An approach for structuring sound sample libraries using ontology

Eugene Cherny[1,2], Johan Lilius[1], Johannes Brusila[1], Dmitry Mouromtsev[2], and Gleb Rogozinsky[3]

[1] Åbo Akademi University, Turku, Finland
[2] ISST Laboratory, ITMO University, St. Petersburg, Russia
[3] The Bonch-Bruevich Saint-Petersburg University of Telecommunications, St. Petersburg, Russia
{eugene.cherny, johan.lilius, jbrusila}@abo.fi, mouromtsev@mail.ifmo.ru, gleb.rogozinsky@gmail.com

Abstract. Sound designers use big collections of sounds, recorded themselves or bought from commercial library providers. They have to navigate through thousands of sounds in order to find a sound pertinent for a task. Metadata management software is used, but all annotations are text-based and added by hand and there is still no widely accepted vocabulary of terms that can be used for annotations. This introduces several metadata issues that make the search process complex, such as ambiguity, synonymy and relativity. This paper addresses these problems with knowledge elicitation and sound design ontology engineering.

Keywords: Ontology Engineering, Knowledge Elicitation, Sound Design, Metadata Management, Web Ontology Language

1 Introduction

Sound design is an essential part of modern media production: documentary and fiction films, mobile applications, interactive installations, games and virtual reality—almost every part of digital content works with audio in order to bring in the top notch experience to the auditory. The sound is so tightly bound with other media that well-made sounds are no longer associated with multimedia in our everyday life. But without it almost every part of media becomes unfinished and not able to maintain one's attention, making digital content unattractive for the public. There are many types of sound design, depending on the application (games, films, theater, mobile applications, etc.), but for the sake of simplicity from now on we will be talking about gaming sound design.

There are two different approaches to sound design according to how a sound is generated and used [1]. A sample-based approach is based on the processing of already recorded sounds, which are triggered at specific game events. A procedural one implies building up signal synthesis and processing chains and making them reactive to a in-game context in real-time. But the inherent complexity of implementing DSP algorithms for artistic tasks made this approach rarely used in the gaming industry, hence the sample-based one is used most to do sound design. However this approach has its own drawbacks, particularly in sound organization and search tasks. Sound sample management software does not completely solve the problem, because it is based on a per-sample hand-added metadata, which is often incomplete or even missing. This leads to the situations when a single sound query returns several dozens of sounds that are needed to be listened in order to find a relevant one that works for a task.

The purpose of this paper is to explore a *sound organization* problem in the context of sound sample libraries. The goal of the paper is to identify factors which cause difficulties with sample libraries usage and to propose a solution to overcome them. To accomplish this goal the interviews with professional sound designers will be conducted, and the ontology-based metadata integration solution will be proposed.

The rest of the paper is organized as follows. *Section 2* describes the current state of sound libraries management solutions. In *Section 3* an approach to a sound ontology engineering will be proposed. *Section 4* will describe results of one iteration of the approach. *Section 5* will conclude findings of the paper and will discuss further steps to develop the project.

2 Related Work

2.1 Timbre Descriptions and Ontologies

One of the first attempts to study and describe sound was conducted by the German scientist Von Helmholtz [2]. He studied the relation between verbally expressed qualities of tone and sound spectrum content using resonator objects. A number of other studies during the 20th century have been conducted to find out how the acoustic properties of the sound relate to the verbalization produced by humans. A review of such studies can be found in [3]. A lot of research focuses on how similar timbres are [4–6], how well they can be discriminated with verbalizations [7, 8], and does not explore the sound domain terms and relationships that would help to structure the sound libraries.

We found very few papers describing projects that use ontologies to represent information about sound [9–11], but these does not provide ontologies themselves for study and have no pertinent resources available online.

W3C recommendation for "Ontology for Media Resources" [12] and the Music Ontology [13] which provide structure for describing and publishing media resources online with general metadata, like keywords, creator, distributor, etc.

