Acoustic directivity measurement using the ITA-Toolbox
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Hardware and measurement
Communication with ASIO (Audio Stream Input/Output) capable audio hardware is implemented to measure directional impulse responses. For full automation, auxiliary instrumentation can directly be controlled via:
- MIDI (Musical Instrument Digital Interface),
- OSC (Open Sound Control),
- serial interface (e.g. RS232).
Measurement classes supply the functionality to store:
- excitation and compensation signals [1,2],
- hardware calibration and latency data.
The (multi-channel) result of a measurement is stored in an audio data class object which can contain:
- uniformly sampled data,
- data in the time and frequency domain,
- audio data details and meta data (e.g. sampling rate).
Spatial information is stored automatically in a spatial data class.

Signal processing
At its core, the ITA-Toolbox[3] provides functions to read, manipulate, and save objects. For the determination of the directivity, the following steps are required:
- detection of the first arriving sound,
- time shift of the impulse response,
- time windowing for artifact removal,
- regularized division to improve signal-to-noise ratio.
Additional processing features are provided by the ITA-Toolbox such as:
- filtering and smoothing,
- resampling and re-quantizing.
Arithmetic options such as summation (+), multiplication (\cdot) and division (/) for the audio objects are supported.
The measured impulse responses can be stored by the measurement routine as an audio object (wav, dat, spk, unv, and sofa) and can be loaded for further signal processing.

Visualization
Besides the core features of the ITA-Toolbox, different methods are implemented to display and analyze the results.
Display routines for:
- impulse responses in time-domain,
- transfer functions in frequency-domain are available.
The coordinate class saves spatial information (e.g. measurement points) as:
- Cartesian coordinates \((x,y,z)\),
- cylindrical coordinates \((r, \theta, z)\),
- spherical coordinates \((r, \theta, \phi)\).
Furthermore, measurement points in a coordinate object can be displayed using the native scatter plot function.
Audio objects which contain frequency and the corresponding spatial data can be directly displayed as directives (see figure below).

Transducer directivities
The directivity of electroacoustic sources and receivers is measured to characterize the transducer in simulations, calibrate room acoustics measurements, and derive directional filters. For this task, time-efficient measurement signals are generated [2] and control stepper motors is used to tilt and rotate the transducer [3].

Head-related transfer functions
Spatial positioning of virtual objects can be realized using head-related transfer functions (HRTFs). These HRTFs describe the directional propagation path of the sound from a source to the ear canal entrance. To measure high-resolution HRTFs of humans or dummy heads, a fast measurement system is required [4].

Musical instruments
Knowledge about the directivity of musical instruments is essential for the understanding of music perception in concert halls and their representation in virtual reality systems. The directivity is sampled with a microphone at a fixed position in space while the instrument is tilted and rotated using the ITA-Toolbox [5].

References