Matlab application for auditory physiology

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Abstract

In this paper we describe a Matlab application for real time measurements in auditory physiology. We have used Matlab executable files to control a data acquisition card. The application is used to perform commonly needed tasks in auditory physiology laboratory.

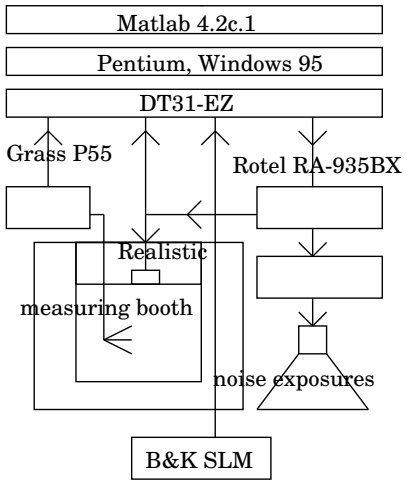

Figure 1: Setup for experimental auditory physiology.

1 Introduction

Matlab is a widely used programming environment for data analysis and visualization. Usually Matlab is used for simulations and for off line analyses. In medical sciences it has been used e.g. for visualization and analysis of electroencephalography (EEG) [9]. Formerly we have used Matlab together with a commercial sound cards to perform noise exposures [7] and to record auditory brainstem responses (ABR) [5, 8]. In those studies external programs were launched from Matlab and results were passed to Matlab through binary files. However, Matlab executable files, C/C++ and Fortran code can be implemented to be part of Matlab environment. This enables one to control data acquisition board in such way, that Matlab is used to generate, acquire and analyze signals in real-time. We have applied Matlab executable files for control of a commercial data acquisition card. The system has been applied to experimental auditory physiological measurements. The system that has been generated include routines for continuous multichannel analog to digital conversion (cad), continuous multichannel digital to analog conversion (cda) and multichannel digital to analog conversion together with simultaneous multichannel analog to digital conversion (cdaad).

2 Methods

Matlab 4.2c.1 (Mathworks, Inc. `http://www.matlab.com`) was used in this study. This 16 byte version of the program was used on 32 byte operating system Windows 95 running on Pentium 166 Mhz with 32 MB RAM. It is necessary to registrate the file name extension `.m` of the Matlab if the program is running under Windows 95 (see `http://www.matlab.com/support/tech-/notes/1100/1110.html`).

The following modifications were made in the batch file `cmex.bat` [6] in order to include data import management and data acquisition import library [2]. It is also necessary to switch the compiling option from

large memory model `-ALw` to huge memory model `-AHw` because it is necessary to return matrices larger than 8192 elements (see `http://www.matlab.com/support/technotes/1600/1615.html`).

```
...
:COMPMSC
...
SET INCLUDE=...;c:\da_sdk\include
%COMP_ROOT%\bin\cl -c -AHw -Zip -FPi87
  -G2sA -Zpe ...
...
:LINKMSC
SET LIB=...;c:\da_sdk\lib
...
echo oldaapi.lib + >> cmexdll.lnk
echo olmem.lib >> cmexdll.lnk
echo cmexdll.def >> cmexdll.lnk
```

The data acquisition board used in the system is Data Translation EISA board DT31-EZ (Data Translation, Inc. `http://www.datatranslation.com`). There exist 16 singe-ended or 8 differential input channels with 12-bit resolution and two digital to analog (DA) channels with 130 kHz simultaneous throughput on the board. Throughput of analog to digital (AD) channels is 250 kHz [3, B Hardware Specifications]. Driver version for Windows 95 was 2.21.02. It was noticed that earlier driver version, the one delivered with board, caused some anomalities in the use. The software development kit used was DataAcq SDK Version 2.20.2 (Data Translation, Inc.) that was installed to default directory `c:\da_sdk`. The software development kit uses Data Translation's DT-Open Layer standard. DT31-EZ board can be replaced by any DT-Open Layer standard supporting board. Board name, in this case `DT3XEZ`, is defined during setup of board and driver and can be checked from the control panel.

