ANINTEGRATEDSYSTEMTOTRIGGERFEEDBACK-COUPLEDEVENT RELATEDBRAINPOTENTIALS

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INTRODUCTION

Long going physiological research [1], strongly suggests that the macroscopic electric (i.e. EEG) state of a subject's brain influences the responses to defined stimuli, manifested in evoked (or event-related) potentials. Since this evidence is up till now based on post-hoc evaluation of EEG data, we designed and built a data acquisition system able to fully digitally record raw EEG signals from up to 32 scalp electrodes in standard configuration over a prolonged period of time. The design was furthermore meant to evaluate the incoming signals according to user defined criteria and in succession trigger the stimulus to evoke an ERP by either of auditory, visual or sensory stimuli [4].

All these requirements have to be satisfied within the space and financial constraints given by off-the-shelve PC technology.

METHODS

HARDWARE

In order to satisfy the need for a cost-effective system, we rely on a Windows-PC and Texas Instruments digital signal processors of type C6701 to record and digitize signals, amplified by any available, analog EEG-amplifier. A single DSP is integrated by Innovative Integration (II, Thousand Oaks, CA) onto a M67 PCI-card, which carries in turn two AD/DA- *(A4D4)* and 4:1 multiplexer-modules *(TERM)* or other external cards connected by the OMNIBUS bus system (see Figure 1).

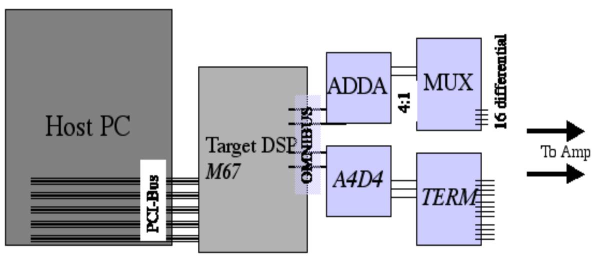

Figure 1: Schematic drawing of subsystems connected to the host computer and DSP target board.

This results in a data acquisition system, which records EEG signals from up to 32 input channels and still provides 8 analog output channels.

SOFTWARE

Programming is done with TI's "Code Composer Studio" and Borland's "C++ Builder". The interrupt driven, DSP-BIOS based, raw data recording routines utilize up to 5% of the DSP's computing power at a sampling rate of 2ksamples/s. The A/D conversion itself may provide up to 50kSamples/sec. However the 4:1 multiplexing step (especially commanding a cyclic data transfer from each MUX channel) consumes excessive interrupts, binding the error free data acquisition below 5kSamples/sec. Leaving it below 2kSamples/sec frees enough computing resources to perform online visualization and analysis.

IMPLEMENTED TOOLS

Acquired channels may due to requests from experimentalists still be displayed in a polygraph mode resembling analog multi-channel EEG-writer. Opposing to those machines, all data are stored digitally and thus no cumbersome writing is needed.

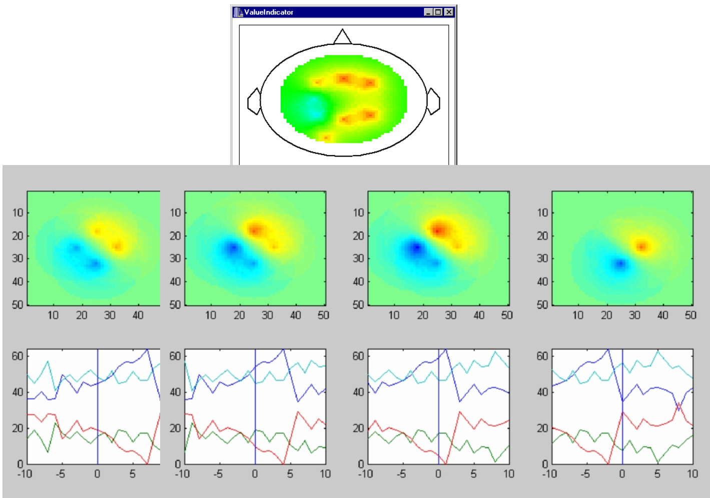

Figure 2: Illustration of online displays: Top: Electrode activity with linear interpolation. Bottom: Time series of 4 exemplary channels (lower part) and their visualization as "array potential display". Time step was 1,5ms between frames.

Personally, we consider the realtime display of activity by color-coding the amplitude acquired from each scalp electrode more informative than the polygraph display (Figure 2, top). The former tool may be used to online display a Current-Source-Density (CSD) [3], but illustrates currently interpolated amplitude values only (Figure 2).

We implemented an averaging panel of data from an arbitrarily chosen channel. On a defined trigger signal of a second channel, this tool averages a time window of 1 second around the trigger ad thus gives a view on the ongoing event related potential. The average and its panel is manually reset, thus continuous streaming of data to disk is maintained without the need to restart after a change of experimental parameters.

As an example of online analysis, we implemented a spectrogram panel, showing the changing frequency components within a selected channel (Figure 3).

