Structuring the sound design process in the automotive industry with a web-based application

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Abstract

The automotive industry is recognised as a challenging arena for sound design, because the presented information needs to not only comply with safety regulations but also match subjective expectations. By means of a structured interview with ten employees (software developers, quality analysists, sound designers, engineers, managers) of the company Continental, we collected requirements for the sound design process in an automotive industry setting. We present a sound design process consisting of three stages: description, design/creation, and verification. We developed a prototype of a web-based application to support the process.

Keywords

Highly automated driving; speech interfaces; sound design; process; industry; automotive

1. Introduction

1.1 The emergence of sound design

It is generally recognized that sound design emerged as a discipline in the 1930s when Murray Spivack created the sounds for the movie King Kong (Murray, 2019). Although the use of sound in movies became popular after its introduction in 1927, for many years through the 1930s, the dominant figure in the world of cinema, Charlie Chaplin, refused to add sounds to his movies (TIME, 1931). Ben Burtt, the creator of the soundtrack for Star Wars, made a decision to add sound to the scenes in space, even though sound does not propagate in a vacuum (Film Sound, 2008). He designed sounds to increase the entertainment value of the movie, contrary to the movie 2001: A Space Odyssey, where attention was given to accuracy, and no sound could be heard in scenes in space. George Lucas, the director of Star Wars, said, "Let's go for what is emotionally right" for the soundtrack of the series of movies (Gould, 2012). For the first few decades since the work of Spivack, early sound designers were mostly musicians working as sound editors (although the term 'sound designer' was coined only in the 1960s, Andriano-Moore, 2018). More recently, we have seen a number of technological developments in sound design, such as audio digitization, samplers, synthesizers, and digital signal processors.

Nowadays, sound design is employed in numerous domains, such as sport sciences (Schaffert, Mattes, & Effenberg, 2009), the video game industry (Collins, 2008; Grimshaw, 2011), landscape design (Fowler, 2013), design of synthetic sound representations (Cook, 2002; Van den Doel, Kry, & Pai, 2001), emotionally enriched product design, feedback in hospital environments and aircraft cockpits (Patterson & Mayfield, 1990; Stanton & Edworthy, 1999), and interactive product design (Hug & Misdariis, 2011; Susini, Houix, & Misdariis, 2014).

Sound design does not have as well-established guidelines as visual design, where products can be described by illustrations (Kress & Van Leeuwen, 1996; Mullet & Sano, 1996; Watzman, 2002; Buxton, 2010), or industrial design, where objects to be designed can be outlined by 3D models or multiple 2D illustrations (Eppinger & Ulrich, 2016; Krishnan & Ulrich, 2001; Roozenburg & Eekels, 1995; Sokovic & Kopac, 2006; Urban & Hauser, 1980). Frauenberger and Stockman (2009) analysed 23 projects involving different aspects of the sound design process that were presented during the 13th International Conference on Auditory Display (2007) in Montreal, Canada. Only 2 out of 23 projects followed a well-defined sound design process for the creation of auditory artefacts. Langeveld, Van Egmond, Jansen, and Özcan (2013) argued that today's product sound is based on the subjective experience of the product sound designer, and that, in the future, sound design should be supported by a theoretical framework in which physical and psychological factors are combined.

The design of product sounds can be supported by software tools. Nykänen, Wingstedt, Sundhage, and Mohlin (2015) considered sound design to be critically dependent on the process of listening, and suggested using "sound sketches" to improve the interaction between sound designers and their clients. Delle Monache et al. (2018) presented an 'embodied' sound design process, which uses the designer's voice and gestures to describe how a certain product should sound like. Carron, Rotureau, Dubois, Misdariis, and Susini (2017) offered a tool for supporting communication during the sound design process, which is based on a shared vocabulary linked with example sounds.

1.2 Sound design in the automotive industry

In the automotive industry, sounds often play a safety-critical role. In a visually complex task such as driving, auditory information is beneficial as a warning signal, as hearing is omnidirectional (Bjork, 1995; Haas & Edworthy, 2006; Salvendy, 1997). For example, it has been found that auditory warnings are preferred over visual-only warnings when the driver has to resume manual control of an automated car (Petermeijer, Doubek, De Winter, 2017). A structured sound design is important in the creation of products that deal with high levels of emergency and urgency (Stanton & Edworthy, 1999).