Microsoft Visual C/C++ 1.52 (Microsoft inc. `http://www.microsoft.com`) for Windows 3 was used to create dynamic link library (DLL) Matlab executable (MEX) file. Use of DLL instead of relocatable executable (REX), for example using Watcom compiler, enables the use of Windows functions but standard C I/O routines must be replaced by Windows file I/O functions. DLL files also yield slightly poorer performance for numerically intensive applications. Microsoft Visual C/C++ 1.52 is not anymore sold and was obtained as part of Microsoft Visual C++ package 4.0. Code was written according the documentation [6, 2] using ANSI C [1]. In contrast to DataAcq SDK examples [2] no Windows message queues were used because they are not possible inside DLL. This limitation was solved using buffer polling, e.g. following lines can be found from `cad.c`

```
...
olDaGetBuffer(board.hdass, &board.hbuf);
while (board.hbuf==NULL) olDaGetBuffer(
  board.hdass, &board.hbuf);
...
```

The basic structure of all acquisition routines is essentially the same: gateway function to Matlab, card initialization, buffer definition, waiting for buffers to be empty and returning data to workspace. Following data acquisition routines were written for controlling DT Open Layer data acquisition card

`cad`	continuous analog to digital
`cda`	continuous digital to analog
`cdar`	cda repeated
`cdaad`	simultaneous continuous digital to analog with analog to digital
`cdaadr`	cdaad repeated
`cdaada`	cdaad averaged
`cdaadm`	cdaad in matrix format

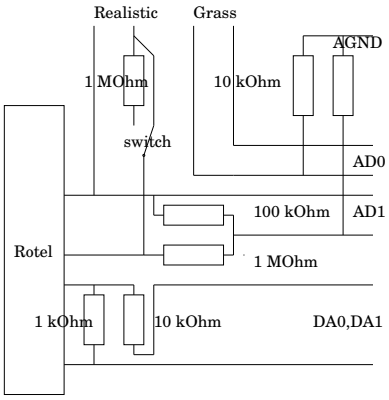

Figure 2: External connection to match voltages and to control volume of sound stimulation.

External equipments connected to computer are shown in figure 1. It consists of Rotel RA-935BX stereo amplifier, Realistic solid-state piezo element (Radio Shack, Cat. No. 40-1379), B&K microphone 4134, preamplifier 2619 and sound level meter 2606. Level of auditory stimulus is manually controlled and the actual voltage over speaker is routed back to channel 0 for determination of chosen level. Around 60 dB attenuation of stimulus for normal threshold mea-

surements is archieved through routing amplifier output through 1 $M\Omega$ resistor. Two analog outputs from DT31-EZ are attenuated through 1kΩ/10kΩ resistors before routing into stereo amplifier, figure 2. In analog inputs 10 $k\Omega$ resistor was used for bias current return [3, 3 Board Installation]. Grass P55 AC amplifier with filter setting bandpass from 300 Hz to 10 000 Hz with gain of 10 000 was used to record auditory brainstem responses with subcutaneous needles. Additional gain of 8 was provided by DT31-EZ.

3 Examples

After the software was installed the functions were compiled with modified `cmex.bat` command. To recompile within each Matlab session `clear` function must be used to free DLL. For users who obtain a copy of `DLL` and `.m` files the only requirement to run examples is Matlab 4.2c.1 and properly installed data acquisition board supporting DT-Open Layer. Following example records consist of 8192 samples recorded with sampling rate of 90 000 Hz from channel 1 with gain 8. Samples of background noise recorded with the sound level meter is shown in figure 3

```
[v,f]=cad('dt3xez',9e4,8192,[1;8]);
subplot(211);plot((0:8191)/f*1000,v)
xlabel('t (ms)')
p=20*log10(abs(fft(v)));
subplot(212)
plot((1:4095)*f/8192,p(2:4096))
xlabel('f (Hz)')
```

