Application of the MATLAB ITA-Toolbox: Laboratory Course on Cross-talk Cancellation

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Introduction

We offer a laboratory course for students in the Master's program where students step into 11 different acoustical fields. Data acquisition and post-processing in most courses is realized using the *ITA-Toolbox*. It offers functionality for a wide range of acoustic measurement and signal processing tasks. Students have access to the source code enabling them to follow, comprehend and even modify parts of the signal processing chain. Since MATLAB code does not require compilation, the *ITA-Toolbox* is a very comfortable framework to provide students with scripts missing important parts, e.g. for *crosstalk cancellation filters*, *Kundt's tube* and *sound isolation*. Students must first complete the codes for data processing, gaining a broader knowledge about the subject under study, to then use it for the tasks required in the courses. In this paper the content and preparation of the course is presented along with the MATLAB-based solution. The acceptance as well as the problems will be shortly dicussed.

Laboratory – CTC

Cross-talk cancellation is a technique used e.g. in the CAVE-like environment at RWTH Aachen University to reproduce binaural signals to a user of the virtual reality framework. Coming from this practical application some simplifications and modifications have been applied to make this task also suitable for students in their Master's program. In this three hour practical course students can design their own loudspeaker-based binaural reproduction system. The task starts with understanding the concepts of binaural hearing, by measuring a set of HRTFs and finally designing their own crosstalk cancellation filters. At the end, their results are tested by listening to filtered binaural signals. First the transfer function from the two loudspeakers are measured with a dummy head including the response of the room. These results are post-processed and used in the CTC filter generation. The signal chain is illustrated in Figure 2. From a signal processing point of view, time-windowing of impulse responses as well as regularization techniques for inversion are of special interest.

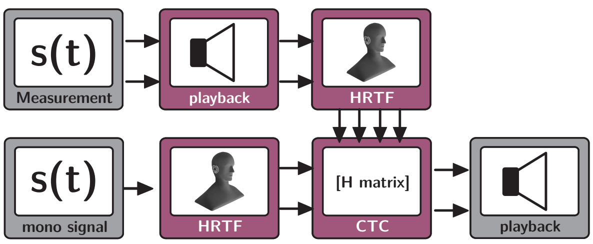

Figure 1: Block diagram of transfer function measurements with dummy head and reproduction of binaural signals using the CTC technique.

About ITA-Toolbox

The ITA-Toolbox is being developed at the Institute of Technical Acoustics in Aachen since 2008. It contains a set of functions for specific, mostly acoustic-oriented, tasks all using a uniform object for audio data and meta data. MATLAB's object-oriented programming is used to provide an easy and simple way of working with recorded or simulated data. Most of the kernel functions can be freely edited, allowing the students—not only in this course—to follow the underlying calculus. Like most MATLAB toolboxes its strength lies in functions, which can be called with various options. This allows beginners to use functions with default settings as well as experts to tweak e.g. signal processing parameters. These command-line-style functions are enhanced by a uniform GUI frontend. Operators are overloaded to allow e.g. the multiplication is realized by a multiplication in frequency domain, i.e. a convolution in time domain. An overview of the toolbox concept is given in Figure 2. The kernel on the left side is developed by the authors and runs stand-alone without the applications shown on the right side. The applications are a collection of scripts and special routines using the toolbox kernel functionality. In this laboratory course this kernel is used, along with some MATLAB functions missing the important solution which the student have to find.

Script Example

Measured and windowed impulse responses from the left and right loudspeaker to the left and right ear of the dummy head are available in the variables HLL, HLR, HRL and HRR as `itaAudio`-Objects. The solution for the CTC filter generation is shown below.

```
%% ***** CTC filter generation *****
beta = 1e-6; %regularization factor

% [a b; c d] = H'.H + beta*I
a = HLL*conj(HLL) + HLR*conj(HLR) + beta;
b = HRL*conj(HLL) + HRR*conj(HLR);
c = HLL*conj(HRL) + HLR*conj(HRR);
d = HRL*conj(HRL) + HRR*conj(HRR) + beta;
determinant = a*d - b*c;

% [LL RL; LR RR] = inv(H'.H +beta) H'
CTC_LL = (d*conj(HLL) - b*conj(HRL))/determinant;
```

