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New tools for data aquisition and analysis in multichannel recordings

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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 on single cell electrophysiological preparations. 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 in 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 multielectrode 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 microcrystalline square grid microchip 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 silicon electrically insulated with polyimide (Fig.1).

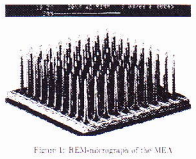

Figure 1: SEM-micrograph of the MEA

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 60channel amplifier and A/D-converter. The digitized signal is further processed on a Unix-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 Faradaic cage. The MEA was vigilo 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 preparation area (Fig.2).

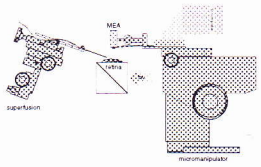

Figure 2: Schematic drawing of Superfusionchamber and MEA

2.2 *Electronical Part*

The electronic hardware part used in the setup consists of two 68k-master, prozessor cards, a workstation, personal computer (200 MHz Pentium-Pro, 128MB RAM, 4GB HD) and a special DSP-card designed at H.Crowbar.

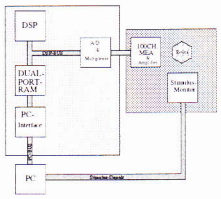

Figure 3: Schematic drawing of hardware

2.2.1 DSP-card

In order to reduce noise, the analog part of the DSP-card is implemented on a daughterboard 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 64 DAT-channels simultaneously. Since data aquisition 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 continuous 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 64channel preamplifier (MEA 1060, Boven & Müller, Reutlingen) is designed to amplify the extracellular signals (ca. 100 microvolt) with a factor of 1000. It uses sand,sandfilters, which operate in the frequency range 300 - 3000 Hz.

3 Operating-Software

Our software-package consists of two parts. The first part realizes the DSP-based data aquisition and sightactive data-reduction-processes. Hence, we have the possibility of migrating new developed preprocessing algorithms from the main-frame computer to the DSP. The rest of the software-package runs on the PC under Linux and X-Windows. In order to ensure a seemless data flow we had to modify the Linux(OS-)sense, be adding a 1MB RAM cache set to a very high priority level. Possible 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).

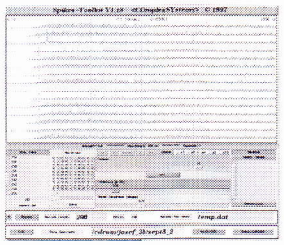

Figure 4: Screenshot of Spike-Tools © showing 16 channel FFT-Analysis.

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 rea. time (see Fig.6).

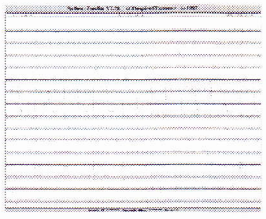

Figure 6: Screenshot: Multi channel extracellular signal.

The tool allows to view the data on different scales and to mark arbitrary data ranges by using cursor lines. 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 (continuous and manual) are implemented. Algorithms for spikedetection, FFT, and primitive component analysis (Fig.7) are already implemented.

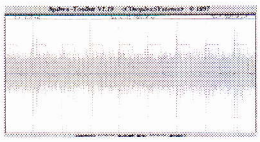

Figure 5: Screenshot: Single channel extracellular signal.

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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).

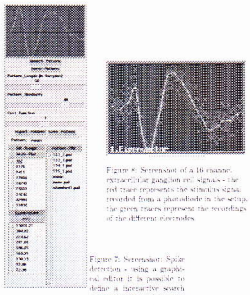

Figure 8: Screenshot of a 16 channel extracellular ganglion cell signals - the red trace represents the stimulus signal recorded from a photodiode in the setup, the green traces represent the recordings of the different electrodes.

