Efficient quality assessment of spatial audio data of high resolution

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Introduction

Recent advances in the field of spatial audio demand a rising number of audio channels that need to be measured and processed. Audio data of high spatial resolution such as e.g. HRTF datasets or sensor directivity patterns may consist of thousands of discrete measurements, amounting to large sets of data. As the required time to perform such high resolution measurements can range up to several days, continuous manual monitoring of the measurement is not feasible (and would only detect some of the possible errors).

In order to assess the usually higher dimensional data of high spatial resolution, mathematical methods and data visualization can both prove beneficial to obtain a quick overview of the data. In this contribution a workflow for the efficient quality assessment of spatial audio data is presented. The data is firstly converted into a flexible data format that allows efficient random access and can then be evaluated and examined for possible negative influence on audio quality. Except for Matlab [1], which is used as a platform for the ITA-Toolbox [2, 3], all tools used for measurement and vizualization are all open-source and run on Windows, Mac OS X and Linux.

Measurement, conversion and storage of spatial audio data

The measurement of spatial audio data, such as HRTFs or source or receiver directivity of high resolution usually consists of a multitude of measurements, often stored in a multitude of files for single directions. In order to extract the data of all directions all files have to be imported.

Specialized data containers exist for fast access of spatial audio data, such as OpenDAFF [4] or SOFA [5]. While OpenDAFF is specialized on ultra fast access for real-time applications, it is limited to equal angular spacing of the measurement point locations. The generic and highly-flexible open-source data format HDF5 [6] act as base for SOFA, extended with specific meta-information for spatial audio data on arbitrary measurement points.

The quality assessment as described in this paper currently uses its own simplistic HDF5 data format as prove of concept and for scientific small-scale use. After the measurement with the ITA-Toolbox [2] the obtained data is converted into a single file containing one or many complete directivity patterns. This file is read by the visualization GUI for fast random access of the data.

Scientific data visualization tools

The graphical visualization is implemented with the open-source software VTK [7], that provids a powerful platform for interactive visualizations with a focus on scientific applications. The Python programming language [8] is used for integrating the components of the software and providing a graphical user interface for data analysis. Several third party packages are employed: MayaVi [9] regards the API for accessing VTK, h5py [10] is used to read and write to datasets stored in the HDF5 format. NumPy and SciPy [11, 12] allow to implement numerical programming algorithms similar to Matlab. The 3D vizualization is combined with fast and interactive 2D plots for frequency and time domain plots, implemented with Chaco [13]. Both plot types in the complete GUI in Fig. 1 are linked interactively via callback routines, so that a click in the directivity plot (left) can trigger an update of the corresponding time or frequency plot (right), and vice versa. The sliders at the bottom allow to vary the plot over frequency (left slider) and over the single measurement directions (right slider).

Physical quantities used for visualization

Depending on the type of possible error in the data, the visualization can be adapted to investigate for specific details. For high precision data a visualization of the phase is useful, as it correlates with the traveling distance of an acoustic wave and can thus give hints about a misalignment of the source to be measured.

For the use in the vizualization the magnitude M, the sound pressure level L and the angular phase A for a directivity described as spherical pressure function $p(\theta, \phi)$ are calculated:

$$M = |p(\theta, \phi)| \tag{1}$$

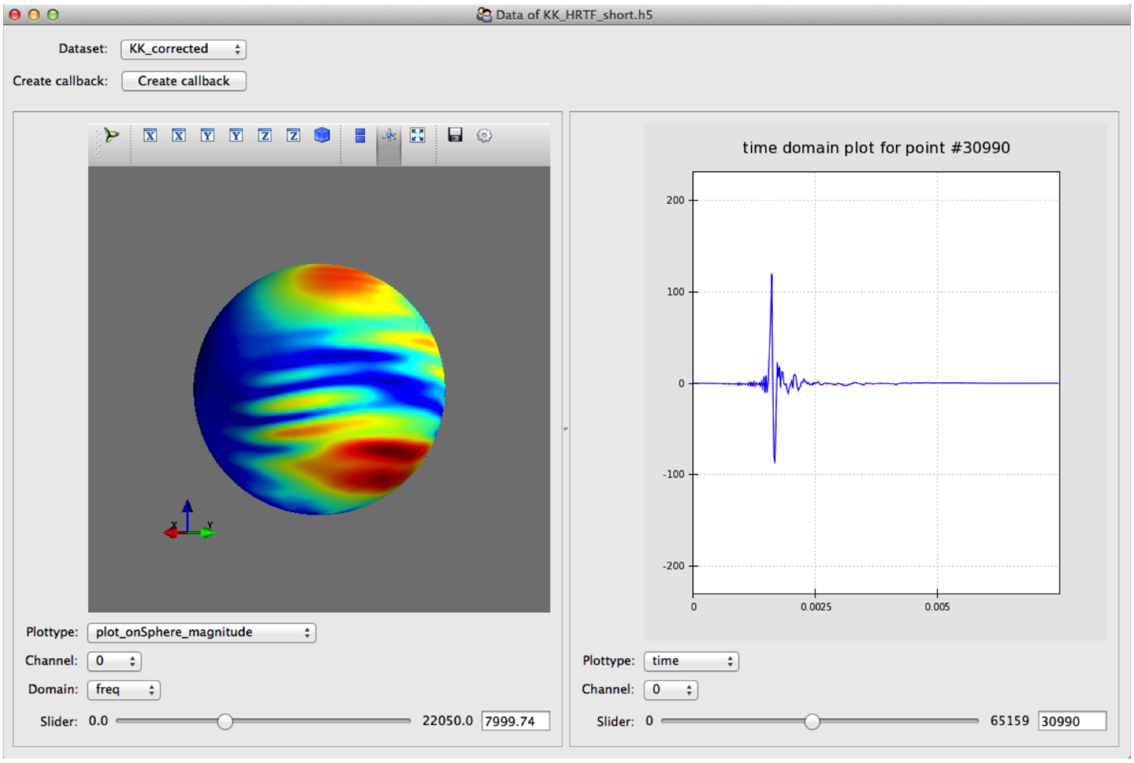
$$L = 20 \log_{10} \left(\frac{|p(\theta, \phi)|}{\max\left(|p(\theta, \phi)|\right)} \right) \mathrm{dB} + \Delta L \tag{2}$$

