openMat - Management of Acoustic Material (Meta-)Properties Using an Open Source Database Format

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Introduction

In recent years, a multitude of software applications has been designed for the simulation of sound propagation in room- and city acoustics, where users, such as researchers and acoustic consultants, usually prioritize only some of them that meet their individual demands best possible. To run such a simulation, not only an appropriate geometrical model of the simulated scene is required, but also the respective acoustical material properties for each of the model's individual surface. Today, these properties are described by (mostly) standardized material descriptors and all known simulation tools rely on them in their internal simulation algorithms. Unfortunately, a direct exchange of such material data between different applications is practically impossible since most simulation tools use their own proprietary file formats. Thus, a change of simulation tool always goes along with a conversion of material data into the current tool's file format. Most of the time, however, such converters do not exist.

To overcome this issue, the open database project *openMat* was founded, which supports a detailed description of materials for the usage in acoustical simulation software. Numerical data as well as supplemental meta-information on the material are provided in an open Extensible Markup Language (XML) database format. The project aims at becoming an international standard data format for storing and exchanging acoustic material parameters. In this contribution, we present the first conceptual design of *openMat*, which was discussed with many developers and acoustic consultants. However, the project shall not be understood as the work of few, but of many. Everyone is invited to contribute to *openMat* in order to make this project a joint success.

Supported Material Descriptors

At the moment, the *openMat* database format supports an angle- and frequency dependent storage of the the five most common acoustical material descriptors:

1. **Acoustic impedance**: the acoustic impedance $\underline{Z}$ is defined as the ratio between sound pressure and sound velocity. This type of material descriptor is mainly used in wave based simulation methods, such as BEM/FEM. The complex reflection factor $\underline{R}$ is directly derivable from $\underline{Z}$ and the respective free field impedance.
2. **Absorption coefficient**: the energetic sound absorption coefficient α is used in energetic simulation methods such as ray tracing and corresponds to $\alpha = 1 - |\underline{R}|^2$. Absorption coefficients are usually measured in reverberation chambers according to DIN EN ISO standard 354.
3. **Scattering coefficient**: the scattering coefficient s describes the ratio of non-specularly reflected sound energy to the totally reflected sound energy. The scattering coefficient is usually measured according to the ISO standard 17497-1, either under free-field or diffuse field conditions, but numerical solutions are also available for some types of corrugated surfaces.
4. **Diffusion coefficient**: the diffusion coefficient d is derived from the auto-correlation function of the polar response measured on a semicircle or a hemisphere. It can be seen as a measure of the surface's ability to uniformly scatter in all directions. The diffusion coefficient is measured in an anechoic chamber according to the ISO standard 17497-2.
5. **Bidirectional transfer functions (BDTF)**: the BDTF describes the propagation of the sound wave as a function of both the incidence angle and the angle of reflection.

For all descriptors, either measured or simulated, the storage of detailed and multi-lingual information on the respective data acquisition is supported. In the case of measurements, this includes a description of the measurement location, the measurement date, the measurement procedure and a contact address, while the name of the simulation software, detailed simulation parameter settings and a contact address setting can be stored in the case of simulations.

Supported Meta-Information

In order to boost the database's fields of application, meta-information can also be included to the database. This includes images and textures for material visualization in different simulation environments as well as price information to achieve a rough estimation of installation costs. Furthermore, CAD files of the surface structure can be linked to each material, which could be used not only for a correct surface visualization, but also for extrapolating scattering coefficients directly from the geometrical structure. By supporting such meta-information, material databases in the *openMat* format can be applied during both the graphical and the acoustical planning stage. This yields two major advantages: 1) the correct materials for the room acoustical simulation are directly assigned in the CAD-model, and 2) serious flaws in the room acoustical design can instantly be detected by evaluating reverberation times after Sabine and Eyring (and example is given in the Sec. 'Python Library and Blender Plugin').

The XML Schema Definition

The XML schema applied in *openMat* is defined by a XML Schema Definition (XSD) file, which is a formal description pattern in compliance with the W3C recommendations. An XSD file provides a list of elements and attributes in a vocabulary and associates types, such as 'integer' and 'string', or more specific descriptors such as 'absorption coefficient' or 'sample picture', with values found in the documents. Furthermore, it constrains where elements and attributes can appear, and what can appear inside those elements. An XSD file is both human-readable and machine-processable, which makes it quite handy to work with. In the following, a short overview on the most important parts of the *openMat* schema is given. A complete and comprehensive description of the *openMat* XSD schema is available online [1].

