

MATLAB Toolbox for the Comprehension of Acoustic Measurement and Signal Processing

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Introduction

A platform-independent MATLAB toolbox called *ITA-Toolbox* is presented that offers functionality for a wide range of acoustic measurement and signal processing tasks. Students have access to the source code of most functions which enables them to follow and comprehend all parts of the signal processing chain. Using MATLAB scripts based on the *ITA-Toolbox* functions and the special data structure, signal processing tasks can be fully automated. This allows students to perform tasks like measuring directivities or calculating reverberation times and acoustic source power. Meta data like physical units, channel names and sampling rates are always kept consistent. In order to facilitate the use of the toolbox, a modular graphical user interface based on the command line functions was developed as well.

Object-Oriented Programming

To make MATLAB code generation as easy as possible, the *ITA-Toolbox* is designed to provide an intuitive handling. With MATLAB's rather new feature of object-oriented programming it is possible to structure data and methods to encapsulated class objects (such as audio data, measurement settings, spatial information) giving them an intelligent behavior. Simple and known built-in routines and operators of MATLAB can be redefined specifically for that class by overloading their functions (polymorphism) [1]. The *ITA-Toolbox* thus defines specific operators for time and frequency domain (e.g., $*$ for frequency multiplication and $.*$ for time multiplication), as well as well-known MATLAB function names (such as `plot`, `mean`, `conj`) for various kind of objects.

A further benefit of object-oriented programming is enhanced structure for the entire software project. New data types can be introduced and the functionality added without the need of large modifications in the existing code (inheritance). Nevertheless, students using the *ITA-Toolbox* can focus on their actual work, as the abstract programming concepts are transparent and do not need to be fully understood to allow the student to work with the *ITA-Toolbox*.

Graphical User Interface

In addition to the usual MATLAB command line usage, a graphical user interface (GUI) lightens the first experiences with MATLAB, the *ITA-Toolbox*, and signal processing itself. The GUI consists of a main window, dis-

playing the current signal in the selected domains and a menu, which gives access to the most common signal processing routines. The GUI uses the standard MATLAB user workspace. All audio objects in the user workspace can be displayed and further processed. The results will be saved back to the user workspace. This usage of the user workspace enables the students to work with a combination of a graphical user interface and the command line. Switching between both handling methods whenever necessary or wanted is seamless and eases the students adaption to the *ITA-Toolbox*.

The input parameters of signal processing functions are retrieved in a parametrized interface, making it easy for students to generate a GUI for their own routines, like the one in Fig. 1. Only required inputs and options need to be defined, all the rest (including GUI generation, data-type verification and compatibility checks) is handled by a parametric GUI routine.

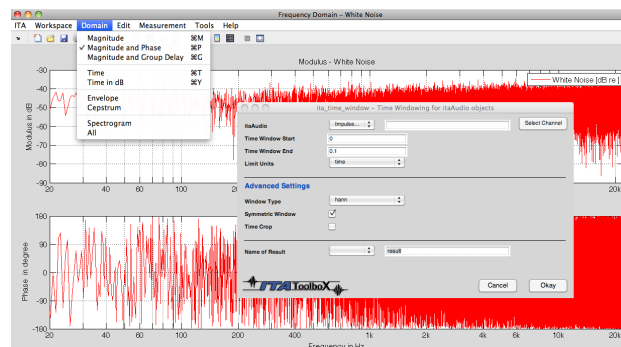


Figure 1: Example of a parametric GUI window

Application in Acoustics Laboratory

The *ITA-Toolbox* is gradually replacing older measurement systems used on laboratory and exercise courses offered at ITA with the advantage that students have direct access to the data being processed, e.g. while measuring transfer functions [2]. Since MATLAB code does not require compilation, the *ITA-Toolbox* is a very comfortable framework to provide the students with scripts missing important parts. First the students have to complete the missing parts of the script to later use it for the tasks required in the courses.

An example where the toolbox has been successfully used is the new experiment on binaural hearing offered since winter semester 2009 as part of the laboratory course on technical acoustics. At this experiment the students are presented to the principles of binaural hearing through the analysis of *head related transfer functions* (HRTFs)