Different types of auditory feedback can be employed in vehicles. One approach is sonification; that is, the use of sound to perceptualize data (see Kramer, 1994). Earcons, that is, sounds that represent a specific event or convey certain information, can also be used for in-vehicle interfaces (Demarey & Plénacoste, 2001). Additionally, the implementation of silent electric engines has stimulated the development of auditory signatures for electric vehicles (Misdariis & Cera, 2017).

The automotive industry is recognized as a challenging arena for sound design, as the presented information not only needs to comply with safety regulations but should also be pleasant to drive and match subjective expectations (Genuit, 1997; Sottek, Krebber, & Stanley, 2005). Nowadays, silence, or the absence of unwanted sounds, is valued highly, especially in luxury cars, and the simple manipulation of the loudness of sounds in cars may not be enough to guarantee driver acceptance (Sottek et al., 2005). The sound of the engine is not the only component for the evaluation of the sound environment of a car. The way the car acoustically reacts to events is important too. Moreover, sounds that used to be unnoticeable, such as the noise from electric motors and squeaks of mechanical components, can now be heard in many models of cars, especially electric cars, as a consequence of cockpits becoming more silent.

Manufacturers and suppliers in the automotive industry often employ no standardized and documented sound design process. At Continental Automotive, for example, there had been a previous attempt to implement a paper-based sheet for describing sound assets. The sheet was in French, had been used only locally in the French office of the company, and never became popular inside the company. At Continental, the process of designing auditory artefacts, from the moment of request to the moment of release of the final version, follows the following steps: 1) verbal or written description/definition of requirements, 2) iterative process of creation of required artefact with updated descriptions given mainly verbally, and 3) validation and testing. We hypothesized that this process could be optimised by employing a classification of auditory artefacts that facilitates the descriptions of assets.

1.3 Classification of auditory artefacts

Sounds can be rated on a variety of emotional dimensions (Altinsoy, 2013). According to Bisping (1997), pleasantness and power are two primary dimensions for rating sounds in the automotive domain. That is, sounds of in-vehicle interfaces can have different levels of pleasantness (e.g., not annoying–annoying, desirable–not desirable, smooth–rough, friendly–unfriendly) and power (racy–not racy, dynamic–not dynamic, fast–slow, and exciting–boring) (Bisping, 1997; Västfjäll, 2003). Bisping (1997) further mentioned that the sounds of luxury cars are mainly powerful and pleasant, while sounds from sports cars typically score in the powerful/unpleasant quadrant. Sounds could also be classified based on their purpose. For example, sounds could be made for entertainment, confirmation or acknowledgement, notification, or warning. Özcan and van Egmond (2012) outlined several factors that underlie product sounds, including perceptual factors (attention, roughness, smoothness, and temporal constancy), cognitive factors (power, machinery, and (un)familiarity), and emotional factors (unpleasantness).

1.4 Aim of the paper

This study aimed to develop a sound design process to guide the workflow of designing sounds in the automotive industry. Requirements for sound design were gathered from the employees of Continental during verbal interviews. Based on these requirements, it was decided to build a prototype of a software product to assist with the sound design process.

2. Problem setting: Interviews to evaluate the sound design process in the automotive industry

Ten employees of Continental participated in a structured interview to gather requirements for the definition and implementation of the sound design process. Six participants were working in an office in Germany, two in France, and two in China. They were recruited by posting a message in the internal network of the company. The average age of the participants was 34.3 years (*SD* = 11.1). Nine participants were male and one was female. The background of the participants was diverse (UI and UX designer, two project managers, audio and speech quality analyst, two software developers, electronic engineer, two sound designers, and ergonomist), and the amount of experience of working with auditory assets varied, from less than a year to 18 years of experience. All the participants had to, in some way, work with earcons, with seven interviewees stating that they used spearcons (i.e., speech-based earcons) in their work. Three participants stated that they had worked with more than 100 auditory artefacts prior to the interview, and four interviewees reported having worked with tens of auditory artefacts in their careers. Eight participants reported being involved in projects dealing with automated driving.