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

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

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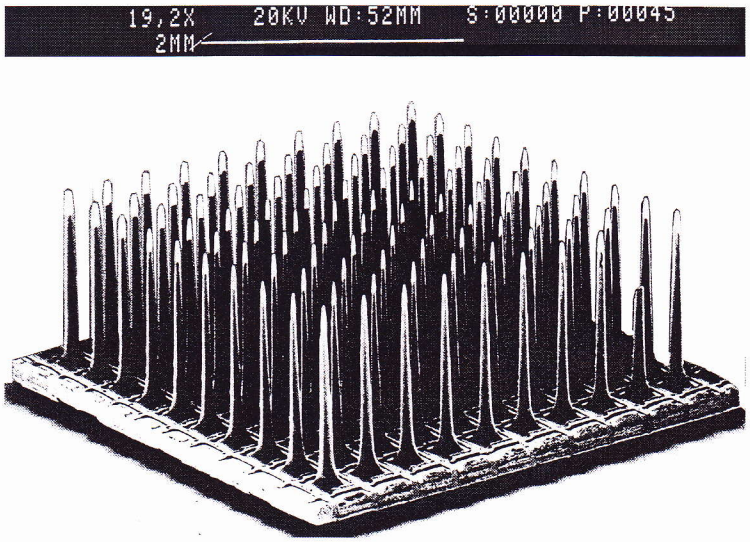

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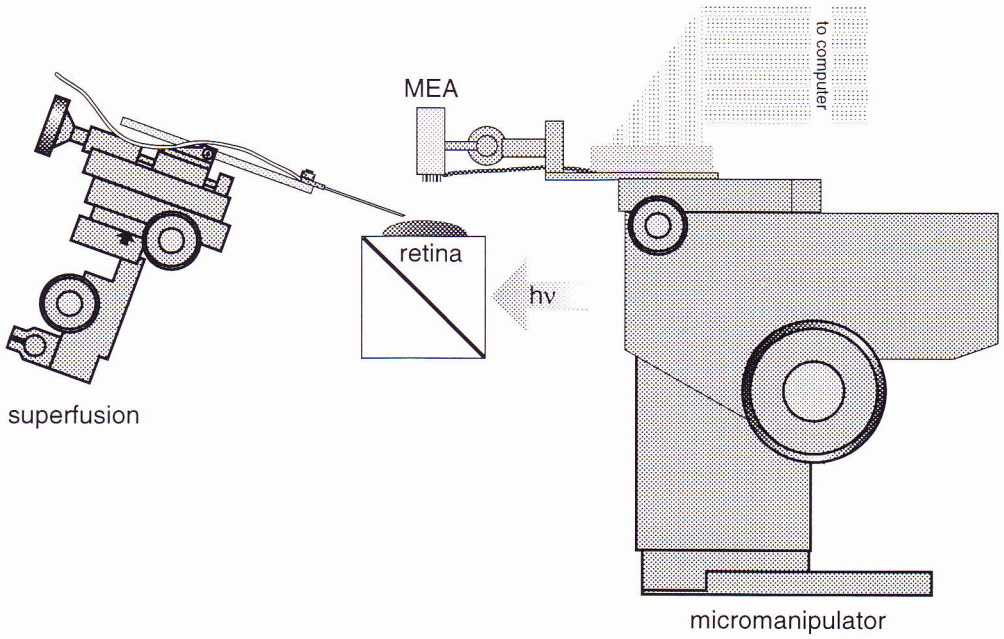