2.2 Metadata management

Nowadays professional sound designers have multi-terabyte sound sample collections[4], containing all kinds of recordings, from door locks to dolphins. The

[4] Tim Prebble, Sound Library Storage Solutions, URL: http://www.musicofsound.co.nz/blog/sound-library-storage-solutions

metadata management software[5] is used to navigate through them, it is the description of the sound file and its contents filled in when the sound is added to library. Commercial libraries provide sample descriptions in different forms: proprietary metadata software formats, spreadsheets or at least a PDF file. The metadata is represented as the table data format with rows corresponding to sound files and columns to different information associated with them. Such information includes, for example, a filename, a creator's name, keywords, a description, and others. Metadata software does the text search in these fields.

3 Approach Overview

Our ontology engineering approach is based on the NeOn methodology [14]. This methodology provides guidelines for different scenarios of an ontology life cycle, covering specification, localization and other issues. For this project we employed several scenarios from the methodology: developing the specification, reusing and re-engineering non-ontological resources, and reusing and merging ontological resources. Before going into methodological details, we would like to give a brief overview of the approach.

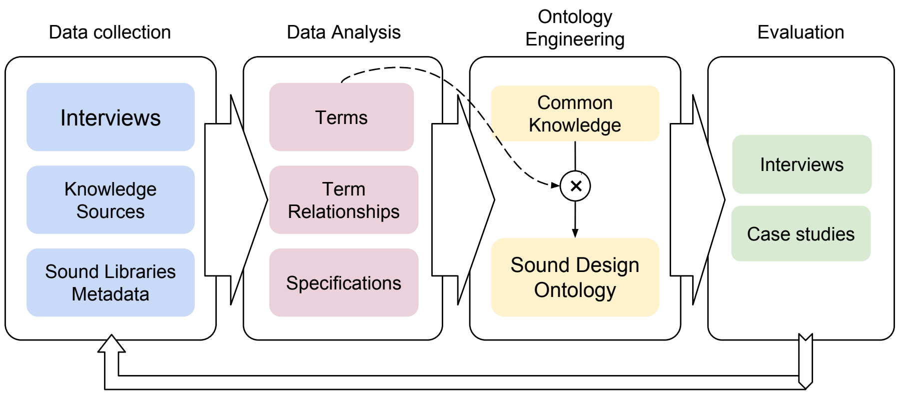

Fig. 1. A sound design ontology life cycle. The dashed shows the links between sound design ontology and the common knowledge ontology based on keywords.

A life cycle diagram (Fig. 1) depicts four major stages in the process. On the first stage we *collect* the data by interviewing professionals, selecting knowledge

[5] There are a number of metadata management software, but they essentially do the same. The differences are in the user experience and in the format of underlying metadata, often incompatible with each other. A comprehensive list of metadata software in the blog of the professional sound designer Tim Prebble: `http://www.musicofsound.co.nz/blog/metadata-support-in-sound-library-apps`

sources (e.g. sound design related books or blog posts), and downloading metadata for the selected commercial sound sample libraries. This data is then *qualitatively analyzed* to find the important domain concepts, keywords, terms and relationships between them. The data is also used to define the domain problems and to write the ontology specifications. The *ontology engineering* stage includes creation of the sound design ontology, populating it with the data and interlinking this data with the common knowledge ontology. After this stage we *qualitatively evaluate* the results to find out how well they work for solving the defined problems. The ontology is then undergoes through all life cycle stages from the beginning in order to address issues found in the evaluation.

3.1 Data Collection

As was already mentioned, the approach involves three distinct data sources that can be used to create an ontology: interviews, knowledge sources (books and other resources on sound design) and metadata from commercial sample libraries. They provide a multifaceted view on the problem domain and naturally validate conclusions drawn from each of them separately.

The *purpose* of the data collection is to get a holistic view on the problem of sound organization by interpreting different sources of sound design related data. This data is then going to be analyzed in order to build a formal representation of the problem domain from the bottom up. The purpose statement is rather broad, but it allows to shift the research focus later on after we started to collect the data.

For the rest of this section we explain the role of each data source in the process.

Interviews. As was mentioned earlier, there is little research done on the sound design concepts' formalization. Books about using related methods and techniques concern mostly theoretical issues (basics of digital signal processing and psychoacoustics [1, 15], recording techniques [16], etc.), and only rare blog posts shed some light on practical problems experienced by professionals when working with sound organization. Thus there is a gap between documented and practical knowledges which makes it impossible to move forward without cooperation with professionals.

