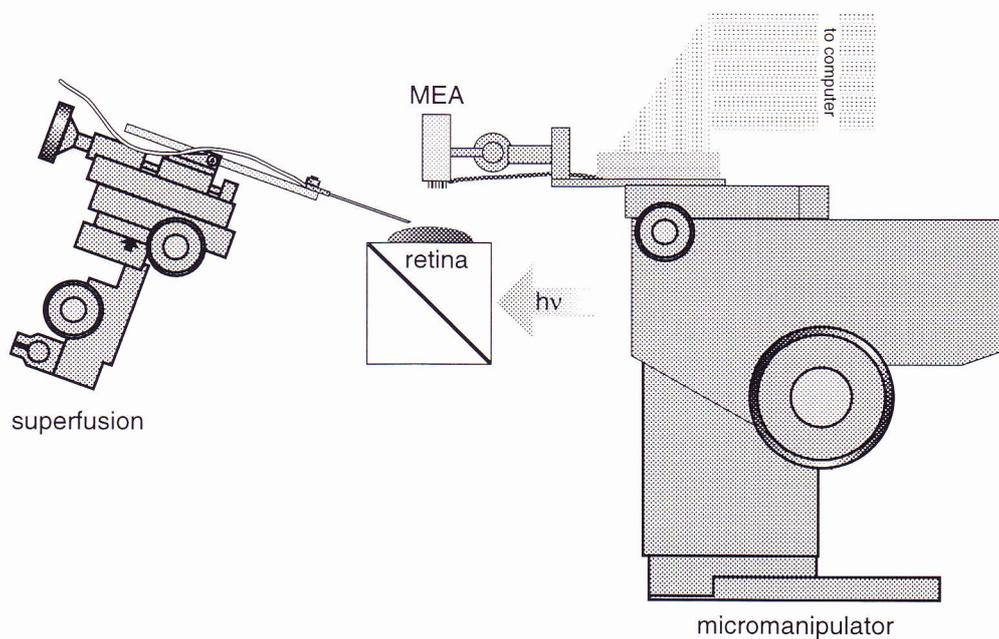


Figure 2: Schematic drawing of Superfusionchamber and MEA.

2.2 *Electrical Part*

The electronic hardware part used in the setup consists of two 60-channel preamplifier cards, a conventional personal computer (200 MHz Pentium-Pro, 128MB RAM, 4GB HD) and a special DSP-card designed by H.Urbschat.

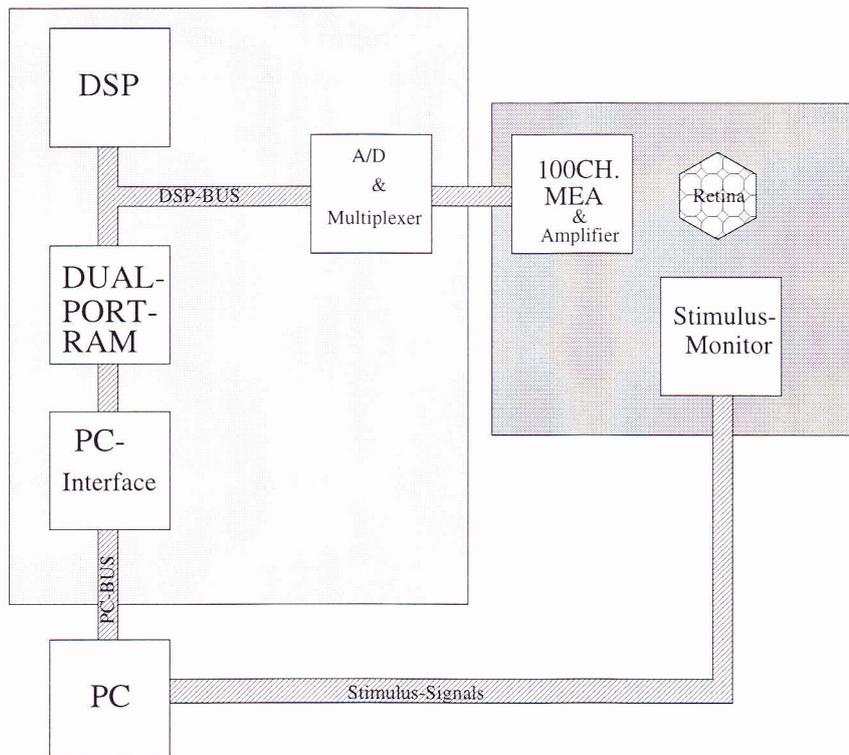


Figure 3: Schematic drawing of hardware.