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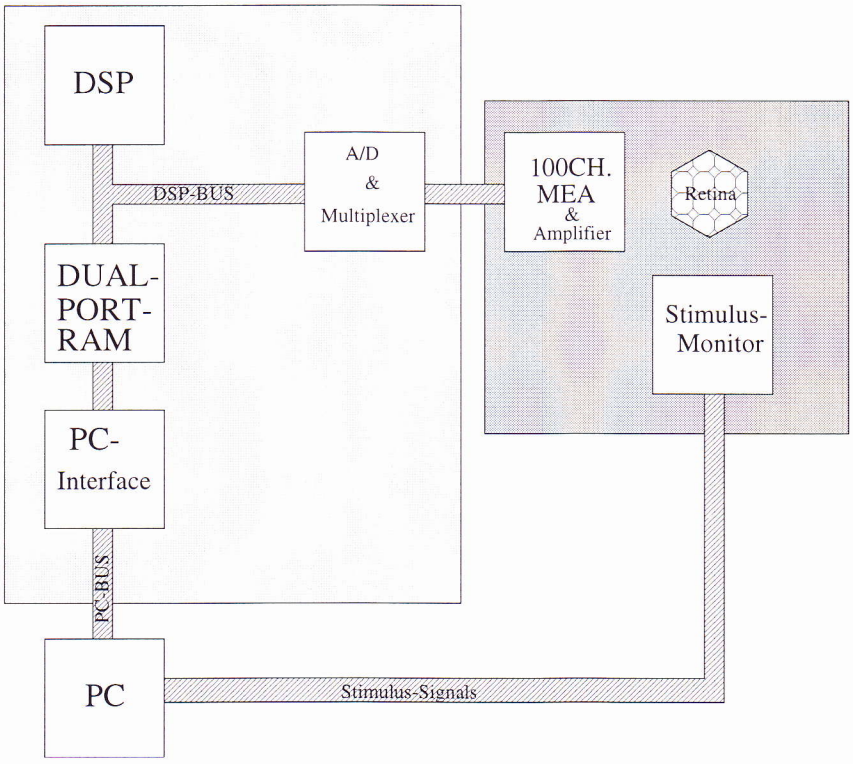

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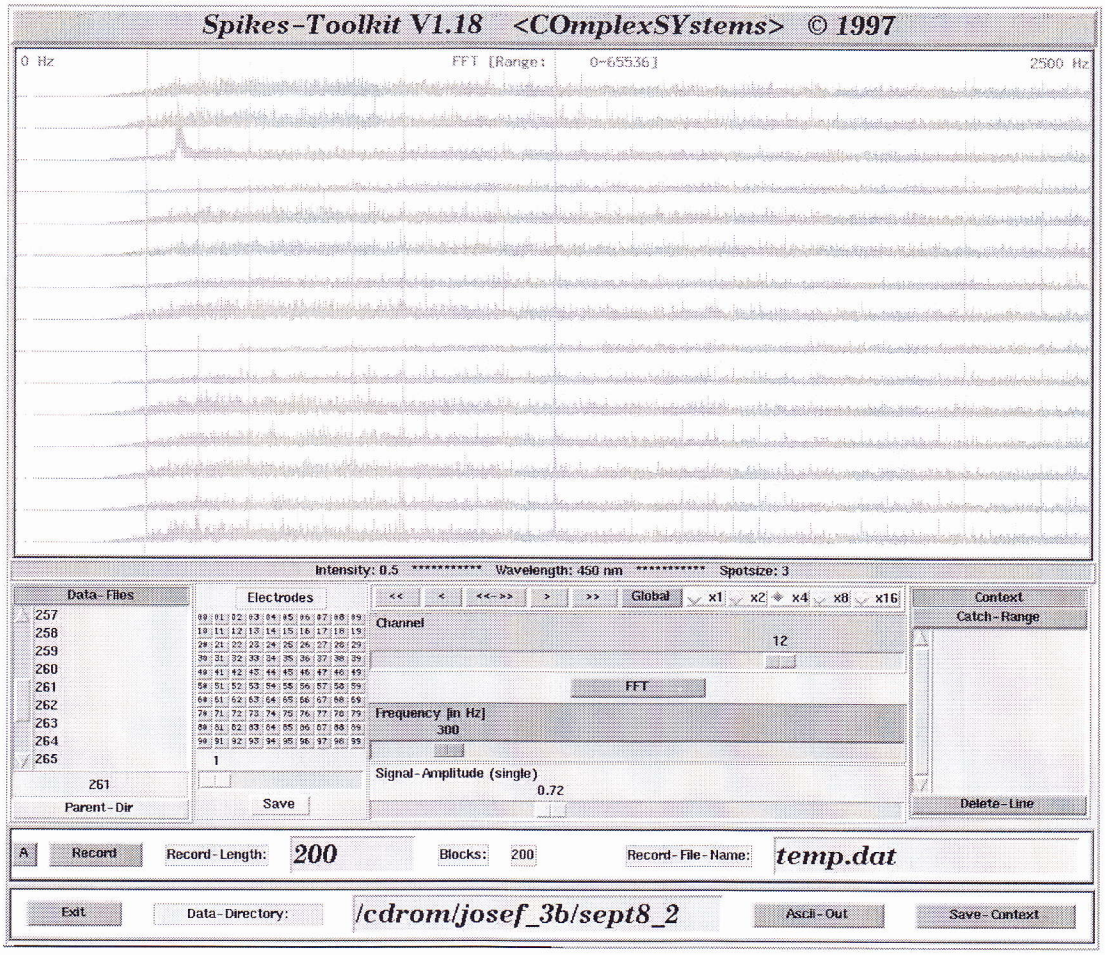