The *purpose* of the interviews is to fill this gap by communicating on the existing issues of sound organization directly with the sound designers working in the industry. The interviews were designed to follow general recommendations for doing the qualitative inquiry [17] and the following two paragraphs describe their organization.

The interviews does not dictate a specific *setting*, hence the data can be collected from different sources: email, chat or phone conversation. All discussions will be documented in the researcher's notebook (verbal conversations are transcribed) and published online on the later stages of the project provided that participants agreed for the publication.

Interviews will be conducted in a *semi-structured* manner, using open- ended questions and following a loose structure to guide general direction of a discussion. The discussion topics include how participants organize their sound libraries, how they search for sounds, what they think about current sound organization solutions, and also more general questions on how they do their work.

Knowledge sources can include several books and other materials for the sound designers. Most of them regarded as trusted sources of structured knowledge that can be used to validate interview results.

The sample libraries metadata contain text annotations describing the sound file content. They have a special value as they provide professionally crafted metadata, designed to be practically useful; thus the terms used in this kind of metadata are of great value for designing the ontology. They also allow to connect the ontology to sound files, which may have possible applications in machine learning field (this aspect is beyond the scope of this paper).

The only issue with the metadata is licensing. A preliminary agreement from metadata owners should be received in order to use it for research.

3.2 Data Analysis

The *purpose* of the data analysis process is to conceptualize the information elicited on the previous stage. The conceptualization includes definition of important domain terms and their relationships, and also writing an ontology specifications in form of competency questions (CQs); together they are main components of the ontology design requirements in the NeOn methodology. CQs are the one sentence user stories[6], telling what question the ontology should answer or how it should be structured.

A typical qualitative data analysis process [17] is employed upon the interviews and knowledge sources [7]. The process can be summarized into the following steps:

1. Data preparation: transcribing, sorting and arranging.
2. Getting the general sense of data by reading through it.
3. Coding—labeling the data chunks, splitting them into categories.
4. Creating the list of terms and competency questions from the codes.

The text processing techniques are used to analyze sample libraries metadata. The main objectives here are to recognize the entities in the text annotations and to perform the exploration of used terms.

3.3 Ontology Engineering

The *purpose* of the ontology is to build a semantic layer on top of a text metadata to perform structural search in a sound database.

This stage has three main objectives:

[6] They do not necessarily have to be questions; declarative sentences can also be used.
[7] Also the grounded theory or case study strategies can be used together with the described process.

1. To create base classes and properties needed to represent the domain knowledge elicited from the previous steps.
2. To populate the ontology with sound instances collected from the commercial sample libraries using manual or automatic entity recognition methods.
3. To interlink the results with common knowledge ontology in order to do basic inference, for example, to find related concepts.

We added the third objective because sound metadata consists of common keywords (such as "car", "water", etc.) which are already structured in the common knowledge ontologies.

3.4 Evaluation

The *purpose* of the last stage is to evaluate how well the resulting ontology solves defined problems using qualitative procedures, such as interviews or case studies. Also quantitative metrics can be provided in order to assess such parameters as ontology size, number of interlinked entities, etc.

Qualitative evaluation (in the form of case studies or interviews) complements these metrics with a subjective evaluation of the ontology by assessing the domain knowledge representation and finding structural and terminological issues. This step also makes it easier to request the comments from professionals, because intermediate results are much easier to receive comments on than to abstract "how X should be done" questions.

New tasks for improving the ontology are defined after evaluation and the process starts over from the first stage with new or refined goals.

4 Implementation

This section describes the project findings up to the moment of finishing this paper, including data analysis and the ontology based on it.

4.1 Data Collection

The ontology engineering starts **interviews** with sound designers, who work professionally in the industry. At this point two professionals have agreed to participate in the project: the first (abbreviated as IO) works as a sound designer at the computer games development company[8], and the other one (abbreviated as AR) manages metadata for commercial sound sample libraries[9]. Thus we have representatives of the two different facets of the problem domain: the one who uses sample libraries and the one who creates them.

Three small interviews have been conducted up to this moment:

– A face-to-face interview with IO about basic sound design topics.

[8] Saber Interactive, URL: `http://www.saber3d.com`
[9] Boom Library, URL: `http://boomlibrary.com`

- An email interview with AR about metadata management issues.
- An internet chat interview with IO also about metadata management issues.