2.2.1 DSP-card

In order to reduce noise, the analog part of the DSP-card is implemented on a daughter-card and placed near the preamplifiers in the Faraday-cage. This modular design is very flexible for it allows the use of different analog components. Our first prototype uses only 16 channels with 20000 samples/s and 12 bit resolution. The second generation board can sample 60-100 channels simultaneously. Since data acquisition is done continuously with high rate (up to 4MB/s of raw data for 100 channels) a fast Dual-Port-RAM is used as an interface between DSP and PC. The DSP (TMS320C50) can be reprogrammed via the Dual-Port-RAM within few milliseconds. The system samples continuously data until the harddisk is full. This data can be written in either raw or compressed format to

a CD-Recorder for later evaluation. The actual version of the DSP-card works on the ISA-Bus-System, the second version uses the much faster PCI-Interface (up to 132MB/s).

2.2.2 64-channel preamplifier

A commercially available 60-channel preamplifier (MEA 1060, Boven & Möller, Reutlingen) is designed to amplify the extracellular signals (ca. 100 microvolt) with a factor of 5000. It uses bandpassfilters, which operate in the frequency range 500 - 3000 Hz.

3 Operating-Software

Our software-package consists of two parts. The first part controls the DSP-based data acquisition and -optionally- data-reduction-processes. Hence, we have the possibility of migrating new developed preprocessing algorithms from the main-frame computer to the DSP. The bulk of the software-package runs on the PC under Linux and X-Windows. In order to ensure a seamless data flow we had to modify the LinuxOS-kernel by adding a 1MB RAM cache set to a very high priority level. Possibly we use in the further version some other preprocessing techniques on the DSP. The main part of the software runs on the PC (under Linux and X-Windows).