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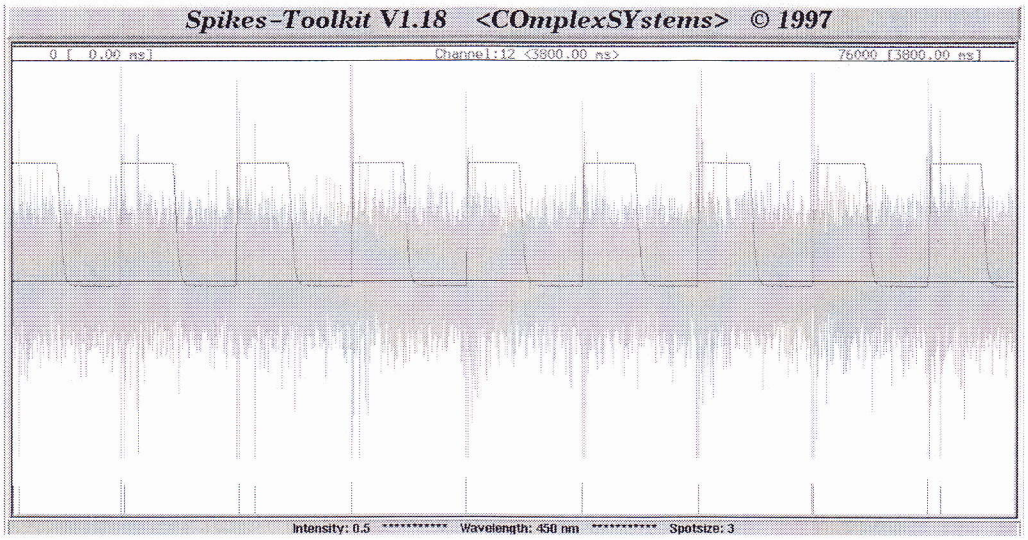