Although this paper focuses on the metadata issues, we would like to describe the sound design workflow in general. Sound design starts with a concept document describing an artificial setting. This document can contain textual descriptions of game elements, as well as visual references. The sound designer's goal is to create such a sound that would convey written and drawn concepts. The design process usually starts with looking for source sounds in a sound library. The new sound is then worked out of the found sounds being manipulated in different ways (cutting, slicing, rearranging, processing, etc.).

AR explained difficulties of metadata-based sound search in the interview:

When I would need the sound of a closing car door, this gives me a lot of good results. I could type in "car", "door" and would get a bunch of results. However, getting more into detail it gets a bit more tricky. When I would specifically search for a squeaking car door closing for example. Some manufacturers dont even include "open" or "close" or if a file consists of a recording opening and closing the door "open / close" or similar. Then others would note "opening" or "closing". "Opening" is not much of an issue, because "open" is in the word "opening" and it would be found. When typing "close" some metadata searches would not find "closing" though. Then even worse: squeaking might be described as "jarring", "squealing", "grating". Even though these words describe different things, it would be too much detail to work with for me personally. This leads to the most annoying part: there are tons of materials, objects, actions or feelings than can be described with a lot of different words. ... Soundminer[10] can do boolean search, but this is only half the deal, because then I got too many results.

One should also make a compromise between completeness and usefulness when adding metadata. Here is a thinking example for whoosh sound annotation:

Whoosh is used for many different things. But if I would work on a cartoonish thing typing in "whoosh" for a cartoon punch I would need a light, high whoosh sound. If only type in whoosh, a lot of things might be super heavy, trailer related things. So I need to add "light", "small", "high" or similar words and hope those are in the description. But then again, if there is a trailer library focussing on whooshes, there might be lighter, smaller, higher whooshes than others for trailers purposes, but still way too large for cartoonish usage. This specific example could be easily solved by adding "trailer" to the trailer whooshes, but this is only one example out of a million possible whoosh usages, so I can not fill in every possible usage / style of this specific whoosh sound without creating an overkill of description which is simply not readable in a nice way.

Metadata issues discussed in the interviews can be summarized as follows:

- Incompleteness: every sound description is always a trade-off between usefulness and completeness.

[10] A metadata management software..

- Ambiguity: sound libraries made by different companies can use different spellings of the same term or use synonyms. For example "GUI" and "UI"; "armor", "armour" and "chainmail".
- Relativity: annotations meanings highly depend on a context.
- Absence of any industrial standard or a guideline on adding metadata, which makes it hard to search in several libraries at the same time: sometimes users exclude libraries from search in order to reduce search results.
- The metadata is usable only when filled in thoroughly. Sound designers often does not have time to do this for their own sounds.

As we can see, most of the issues are caused by the textual format of the metadata. A well-made ontology can address these issues of sound organization, as the sound will be linked not simply to text keywords, but to concepts that may have different textual representation making the search more convenient and less dependable on spelling differences. The concepts interlinked with common knowledge can solve the problem of querying through using synonyms or closely related concepts. The ontology can also be used improve sound search by providing structure for common terms and adding query suggestions: for example suggesting the "car closing door" or "car engine" when putting in the "car" keyword into a search field. Besides search, similar mechanisms can be employed to improve sound annotation process.

In this project we also analyze the BOOM Library metadata, which the company has kindly granted permission to work with. The metadata was provided in the form of XLS files and available from the company's web site.

4.2 Data Analysis

We define the *ontology specification* as the following list of competency questions created based on the metadata management problems and elicited from the interviews and authors' understanding of the problem:

1. The basic concept is *sound file*.
2. A sound file has a *common sound metadata*: filename, designer, microphone[11].
3. A sound file belongs to a *sound library*.
4. A sound library has a textual *annotation* describing the contents.
5. A sound file contains *sound*.
6. A sound file has one or more terms associated with it.
7. A term can have one or more topics associated with it.

These CQs describe the ontology structure needed to represent the sound content in terms of keywords. The purpose of the ontology is to aid search and annotation tasks, hence we do not need to introduce linguistic variables and can limit ourselves to using only "crisp" formalisms. This structure can be revised when new topics are added to the ontology.

[11] The list was created based on the BOOM Library metadata files.