The interviewees were based in the office of the company in Germany, France, and China. The interviewer was the first author of the present article. The interviews were conducted between May 10, 2016 and May 19, 2016. The interviews were later transcribed and the transcripts can be found in the supplementary material. Together, the transcribed interviews were 34,125 words, including answers and replies of the interviewer. The shortest interview had 1,810 words in its transcription and lasted for 14 min 43 sec, and the longest interview had 5,835 words in its transcription and lasted for 47 min 12 sec. The average length of the interviews was 3,413 words. The average duration of the interviews was 30 min 56 sec. All participants were informed that their responses would be treated anonymously, and the results will be published. The questions that were asked in each of the interviews (see Table 1) focused on receiving general information about the interviewee, their level of involvement in sound design at Continental, and their views on how the sound design process should be structured.

Table 1. Questions asked in the interviews

Q1	What is your age?
Q2	Can you tell me about your activities at Continental (your job description)?
Q3	Why do you (need to) work with auditory artefacts?
Q4	What type of auditory artefacts do you have to work with?
Q5	How many artefacts did you need to design so far?
Q6	For which types of scenarios do you give preference to the auditory modality over the visual and tactile modalities?
Q7	Are you involved in automated driving in any way?
Q8	How long have you been involved in the process of creating auditory artefacts?
Q9	What software do you use to design auditory artefacts?
Q10	What do you think is the best software for the design of auditory artefacts?
Q11	If you need to describe auditory artefacts, what software do you use for this?
Q12	What do you think is the best software for describing auditory artefacts?
Q13	What qualitative parameters of the auditory modality do you use to describe auditory artefacts?
Q14	Could you give an example of a verbal/textual description of an auditory artefact you used in one of your projects?
Q15	What quantitative parameters of the auditory modality do you use to describe auditory artefacts? (for example, frequency, duration, etc.).
Q16	We will build a database of auditory samples to be used in the auditory artefact creation process. All samples will be associated with tags and categories to support search. Could you name examples of the essential tags and categories to be used in such a database?
Q17	How many iterations do you (your team) normally go through before the final version of an auditory artefact is produced?
Q18	At which stage do things normally go ‘wrong’ in the design process of auditory artefacts? What would you name as a main drawback of the current design process?
Q19	Do you use any “agile principles” in the process of auditory artefacts creation?
Q20	Can you give an example of a situation where the auditory artefact design process went wrong? When you did not receive an auditory artefact, you asked for.
Q21	Do you interact with GUI developers and designers during the process of creating auditory artefacts? How are auditory and visual outputs harmonized?
Q22	Are there any standardized tests for auditory artefacts? If yes, what tools do you use for such tests?
Q23	Which types of people participate in these tests?

Q24	Would you wish to see a standardized approach to producing auditory artefacts at Continental?
Q25	How would you improve the sound design process at Continental?

Not all participants were able to give answers to all questions. For example, if the participant said in response to Q11 that they never describe auditory artefacts by means of software, Q12 was skipped. We asked the participants to talk about situations where they would prefer the auditory modality to visual and haptic modalities. Nine participants gave a response. Three interviewees replied that the auditory modality is beneficial during take-over requests in automated driving. Three persons indicated that it is beneficial when the information presented is not in the visual field. One person stated that auditory feedback should be used when it is not needed to attract the visual attention of the driver to a certain point in space. Furthermore, one participant expressed his opinion that speech output may be beneficial "…if you really need to transport content and specific information". He also stated that auditory output might be preferred in the context of transition of control where it is assumed that the driver will not be able to observe information in the cluster instrument due to visual distraction of doing a non-driving related task. Finally, two participants stated that the auditory modality is beneficial for issuing confirmations.

The majority of participants describe their required sound artefacts verbally or by means of simple text descriptions created with word processing tools, such as Microsoft Word or plain text emails. Two participants reported being closely connected to the process of designing sounds as sound designers; they used Ableton Live, Logic Pro, Cubase, or Audacity software in their work. No clear opinion about the best software for designing auditory artefacts was given.