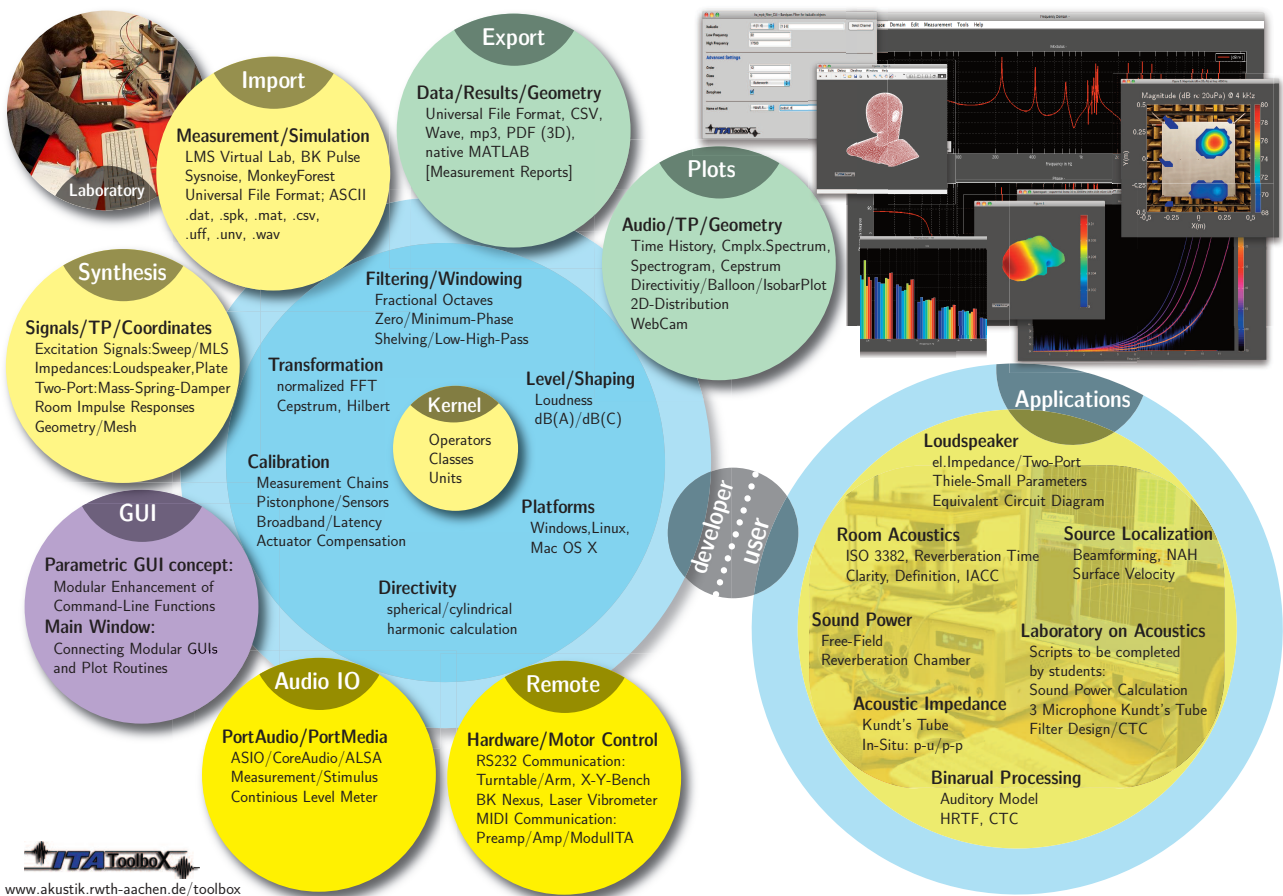


Figure 2: Structural overview of the *ITA-Toolbox* and its functionality, divided into developer section (functions maintained by developers) and user section with applications (using the basic functionality provided, thus leading to an intuitive scripting on a high abstraction layer).

and of binaural reproduction through the concept of *crosstalk cancellation filters* (CTC).

The *ITA-Toolbox* is used by students in all tasks of this experiment. First, the main GUI is used to measure the HRTF of a dummy head in several directions which is used later on. A comparison of the measured HRTF in time and frequency domain by supplied transformation and plotting routines helps to understand the effects on variation of the incidence angle. In a second task the students are required to complete three scripts in order to a) calculate the CTC filters, b) filter a binaural signal with a CTC filter and c) estimate the achievable channel separation. By using the object-oriented framework provided, scripts can be written in a compact and intuitive manner. Once the codes are complete, the students apply them to the measured HRTFs to first obtain a CTC filter. They then filter a given binaural signal with the computed CTC filter and play it back through the *ITA-Toolbox*, thus being able to subjectively analyze the CTC filter designed.

Other examples of applications are an experiment with the Kundt's tube and an experiment about wall isolation. In both cases the multichannel measurement allows for fast data acquisition and students have to complete the

codes for data processing, gaining a broader knowledge about the subject under study. The toolbox is also used by students during their bachelor and master projects for a wide range of measurement and signal processing applications, as presented in Fig. 2.

Acknowledgment

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