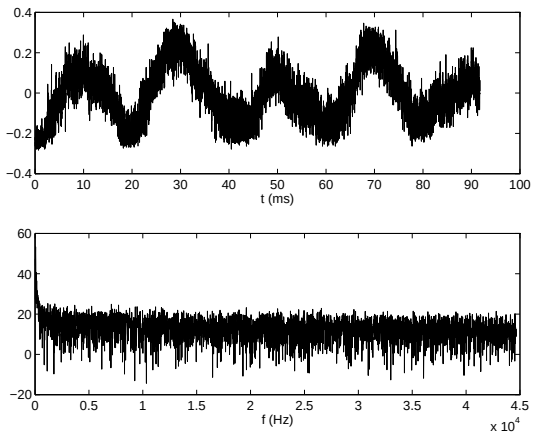

Figure 3: Background noise measured inside booth using B&K sound level meter 2606.

Auditory evoked potentials from 300 g female albino guinea pigs were recorded. Following commands are used to record two 50-response averages, total of 100 responses averaged to stimulus `y`. Second variable returned by the function consists of last single response to stimulus. Figure 4 shows single run and average of 50 to 32 kHz 1 ms stimulus in 10 ms time window. Stimulus starts at point 1 ms and additional delay for 20-cm distance between animal and speaker must be taken account when the absolute latencies are of the interest. With single noisy record same peak originating from auditory nerve and following auditory pathways [4] are seen as in ones with 50 averages.

```
[v,s,f,n]=cdaada('dt3xez',f,y,100,...
   [0 1;1 8]);
t=(0:982)/f*1000;
plot(t,s(2:2:1966)*1e6/8e4,t,...
  v(2:2:1966)*1e6/8e4/n*2)
ylabel('uV')
xlabel('t (ms)')
```

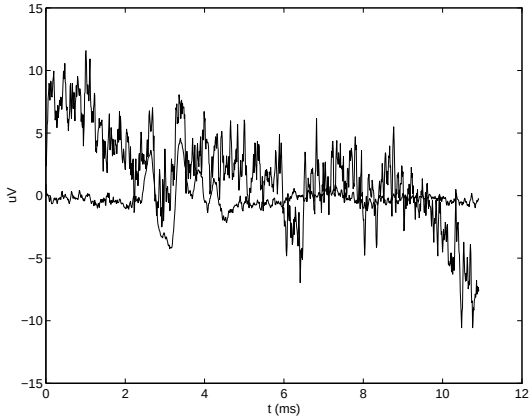

Figure 4: Auditory brainstem responses from guinea pig. Single response and a average of 50 at same intensity level.

In another example of auditory evoked potentials averages with decreasing stimulus intensities are shown. Increase of latencies and decrease of amplitudes can be observed in the results in Figure 5.

4 Discussion

Matlab is a widely used programming language in engineering for data analysis and visualization. Matlab is also incresingly used for biomedical signals [9]. Using functions for data acqui-

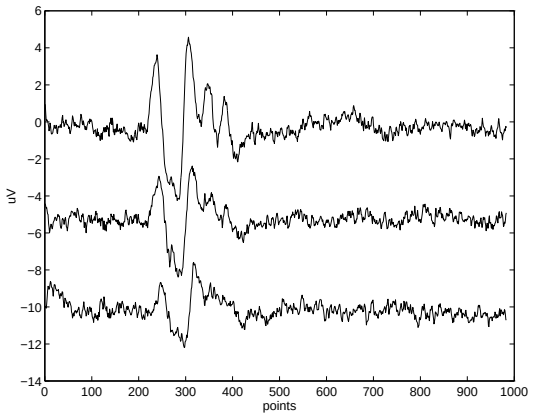

Figure 5: Auditory brainstem responses from guinea pig at different intensity levels.

sition biomedical signals can be analyzed online with Matlab. The Matlab executable files created in this work make it possible to form new acquisition and analysis routines for auditory physiology [10].

The 16 byte version of Matlab used here can be replaced by 32 byte versions for Windows 95 and Windows NT or by standalone compiled C program. The program source code as well as the compiled DLL's can be obtained from authors homepage http://www.uku.fi/~virkkala.

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