In Q13, the interviewees were asked to list the qualitative parameters of the auditory modality that are used in the company for describing auditory artefacts. Six interviewees mentioned that the "mood" (happy, sad, etc.) of the artefact was important to mention. Four participants reported the "urgency" (not urgent, urgent) as an important parameter. Two interviewees said that the "value" (sounds cheap, sounds expensive or luxury) of the artefact has an important role in the process. In Q15, the participants were asked to report the quantitative parameters of the auditory modality they used for describing auditory assets. The most commonly used parameters were frequency, duration/speed, and pitch. One of the sound designers reported that the duration of the required auditory artefacts was dependent on the animations that were used. None of the interviewees was willing to provide examples of the descriptions of auditory assets from the projects in the company, due to confidentiality restrictions.

For Q16, tags and categories to be used in the software tool and design were mentioned. Figure 1 shows the word cloud generated based on the responses (at http://www.wordclouds.com). The most commonly mentioned tags were: spearcon, earcon, warning, metal, percussive, attention, emergency, indicator, and awareness.

Figure 1. Word cloud of suggested during interviews tags for the database.

The participants reported a diverse range of the number of iterations that happen when an auditory artefact is created in the company: from two to three iterations to having hundreds of iterations in one project. Seven participants replied affirmatively to Q19, where they were asked if the principles of agile development (an iterative approach to software development; Collier, 2011) are used for the creation of auditory artefacts in the company. Five of them reported the use of agile principles for the creation of auditory artefacts; a number of participants said that they often face problems in the design process of auditory artefacts (Q18) during the description stage. All ten participants wanted to have a more structured sound design process in the company. The interviewees wished to have a simplified process featuring possibilities to verify the designed auditory artefacts in the company.

Based on the interview, the changed sound design process shall comply with the following requirements:

1. To support two roles: client and supplier.
2. To support multiple iterations.
3. To have a structured sound design process in place.
4. To have a means for the verification of created auditory artefacts.

3. Proposed solution: Three-stage process of sound design in the automotive industry

Figure 2 shows the three-stage sound design process for developing auditory artefacts for the automotive industry. It is based on the workflow of creating auditory assets that was employed at Continental prior to the start of the project. During the new sound design process, the auditory asset is created by the following three stages: 1) description; 2) design/creation; 3) verification. Compared to the previously employed process, the three-stage process adds the verification stage and digitalises the flow of information.