Existing metadata can be very useful for understanding the sound design concepts. To demonstrate this we had chosen a sound library containing user interface sounds[12] and elicited domain concepts from the supplied metadata.

The metadata is represented as 10-column table, including such columns as “filename”, “license”, “designer” and others. The most important one for our purposes is “description”. It contains keywords written using uppercase letters followed by a concise and more detailed description of the sound, for example *“DIGITAL CLICK SYNTHETIC Short notes, clicks, high pitch”*. Merging these two data types in one text string was made in order to fit in the common metadata format.

Keywords analysis. 23 keywords used in the sound library, which can be split into the following groups:

– *Sound mood*: “arcade”, “digital”, “generic”, “orchestral”, “organic”. This group roughly represent the content of the sound, for example, “arcade” means that the sound is synthesized to resemble the arcade games sound, “digital” is for emotionless synthesized computer sounds, etc.
– *Sound form*: “jingle”, “button”, “click”, “slide”. This group represents the temporal evolution of the sound, for example, “jingles” are the little pieces of music, “clicks” are sounds with a short decay, “buttons” are recorded sounds of button pressing, etc.
– *Materials*: “human”, “paper”—and also *material adjectives*: “synthetic”, “plastic”, “metallic”, “woody”, “glassy”. This group provides the clues on what kind of sound sources were recorded. It can be confused with the first group, but there is a fundamental difference: the “sound mood” group represents an *intended* usage of the sound, but the “material” group represents the way how the sounds were made. For example, “digital” and “arcade” sounds are “synthetic”[13]. “Plastic”, “metallic”, “woody” and “glassy” materials are in the “generic” group[14].
– *Sound size*: “tiny”, “small”, “medium”.
– *Interaction type*: “negative”, “normal”, “positive”. For example, navigation sounds through the menu hierarchy (up, down, stay on the same level). Interaction sounds are labeled with the “feedback” keyword.

Descriptions analysis. The second part of the textual annotations describing the sound content is descriptions. It consists of a short comma-separated statement, written in free form. They indicate, for example, *sound effects* applied, *instruments* or *objects* used in the record, or *action* performed on the

[12] BOOM Library – The Interface, URL: `http://www.boomlibrary.com/boomlibrary/products/the-interface`
[13] According to metadata, i.e. synthetic sounds are also annotated either with “digital” or with “arcade” keyword.
[14] Although the terminology is questionable and can be improved, at we use it “as is” for now.

recorded object. There are 221 of these descriptions in the library, hence we do not list everything here and instead suggest the reader to have a look at the ontology [18].

4.3 Ontology Engineering

The ontology has 4 top-level classes: *SoundFile*, *SoundLibrary*, *SoundFileTerm*, and *Topic*. The first two represent basic metadata (file and library names, creator, licensing, etc.). *SoundFileTerm* class connects sound file to one or more abstract *topics* extracted from the library: it either represent a keyword or a comma-separated description. This structure reflects the keyword-based search procedures sound designers use today with additional categories introduced in the knowledge engineering process. Intermediate *SoundFileTerm* class connects several topics together but does not specify the connection type. It was introduced for the future development of enrichment methods using external ontologies to provide the connection between them.