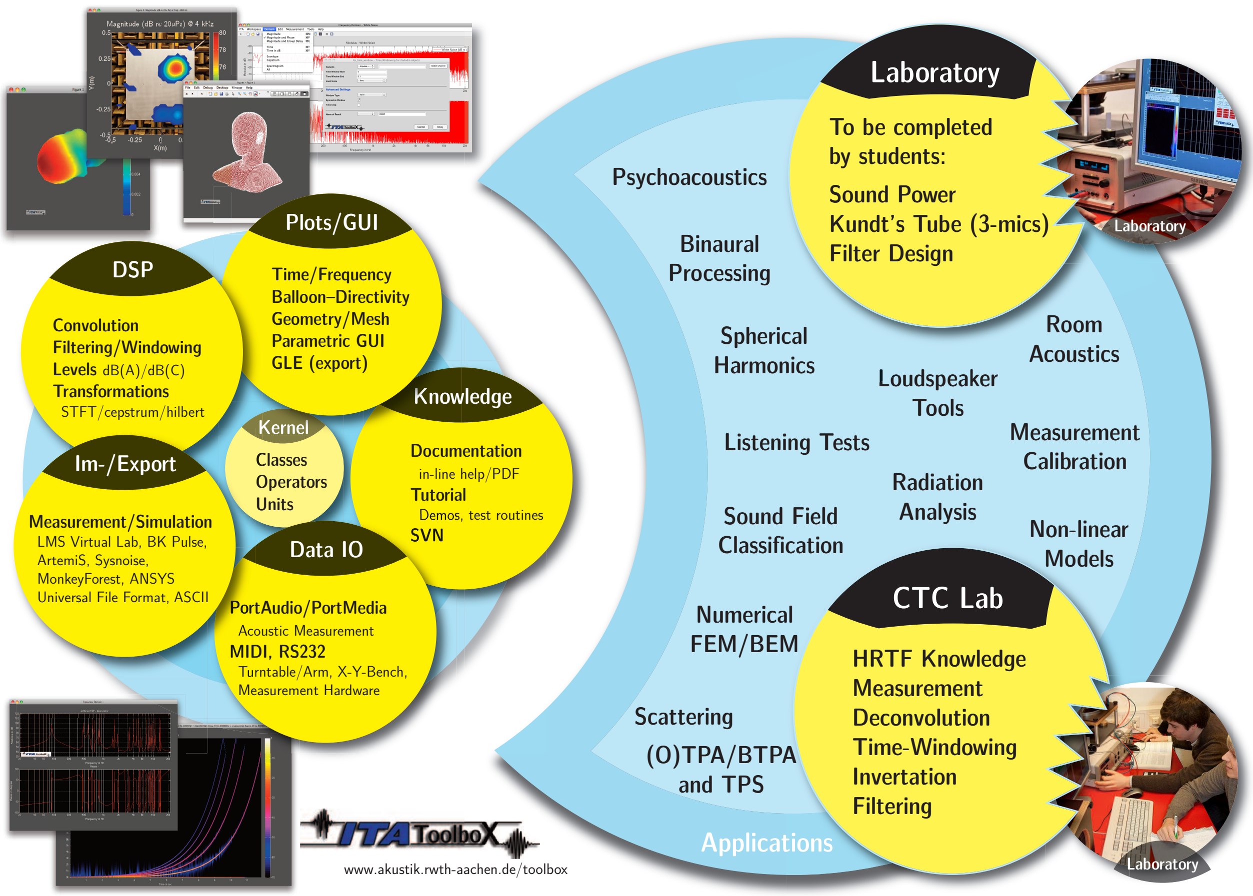

Figure 2: Structural overview of the *ITA-Toolbox* and its functionality, divided into kernel section (functions maintained by developers) and user section with applications (using the basic functionality provided, thus leading to an intuitive scripting on a high abstraction layer).

```
CTC_LR = (a*conj(HRL) - c*conj(HLL))/determinant;
CTC_RL = (d*conj(HLR) - b*conj(HRR))/determinant;
CTC_RR = (a*conj(HRR) - c*conj(HLR))/determinant;
```

In order to continuously filter a binaural signal for representation with this loudspeaker setup, the solution is the following.

```
%% ***** CTC filtering *****
outL = inL*CTC_LL + inR*CTC_RL;
outR = inL*CTC_LR + inR*CTC_RR;
```

The theoretical result in terms of achievable channel separation can be easily calculated and also plotted.

```
%% ***** Test Channel Separation *****
LL = HLL*CTC_LL + HRL*CTC_LR;
LR = HLR*CTC_LL + HRR*CTC_LR;
RL = HLL*CTC_RL + HRL*CTC_RR;
RR = HLR*CTC_RL + HRR*CTC_RR;
```

Feedback

Students showed great interest in the application of theoretical signal processing in this practical task. They adapt fast to the new MATLAB environment and benefit from the available functionality in plotting.

Acknowledgments

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References

[1] Schroeder, M. R. and Atal, B. S., *Computer Simulation of Sound Transmission in Rooms* IEEE Cony. Rec., pt. 7, pp. 150-155 (1963).

[2] Bauck, J. L. and Cooper, D. H. 1996. *Generalized transaural stereo and applications* J. Audio Eng. Soc. 44:683-705.

[3] O. Kirkeby, P. A. Nelson and H. Hamada. *The Stereo Dipole-a virtual source imaging system using two closely spaced loudspeakers.* J. Audio Eng. Soc. 46, pp.387–395, 1998

[4] Dietrich, P., Masiero, B., Müller-Trapet, M., Pollow, M., Scharrer, R.: *MATLAB Toolbox for the Comprehension of Acoustic Measurement and Signal Processing*, DAGA, 2010

[5] Fingerhuth, S., Dietrich, P., Kaldenbach, R.: *Mess-Blackbox zum Verständnis des Übertraungsverhaltens und der akustischen Messtechnik*, DAGA, 2010