$$A = \arg\left(p(\theta, \phi)\right) \tag{3}$$

As the logarithmic scale is not bound, an effective dynamic range ΔL is chosen as the maximum level and all values below 0 dB are truncated to zero.

Various plot types can be composed from these physical quantities by a variation of the radius r and the color c, with the following plots currently supported:

- Complex balloon plot ($r = M$, $c = A$)
- Log. complex balloon plot ($r = L$, $c = A$)
- Magnitude balloon plot ($r = c = M$)
- Log. magnitude balloon plot ($r = c = L$)


Data of KK_HRTF_short.h5

Dataset: KK_corrected

Create callback: Create callback

Plottype: plot_onSphere_magnitude

Channel: 0

Domain: freq

Slider: 0.0 22050.0 7999.74

Plottype: time

Channel: 0

Slider: 0 65159 30990

Figure 1: Screenshot of GUI for data visualization. In this example a HRTF dataset of an artificial head measured in a 1°/1° resolution (elevation/azimuth) is plotted at 8 kHz in the mode *magnitude on unit sphere*. On the right side the time domain plot of a specific direction is plotted.

- Magnitude on unit sphere ($r = 1$, $c = M$)
- Log. magnitude on unit sphere ($r = 1$, $c = L$)
- Phase on unit sphere ($r = 1$, $c = A$)
- Single points plot (interactive) ($r = r_{\text{geometry}}$, $r_{\text{points}} = L$, $c = A$)

The last plot consists of a collection of small spheres that vary in radius according to the levels and in color according to the phase. The location of the single spheres now indicates the location of the measurement, which can be useful to visualize the sensor positions in case they are irregularly distributed. The vizualizer was used for sensor positions obtained by the time-of-arrivals using an optimization strategy [14].

Conclusions and outlook

With the developed tool a scientific data analysis of spatial audio data of high resolution is feasible, allowing to gain understanding of the wave propagation and the features and issues that possibly arise. Using data files and methods for fast random access, a responsive GUI can be implemented that allows data analysis in real-time with variation over time or frequency. For very large sets of high-resolution data the performance drops, but optimization such as varying the chunk size of the HDF5 data or saving lower resolution directivity in blocks might increase performance. Currently, only a proprietary data format is supported, but a future support of commonly used data formats for spatial audio data such as OpenDAFF and SOFA is desired and planned.

References

[1] The MathWorks: MATLAB `http://www.mathworks.de/`

[2] ITA-Toolbox for MATLAB `http://www.ita-toolbox.org/`

[3] Dietrich, P. et al.: MATLAB Toolbox for the Comprehension of Acoustic Measurement and Signal Processing. Fortschritte der Akustik – DAGA, 2010

[4] OpenDAFF (Software package for directional audio data) `http://www.opendaff.org/`

[5] SOFA (Spatially Oriented Format for Acoustics) `http://www.sofaconventions.org/`

[6] HDF Group (Hirachial data format) `http://www.hdfgroup.org/HDF5/`

[7] Visualization Toolkit (VTK) `http://www.vtk.org/`

[8] Python programming language `http://www.python.org/`

[9] Mayavi (3D scientific data visualization in Python) `http://code.enthought.com/projects/mayavi/`

[10] h5py (HDF5 for Python) `http://www.h5py.org/`

[11] NumPy (Numerical computations in Python) `http://www.numpy.org/`

[12] SciPy (Scientific algorithms in Python) `http://www.scipy.org/`

[13] Chaco (2D plotting in Python) `http://code.enthought.com/projects/chaco/`

[14] Masiero, B.: Individualized Binaural Technology. Measurement, Equalization and Perceptual Evaluation. PhD thesis, RWTH Aachen University, 2012.