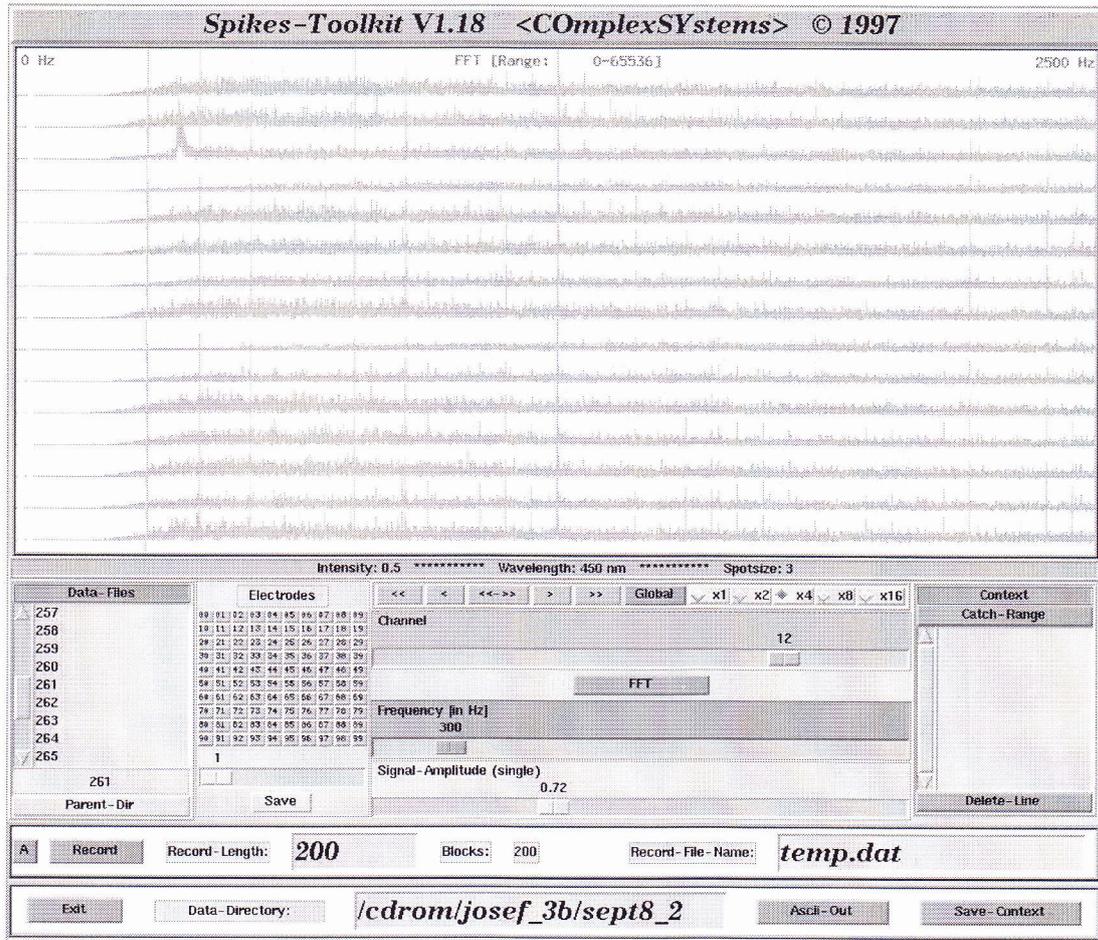


Figure 4: Screenshot of Spike-Tools [©] showing 16 channel FFT-Analysis.

Fig. 4 shows the graphical user interface Spike-Tools [©]. The digitalized signals can be displayed either in multichannel mode (see Fig.5) after recording or in single channel mode in real time (see Fig.6).

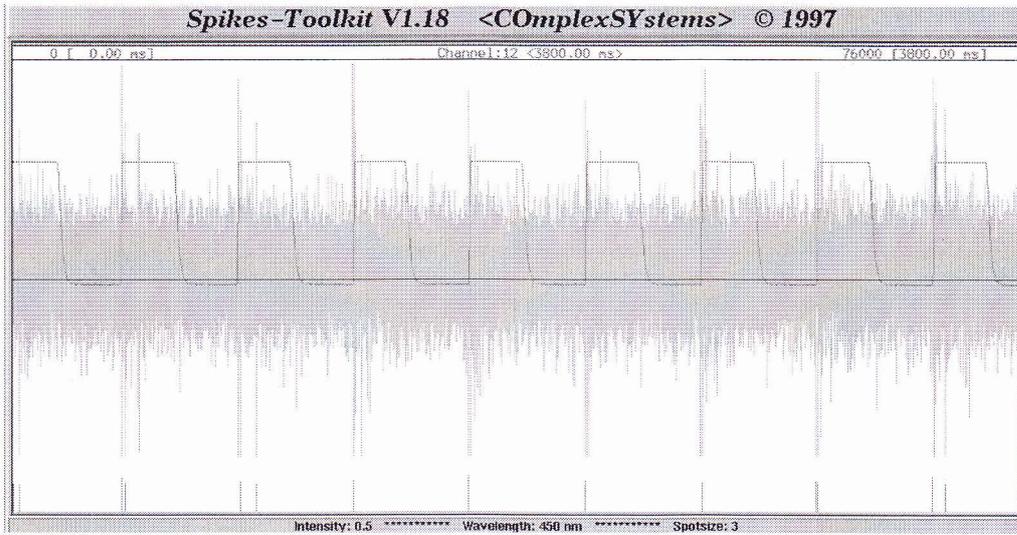


Figure 5: Screenshot: Single channel extracellular signal.

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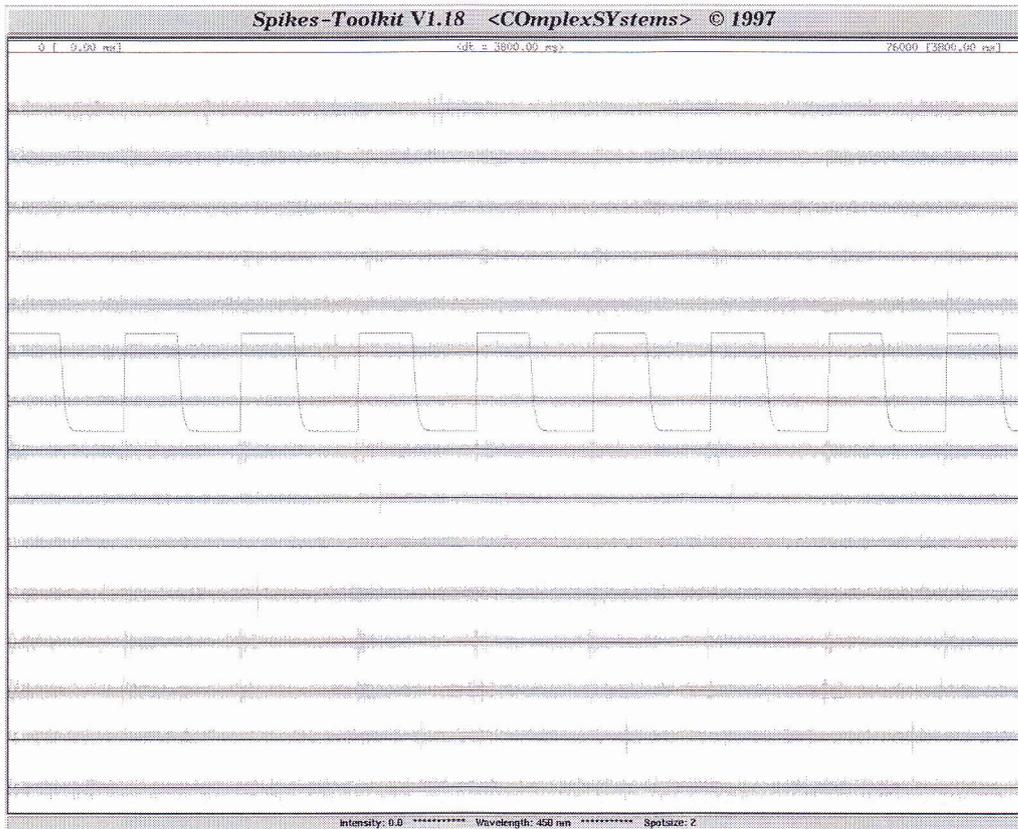