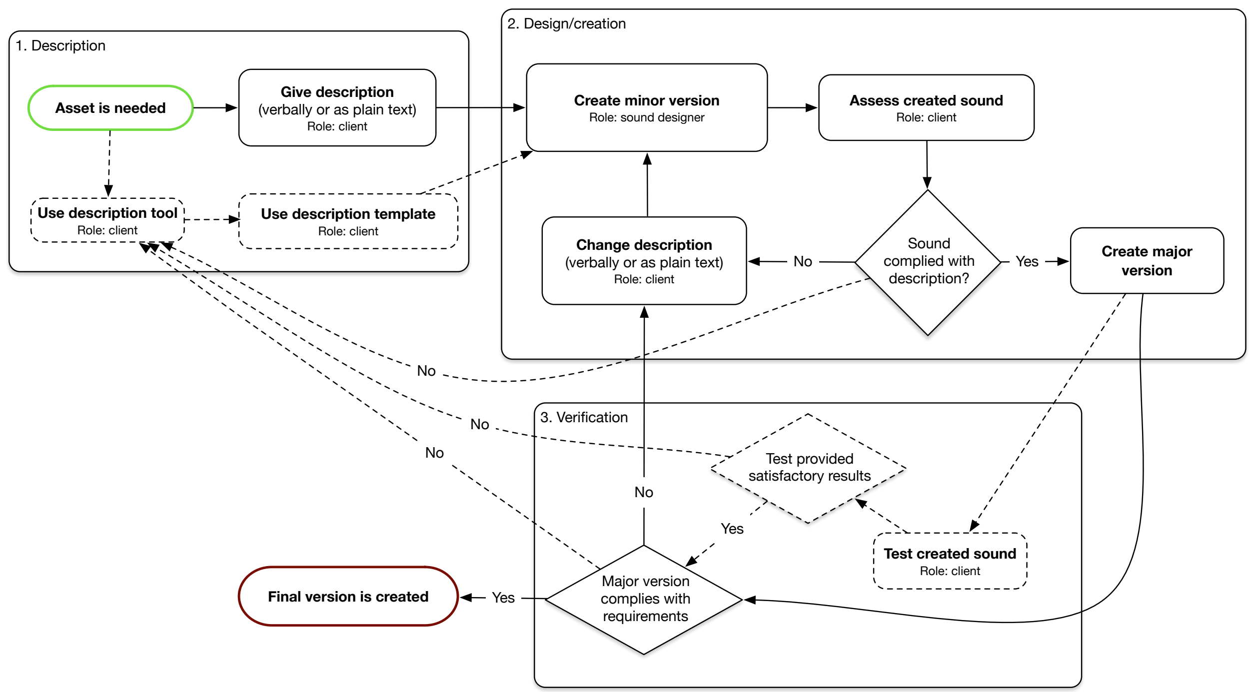

Figure 2. The proposed three-stage sound design process for the automotive industry. Rectangles represent actions; rhombuses represent a decision to be taken. Shapes with solid borders and solid arrows represent steps and actions, respectively, which were already implemented in the existing process. Steps in boxes with dotted borders and dotted arrows indicate the newly developed steps and actions, respectively. The process assumes two roles of users: client (the person who needs the sound to be designed and created) and sound designer or supplier (the person who works with the given descriptions to design and create the required sound).

The process starts in the description stage (Stage 1), when a person that requires the asset to be designed and created gives the initial description. Then, one or more iterations are performed in the design/creation stage (Stage 2). During this stage, the designer uses descriptions provided in Stage 1 (initial description) or Stage 2 (updated descriptions), to create a 'minor version' of the sound. The client assesses the created sounds and decides if the given version can be recognised as a 'major version'. If this is the case, the process enters Stage 3, where verification of the created sounds is undertaken. If the given sound satisfies all requirements, it is recognised as final, the process comes to an end, and the final version is created. If the verification is not passed, the process goes back to Stage 2, and further modifications are undertaken in an iterative manner until a new 'major version' is created that enters the verification stage (Stage 3).

4. Design process: Software tool and database

A prototype of a software tool and accompanying database were created. The tool was developed with Flask library of Python 2.7 in the backend and Jinja2 in the frontend. The tool is available for testing at https://wordsforsound.herokuapp.com. The version is populated with auditory samples with CC licenses from the Internet, that is, it does not contain any confidential material belonging to Continental. The source code of the tool is available in the supplementary material. The prototype was developed between June 13, 2016 and July 27, 2016. Additional bug fixing and implementation of new features and improvements to existing functionality took place after July 27, 2016.

4.1. Design of the tool and database

The final version of the tool is based on the sound design framework proposed in Section 3. The tool features two types of users (clients and suppliers). Clients are users that need auditory assets to be made. Suppliers are users that need to make (design/create) the requested assets. Multiple clients and multiple suppliers can be involved in the creation of one asset. Assets need to belong to projects. Each project can have one or multiple assets.

In the tool, both clients and suppliers see the assets they are involved in. That is, a client sees a list of assets that they commissioned and a supplier sees a list of assets that they were assigned to. Clients can see iterations provided by suppliers. Suppliers can provide new iterations for review by the client. Users can see lists of tags, sounds, projects, and assets available in the database of the company. It is also possible to search the database. The users have an option to change settings of their account, such as the email, username, etc.

Figure 3 shows the home page of the developed prototype. In this figure, the logged in user *philip_j_fry* is involved in six assets. Since he is a client, he needs to verify one of the assets ('Asset 2B' from the project 'Validation 3'), which is in Iteration 1 (Stage 2 in the process described in Figure 2). This means that the sound designer working on the asset has submitted one version of the asset as Iteration 1. Five other assets are 'in other hands', meaning that *philip_j_fry* needs to wait until he can take action on those assets, as other users involved in the creation of those assets need to finish their tasks.