The database contains an unrestricted number of xsd:elements that are of type *materialElement*. A *materialElement* consists – at the moment – of up to fourteen sub-elements of different data types. However, only three of these 14 sub-elements are mandatory, while the rest is optional.

XSD:Element	Data-Type/Description
name	*textElement* Name (and only the name) of the material.
description	*textElement* Detailed description of the material.
type	*typeElement* Each material has a specific type, either *material* or *object*.

Table 1: XSD schema for basic information on the respective material (mandatory).

For creating a well-structured database, basic information on materials is essential. Thus, the xsd:elements *name*, *description* and *type* are *mandatory* for each *materialElement* (see Tab. 1). The elements *name* and *description* are of type *openMat:textElements*, which can handle multi-lingual text entries. At the moment, eleven languages (en, da, de, es, fi, fr, it, nl, no, sv, pt) are supported, whereby entries in English are mandatory. The third element *type* defines if the respective database entry represents a material or an object (e.g. chairs or tables). This differentiation was introduced since acoustical properties of objects, such as scattering, are dependent on the object's geometrical shape and, thus, can differ extremely much in comparison to the properties of the materials they were made of.

XSD:Element	Data-Type/Description
diffData	*dataElement* Contains diffusion coefficients.
scatData	*dataElement* Contains scattering coefficients.
absoData	*dataElement* Contains absorption coefficients.
impeData	*dataElement* Contains impedance.
BDTFData	*dataElementBD* Contains BDTF values.

Table 2: XSD schema for storing acoustical material properties (optional).

Data on acoustical material properties build certainly the core of the database. As mentioned before, *openMat* supports (so far) the storage of acoustic impedances, absorption coefficients, scattering coefficients, diffusion coefficients and BDTFs. All these numerical descriptors are encapsulated in the data types *openMat:dataElement* and *openMat:dataElementBD*, respectively, which both support angle- and distance-dependent data, complex values as well as multi-lingual information on the respective data acquisition, e.g., measured (who, when, where, how), simulated (who, when, where, software, simulation settings), or from literature (reference).

XSD:Element	Data-Type/Description
URL	*xsd:string* Contains a URL (manufacturer, etc.).
sampleImage	*xsd:string* Contains one file link to one photo.
CADModel	*xsd:string* Contains one file link to one CAD file.
texture	*fileElement* Contains one or more file links to (seamless) textures.
additionalFile	*fileElement* Contains one or more file links to one or more additional files.
price	*priceElement* Contains price information of the material.

Table 3: XSD schema for additional meta-information (optional).

In addition to the numerical material descriptors, the *openMat*'s XML schema supports a large variety of meta-information (compare Tab. 3). Each *materialElement* can additionally contain links to a) external websites, b) a sample image of the material, c) one or more surface textures (e.g. with different colors), d) one CAD model of the surface structure, e) one or more (arbitrary) external files. Furthermore, information on pricing can be added (supported currencies are EUR, USD and NOK at the moment).