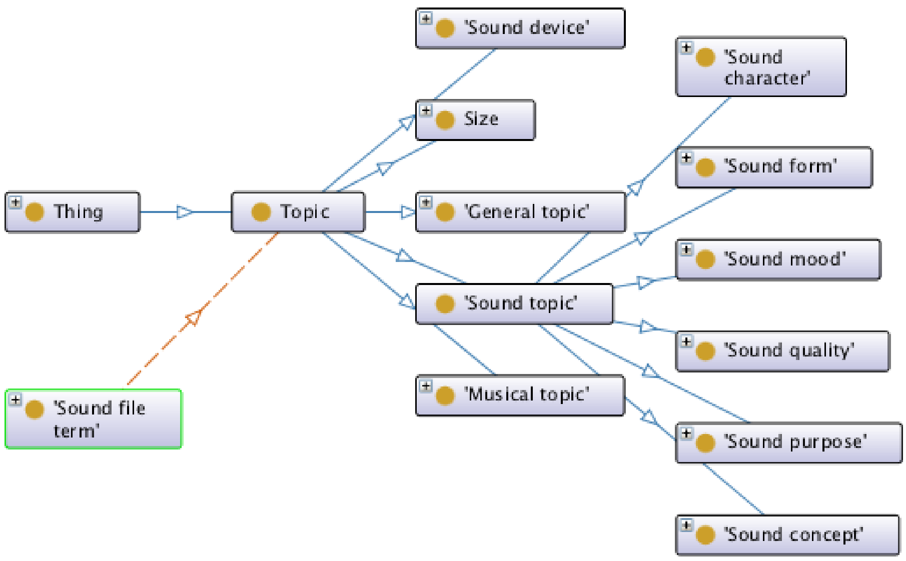

Fig. 2. "Topic" class and its subclasses. All subclasses except "SoundTopic" have their subclasses hidden. Dashed arrow is the ":hasTopic" property, all other—"rdfs:subClassOf".

Interlinking. We considered three common knowledge ontologies to interlink with: OpenCyc[15], DBpedia [19] and Wikidata [20]. We have done subjective

[15] OpenCyc for the Semantic Web, URL: `http://sw.opencyc.org`

evaluation of each of them and decided to go with OpenCyc, because it has better text annotations (including synonyms) and common concepts structure.

The interlinking process was done using OpenCyc's search and disambiguation facilities with some human aid when they did not work well. Suitable OpenCyc concepts were linked with our ontology using *rdfs:seeAlso* property. We didn't use OWL axioms, because on the interlinking stage it is still unclear what keywords should be refactored from classes into properties, so *rdfs:seeAlso* is used as the marker, that a human attention will be needed later.

4.4 Evaluation

This section provides a subjective evaluation of the ontology.

A rather important issue is that the sound design field widely spreads between computer gaming and academic music avant-garde. Such a field determines a large list of sound-related specialties, i.e. composer, sound designer, sound engineer, sound programmer, arranger, etc. All of them operate a number of sound libraries, sometimes using absolutely different sets of notions. For instance, the situation when low-pass filter opens during trance sequence will be described differently according to an academic composer and to a DJ. The first thinks about harmonic contents and interprets the sound as an addition of higher notes (octaves and so on), while the latter thinks about filtering of sound complex without dissecting it into separate sounds. Meanwhile, somebody whos not familiar with sound technology thesauri can describe the same sound saying timbre is getting brighter. This simple example shows that more descriptors are needed, or probably there should be several sets of synonyms.

Another issue is the crisp nature of the descriptor set. For example the distinction between real-world and synthesized sounds might be obvious when comparing a violin playing legato notes (real-world sound) with Access Virus playing neurofunk bass (synthetic). But what if we take some samples of spectral music (i.e. Gèrard Grisey) or sound mass music (i.e. Iannis Xenakis or György Ligeti), it would be hard to describe some elements as real-world. At the same time, sounds of instruments with poor harmonic contents, i.e. bells, xylophones, jaw harps, kalimbas, could be synthesized from scratch very realistic.

These points reveal new epistemological depths of the problem and will be discussed in the following section.

5 Discussion and Future Work

The evaluation has shown that the structure elicited from the metadata should be revised in order to resolve terminological problems. From the other side, a great care should be taken when working out the professionals' comments, as some issues may be less important for the project's problem scope.

At the present state the ontology does not benefit from linking with the OpenCyc ontology, because the integration of these two is loose. In the future we plan to reflect many abstract OpenCyc concepts, for example, relative descriptions ("high", "low", etc.) to describe timbral similarity. After adding proper interlinking using OWL axioms the ontology can be validated using reasoner facilities.

The next steps of this project will be adding a number of other sample libraries to the ontology and implementing a sound search software to test it in the real situation. Once the demo software is ready we can involve more professionals into the project to build a better tool for the field.

6 Conclusions

In this paper we investigated key factors which cause difficulties with using sound libraries by interviewing working sound designers. Main difficulties are mostly caused by widely adopted text-based metadata format, which leads to such problems as synonymy, typos, misspellings and so on. To deal with this problem a knowledge-engineering approach was proposed. The approach was validated by demonstrating one iteration of the sound design ontology development. The outcome of this iteration was the ontology [18] with terminology elicited from "The Interface Library" by BOOM Library[16]. This terminology was manually structured and then linked with the OpenCyc ontology.

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