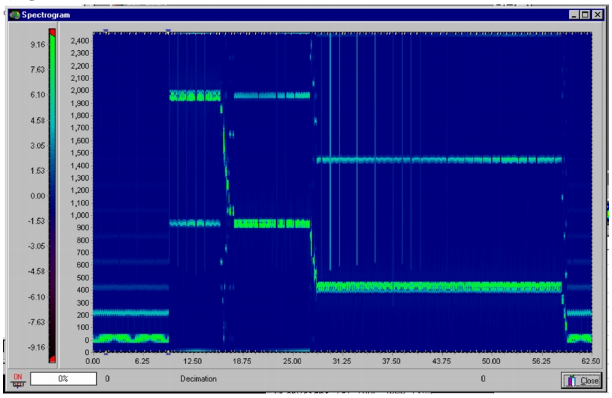

Figure 3: Online spectrogram of a changing triangular signal on one arbitrarily selected channel.

As by the time of this writing, ongoing work was aimed to online implement the wavelet decomposition algorithm proposed by [2]. This algorithm decomposes by smart choice of mother wavelets the EEG signal in its frequency bands, thus enabling us to apply a window discriminator (threshold and times) to the energy content of each frequency band (α, β, γ ...). This online calculated energy-band distribution on one or more EEG-channels will then be used to trigger the stimuli system of the ERP experiment.

GRAPHICAL USER INTERFACE

The following Figure 4 shows in clockwise order one possible screen of the whole program: A traditional 16 channel **polygraph** plot displays scalp electrodes and trigger channel for a visual ERP experiment. A **spectrogram** window on the right upper corner shows the Fourier transform of an artificial rectangular signal of uniform frequency. Below that, an **array potential display** illustrates the ongoing activity on 13 scalp electrodes by color-coding and logarithmically interpolating their potentials. This panel may be replaced by a current source density display. The following panel shows an **average** of channel 2 based on a rectangular trigger signal on channel 8. Our last panel, the **command panel**, in the lower right corner of the screen contains the command and editing functions necessary to each experiment and known from a tape recorder: Run, Stop, Record, Replay, Forward, Back. It furthermore toggles the available online toolboxes and provides information on the hardware status and opportunity to take notes, which are all stored together with incoming data.

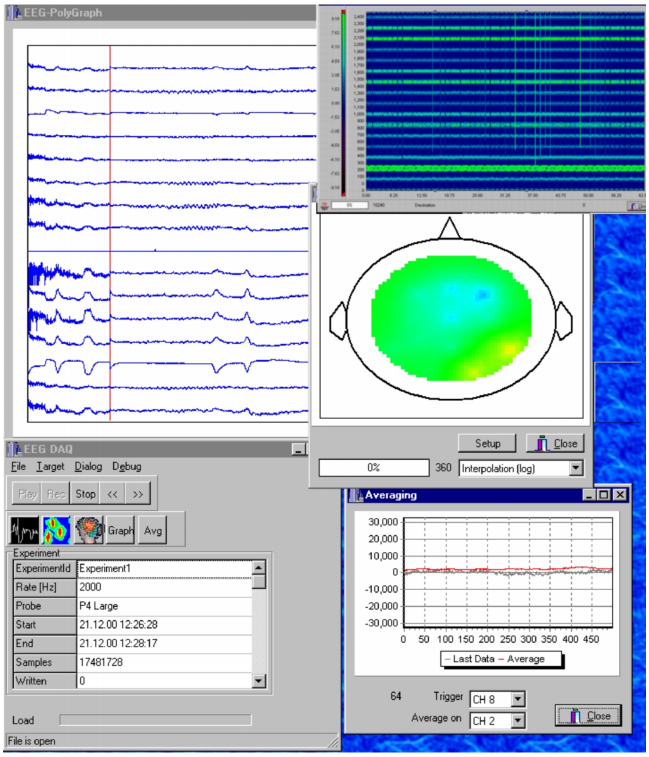

Figure 4: Screenshot of a fully functional system. Panels clockwise from top: Polygraph, spectrogram, array potential, averaging and command panel

DISCUSSION

The goal of this development was to build a fully digital data acquisition system for EEG/ERP experiments. Although we succeeded in continuous recording of EEG signals, ongoing work still aims to integrate the feedback loop to trigger the ERP stimulus on an arbitrarily set energy level of EEG activity. Another developmental stream is aimed to replace the cumbersome multiplexing units and shows a clear reduction in the DSPs workload, thus freeing even more DSP cycles for online tasks.

LITERATURE

1 Rahn,E.andBasar,E.,PrestimulusEEG-activity stronglyinfluencestheauditoryevokedvertexresponse: Anewmethodforselectiveaveraging,Intern.J. Neurosc,69(1993)207-220.

2 Rosso,O.A.,Blanco,S.,Yordanova,J.,Kolev,V., Figliola,A.,Schürmann,M.andBasar,E.,Wavelet entropy:anewtoolforanalysisofshortdurationbrain electricalsignals,J.Neurosci.Meth.,105(2001)65-75.

3 Scherg,M.,FromEEGsourcelocalizationtosource imaging,ActaNeurol.Scand.,Supp.152(1994)29-30.

4 Windhorst,U.andJohansson,H.,Modern TechniquesinNeuroscienceResearch,1edn.,Springer, 1999.