Figure 6: Screenshot: Multi channel extracellular signal.

The tool allows to view the data on different scales and to mark arbitrary data ranges by using context files. The relation of the electrodes of the MEA to the different channels is documented via an electrode-matrix, which can be configured individually. FFT-spectra can be calculated for all channels, helping to detect periodic noise generated by the different components of the electronic equipment and the lab's environment. Actually, two recording modes (automatic and manual) are implemented. Algorithms for spike-detection, FFT, and principal component analysis (Fig.7) are already implemented.

3.1 Analysis tools

To search for spikes in the data, a spike-pattern can be interactively generated using a graphical editor. The computer calculates the similarity between the pattern and different data-ranges using predefined cost-functions. The detected spikes are marked with small red bars at the bottom of the display area (Fig.6).

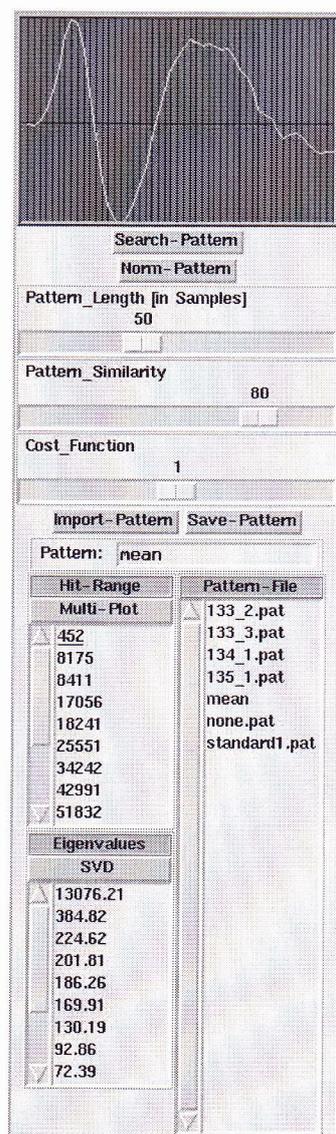


Figure 7: Screenshot: Spike detection - using a graphical editor it is possible to define a interactive search pattern which can be convoluted with the extracellular recordings.

For results see Poster Nr.219 *"color information representation by a small network of ganglion cells in the turtle retina"*.

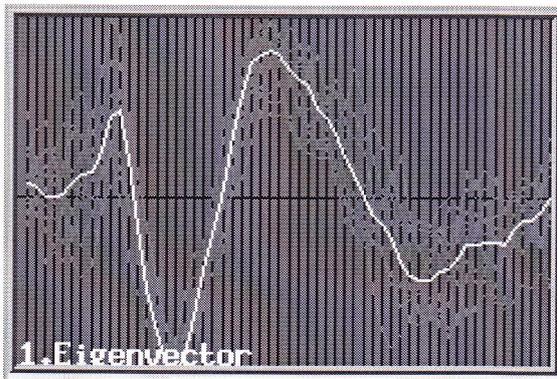


Figure 8: Screenshot of a 16 channel extracellular ganglion cell signals - the red trace represents the stimulus signal recorded from a photodiode in the setup, the green traces represent the recordings of the different electrodes.