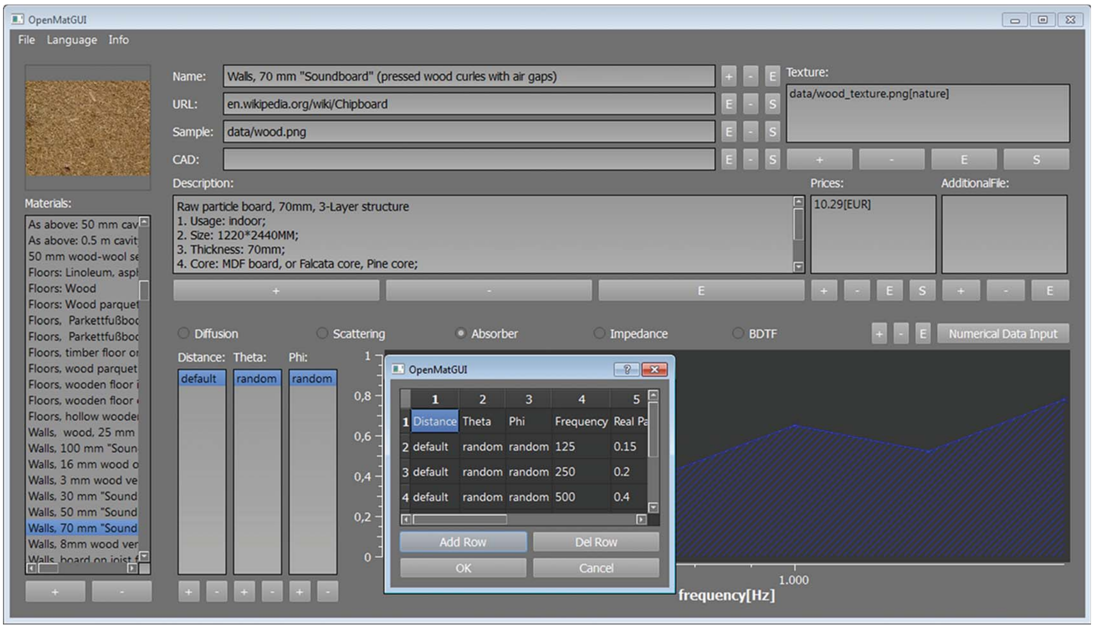

Figure 1: Graphical user interface for creating, exploring and modifying databases in *openMat* format.

Exemplary XML Code Listing

An exemplary, one-element and intuitively understandable *openMat* database example is given below.

```
<material_database>
  <material type="mat">
    <name lang="en">   Mineral Wool    </name>
    <name lang="de">   Faserabsorber   </name>
    <description lang="en">
      inflammable, 5 mm thick, white
    </description>
    <description lang="de">
      nicht brennbar, 5mm dick, weiss
    </description>
    <diffData method="1">
      <acquisition>
        <location>Meran, Italy    </location>
        <person>Dr. U.N. Known   </person>
        <institute>Company Inc. </institute>
        <date>2013-03-18          </date>
      </acquisition>
      <distance>
        <frequency f="125"  >
          <angle>
            <value>0.25    </value>
            <value>0.5     </value>
          </angle>
        </frequency>
      </distance>
    </diffData>
    <url>          openmat.info </url>
    <sampleImage>  Wool.png
</sampleImage>
    <texture>      blue.png       </texture>
    <price currency = "EUR"
           source   = "www.santa.com">
      12.00
    </price>
    <cadModel>     mount.dxf      </cadModel>
  </material>
</material_database>
```

C++ Library with Graphical User Interface

A reference implementation in *C++* has been created to demonstrate the usage of *openMat* databases. The library provides different functionalities for both exporting and importing databases in *openMat* format. During the database import, the content gets validated against the *openMat* schema file before it gets further processed. This way, it is guaranteed that the database is not corrupted. The *C++* library contains functions for reading and writing complete databases as well as single database entries, and aims at giving a reference implementation such that more optimized functions can be derived quite easily for personal use. On top of this library, a graphical user interface (GUI) has been implemented for an easy usage of *openMat* databases (see Fig. 1). This GUI can be used to create, explore and modify database entries in *openMat* XML structure in a very convenient way, e.g., it features a graphical editor of numerical data, supports copy-and-paste functionality for common spreadsheet applications such as Microsoft EXCEL and many more. A more detailed description of the graphical user interface is provided as a user manual which is delivered together with the software. Binaries are available for Windows, Mac and Linux in addition to the complete source code.

Python Library and Blender Plugin

In addition to the *C++* library, a Python library has been implemented for easily embedding *openMat* in third party software or writing scripts for data conversion from other formats into *openMat*. The library contains classes and methods to read and write data in *openMat* format and to access these objects. To demonstrate how the *openMat* Python library can be used in other applications, a plugin for the open source 3D modeller Blender [2] has been implemented. With the offered plugin it