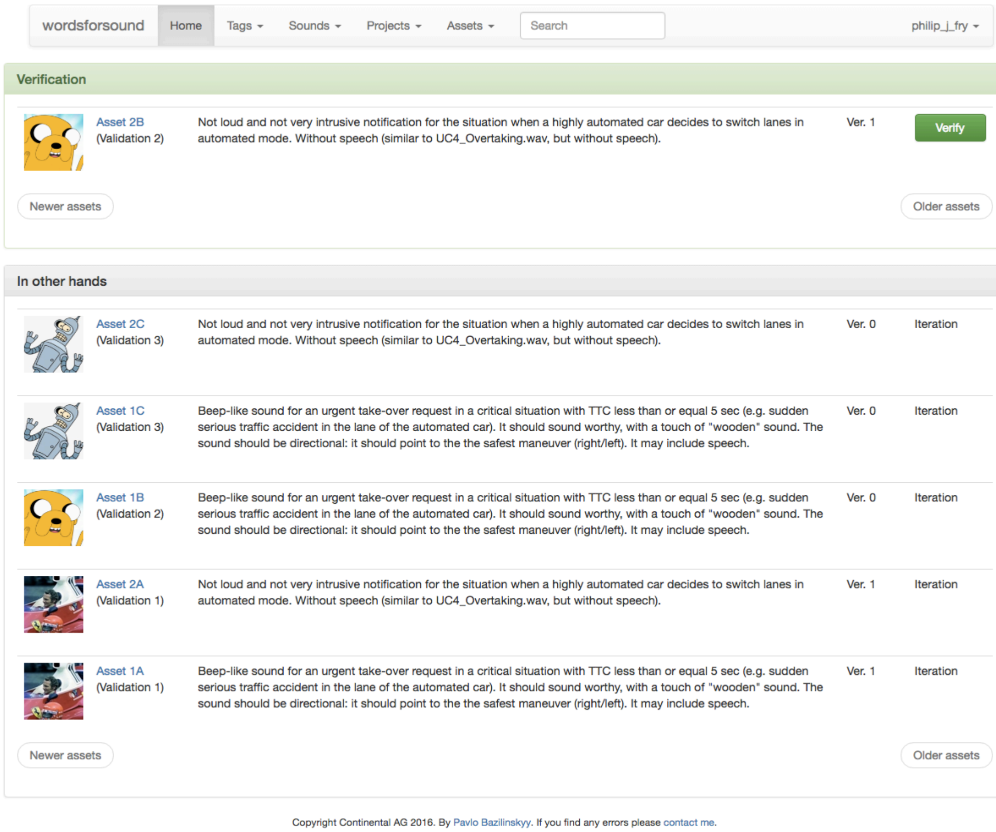

Figure 3. The homepage of the tool prototype.

The tool is supported by a database. Besides being the platform supporting the process of creating auditory assets, the database also serves as a company platform for storing new and finding already stored tags and auditory samples. It is a ‘living’ database, which is enriched by the employees. Figure 4 shows the view of tags in the database. The word cloud displays all tags in the system, where the size of the tag outlines how frequently it is used in the company. Figure 5 shows the view of the sound examples in the system. All sounds on the page are accompanied with embedded clickable previews of the sounds. All elements on both of these views are clickable. Figure 6 shows the view of an individual asset. On this page, users that have access to the asset can see all descriptions, iterations, and verifications for the asset.