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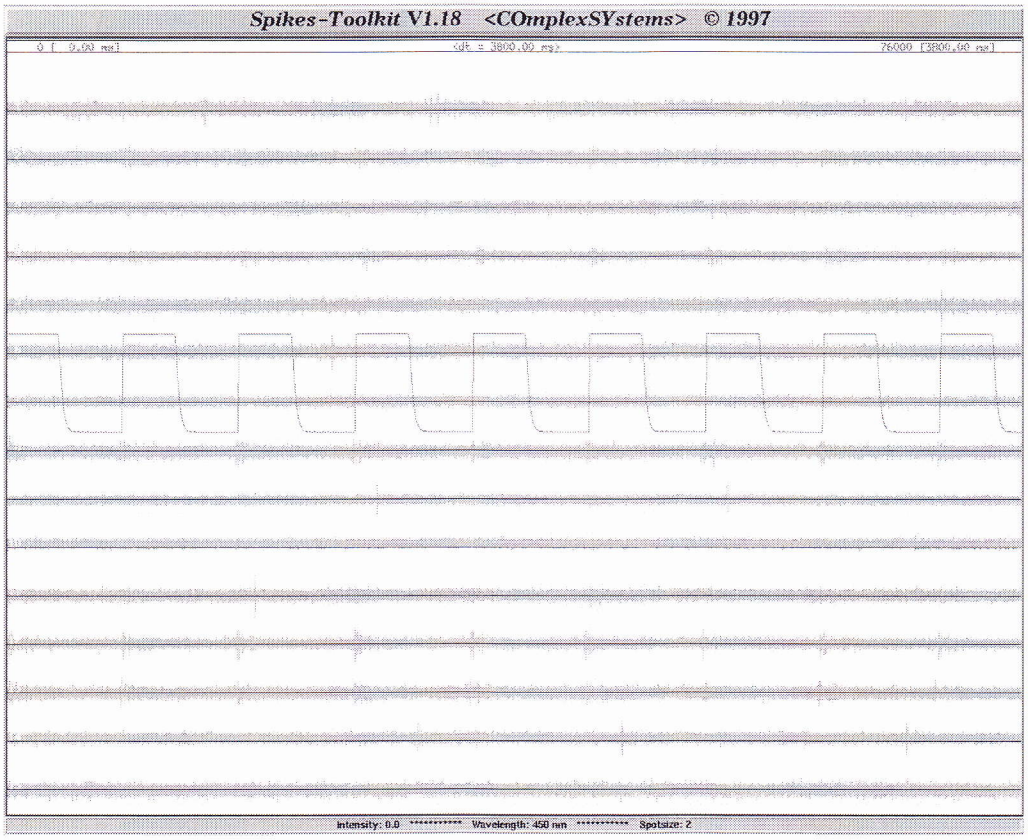

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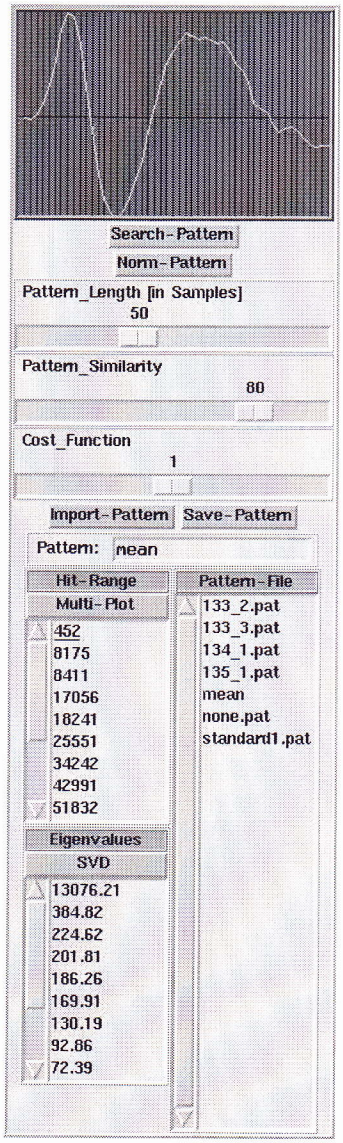

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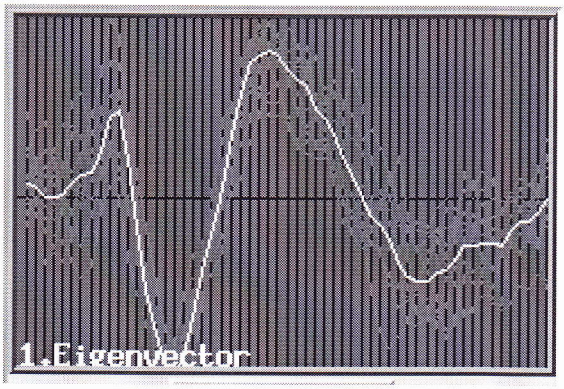

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