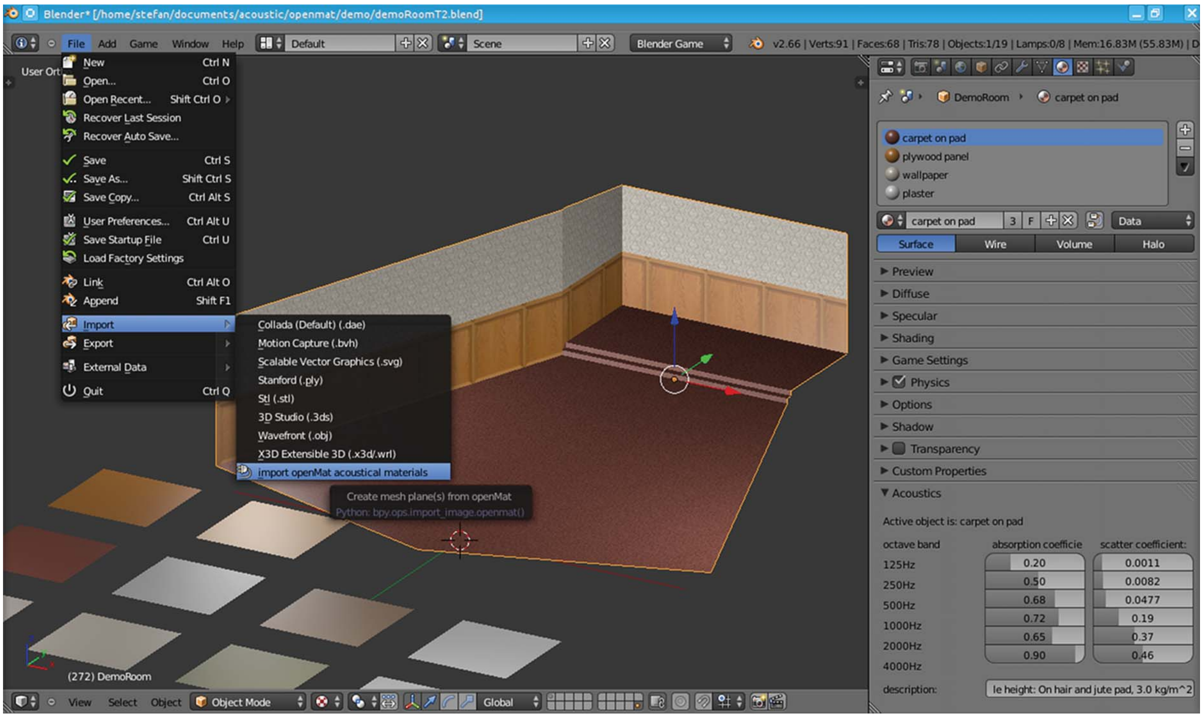

Figure 2: By using the *openMat* Python library and the *openMat* Blender plugin, an additional menu item offers to import acoustical materials in Blender. The materials are shown as squares with the materials attributed to them. The absorption and scatter coefficients of the materials are presented as additional properties in the material panel.

is possible to import both acoustical data and texture files from an *openMat* database. The imported materials can be assigned to walls of an enclosure and textures are directly mapped to the surfaces that are linked to the respective database material (see Fig. 2). In addition, the plugin demonstrates the usage of the absorption coefficients attributed to the materials of a 3D-model by determining its reverberation time according to Sabine or Eyring.

Availabe openMat Databases

By using the *openMat* Python library, the well-known material database of the Physikalisch Technische Bundesanstalt (PTB) in Braunschweig, Germany, was converted into the *openMat* database format. The PTB-database is a huge collection of absorption coefficients for different frequencies as found in published measurements, handouts from manufacturers and in relevant literature. It contains data not only for specially designed absorbers, but also for everyday materials such as brick walls, plate glass or different types of concrete. By permission of the PTB, the converted database with more than 2000 materials is available online at the *openMat* website.

Licensing

The entire source code of the *openMat* project is published under the Lesser General Public License (LGPL). This way, we hope that also commercial applications will support *openMat* in the future.

Website

Everything related to *openMat* is published on the project's website [1], which is hosted by Dirk Schröder and Alexander Pohl. This internet platform provides not only information on *openMat's* current XML scheme, but also offers a large number of downloads such as a huge material database stored in *openMat* format, powerful database editors and open source code libraries as well as plugins for a direct integration of the *openMat* format in other programs.

Summary

This paper presented the first conceptual design of a freely available, open source, XML-based database format for storing both numerical and meta information on acoustic materials. The XML schema definition was shortly discussed and insights on example implementations in different programming languages for reading and writing *openMat* databases were given. Furthermore, an example for the usage of *openMat* with third party software was described. To further improve the XML specifications of *openMat*, the authors invite all interested consultants and developers to come up with suggestions and ideas, so that the project gets soon mature enough to become an international standard data format for storing and exchanging acoustic material parameters.

References

[1] OPENMAT WEBSITE http://www.openMat.info/.

[2] BLENDER WEBSITE http://www.blender.org/.