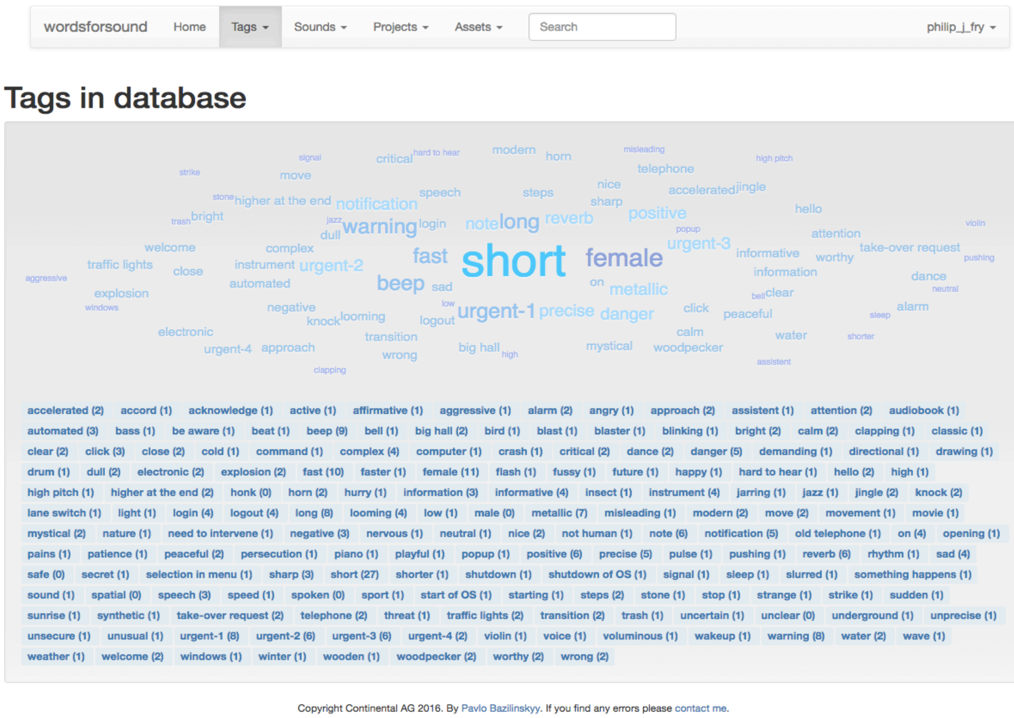

Figure 4. View of tags with word cloud in the tool prototype.

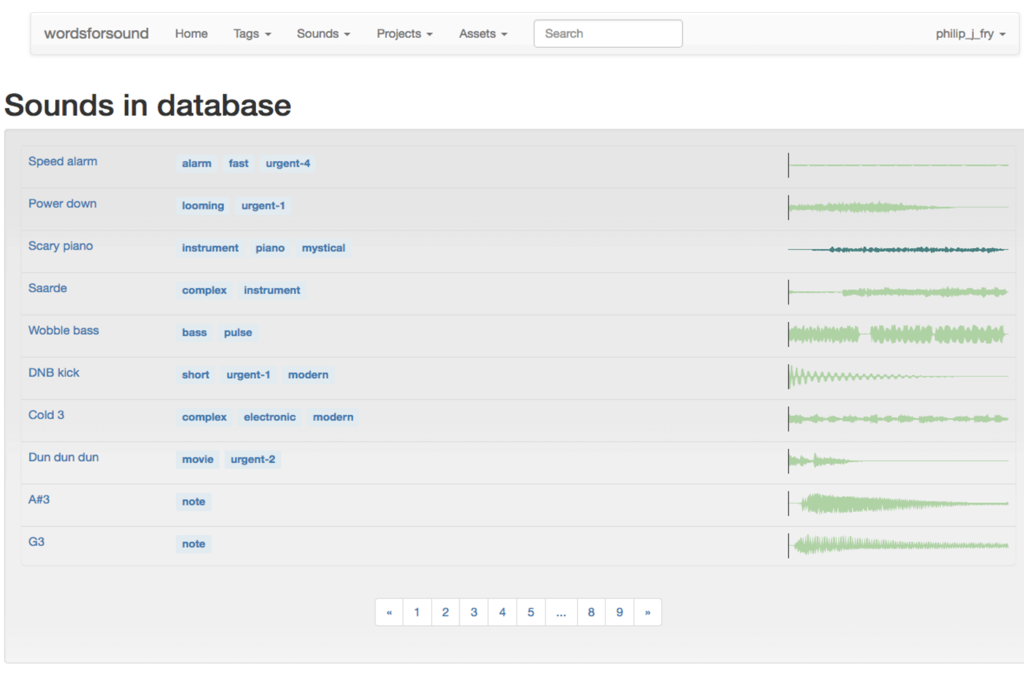

Figure 5. View of sound examples with clickable items in the tool prototype.

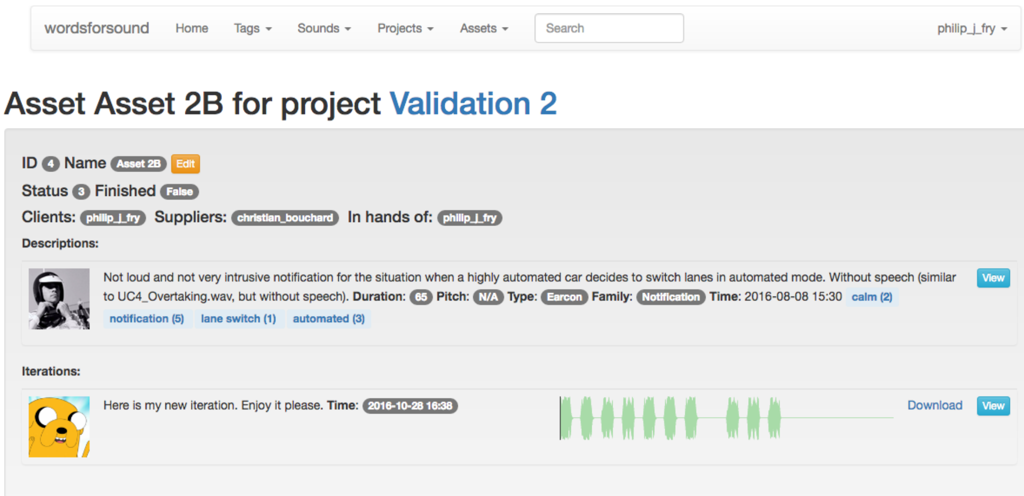

Figure 6. View of an asset with a history of changes.

4.2. Population of the database

The following commonly-used resources offer sounds for downloading: freesound.org , soundsnap.com, audiomicro.com, freesfx.co.uk, getsoundly, and prosoundeffects . Some of the services also provide API's, e.g. freesound.org and pond , but generally it is complicated to get direct access to the content of the collections, which is a limiting factor for the development of a stand-alone solution that relies on having access to the databases.

Our database was initially populated with 52 sounds from previous and ongoing projects in the company. To enrich the database with tagged sounds, the employees at the company were asked to tag the sounds with as many tags as they could think of during a week. This allowed generating the first pool of tags to be used in the tool. Five people responded to the call and provided tags. In total, 310 tags were collected and added to the database, see Figure 4. The tags were diverse, indicating the different needs of clients and designers of sounds. Words "short", "female", "fast", "warning", "reverb" were the most commonly used tags. Additionally, 32 sounds under CC license from the Internet were added to the initial pool. This pool of sounds featured commonly used auditory assets, such as beeps, alarms, and alert sounds; they were tagged by the first author of the article.

5. Discussion

In this study, we designed and implemented a three-stage sound design process in an automotive setting. Multiple factors make the creation of auditory feedback for in-vehicle interfaces challenging: strict requirements for reliability, end-users with requirements that are difficult to outline, etc. A well-defined process is needed to support the design of auditory assets in such an environment. Previously, the designers had no access to a structured process. In this project, we offered a solution to this problematic situation.

By means of structured interviews with ten employees of the company Continental, we collected requirements for the process of designing and creating auditory artefacts. The results of the interviews showed that the needs and expectations of the employees of the company varied greatly. It was challenging to develop the sound design process that would be used by two rather different types of employees: employees who request auditory feedback to be designed, and those who are asked to design such feedback. Based on the interviews, it was clear that the interviewed employees were interested in structuring and formalization of the process of designing auditory artefacts in the company. An easy-to-use software solution was needed.

Based on the results of the interviews and a literature survey, we created a sound design process tailored to research and development activities in the automotive industry. It consists of three stages: description, design/creation, and verification (Fig. 2). The designed process assumed two roles of users: client and supplier. These roles correspond to the unstructured sound creation process employed by the company prior to the project. A verification stage was added to the process, because multiple employees of the company reported problems arising from not having a structured process for verifying whether created auditory assets correspond well to their requirements. The creation process is iterative, and both clients and suppliers can enter all three stages multiple times while working on a particular auditory asset. It can be argued that our process facilitates a shared language between designers and stakeholders, as we introduced a sound-based communication in addition to a verbal-only one.

The company has added the sound design process to their workflow. A randomized controlled validation study with a substantial number of participants should be conducted to examine whether using the tool improves efficiency and acceptance as compared to not using the tool. Furthermore, it would be worthwhile to explore whether our proposed sound design process and software tool are also applicable in application areas other than automotive.

6. Supplementary material

Anonymised transcripts of interviews can be found here: https://www.dropbox.com/sh/u41zopx1220x97x/AAAr3j0abXrYOeezfKWut5F1a.

Source code: https://github.com/bazilinskyy/wordsforsound

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