EMPIRICALLY BASED AUDITORY DISPLAY DESIGN

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ABSTRACT

This paper focuses on everyday sounds and in particular on sound description, sound understanding, sound synthesis/modelling and on sonic interaction design. The argument made in this paper is that the quantitative-analytical reductionist approach reduces a phenomenon into isolated individual parts which do not reflect the richness of the whole, as also noted by Widmer et al. [1]. As with music, so is it for everyday sounds that multidimensional approaches and techniques from various domains are required to address the complex interplay of the various facets in these types of sounds. An empirically inspired framework for sonic interaction design is proposed that incorporates methods and tools from perceptual studies, from auditory display theories, and from machine learning theories. The motivation for creating this framework is to provide designers with accessible methods and tools, to help them bridge the semantic gap between low-level perceptual studies and high-level semantically meaningful concepts. The framework is designed to be open and extendable to other types of sound such as music.

1 Introduction

There is a growing acknowledgement [1] that reductionistic approaches cannot reflect the rich variety within sound. However, it has yet to be systematically addressed in the SMC [1] community or within any of the related fields such as auditory display or sonic interaction design. This article synthesises and organises the existing research within these fields. It presents a discussion on the qualitative and quantitative research that led to the development of a foundation for a framework, its structure and components, and examples of its application towards a practical empirically based design framework. This framework uses multiple approaches to capture different aspects of the sounds under exploration as a means of providing a better reflection of their richness.

There is no single methodological framework that can deal adequately with the complex socio-cultural context of auditory display design in a coherent and non-reductionist manner. This is a similar problem faced by most design oriented research, a suggestion by Melles [2] has been to take a pragmatic stance towards methodology, where methods are selected and combined according to their usefulness for achieving specific goals. This approach of design research has found support in many methodological dialogues such as those discussing multimethod research [3]. The framework presented is structured to support the selection of sounds while allowing the exploration of specific aspects of the sounds. Our approach suggests it is possible to gather the necessary information using complementary techniques [4].

A general observation from many auditory display designers is that auditory icons are not easy to design [5, 6]. This research has synthesised and organised the existing work to provide an empirically based auditory design process. The studies and methods explored provide indicative trends, which can assist designers in making the best selection and use of everyday sounds in their interface. In selecting these methods, preference was given to lighter weight approaches suitable for use outside strict laboratory conditions. This allows designers access these methods and the framework at an acceptable cost and without access to dedicated facilities such as listening booths or anechoic chambers. A number of additional criteria such as ease of use, prior similar use in the field or related fields, ability to concisely present the results, and time required to use the method were also considered.

The underlying rationale was to provide a similar type of approach to that of discount HCI as proposed by Nielsen [7]. Designers need empirically based or inspired methods to guide their overall design process, which do not suffer from the specificity of psychoacoustic studies or that require a relatively long time to conduct. A typical design problem is wider than those addressed by psychoacoustic studies and the approach of this framework joins these disciplines in a manner that is accessible at a reasonable cost to designers. The benefit from this type of approach should be a reduction in the ad-hoc selection of auditory icons and similar sounds [6].

[1] http://www.smcnetwork.org/

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2 Existing Design Methodologies In Sonic Interaction Design

There are few design methodologies which are specifically situated within the field of Sonic Interaction Design (SID). Our framework was inspired by the work in the EU FET Closed project [8], by work on interactive public installations [9], and by work on narrative inspired interactive artefacts [10]. The first methodology was focused at the creation of *functional artefacts* and had close roots to industrial design and interaction design. The second methodology was targeted at *interactive public spaces* and came from an interaction design background that was complemented by empirical explorations. The third methodology came from an interaction design background with strong influences from film and game design to focus on creating narrative driven interactive artefacts. It aimed to create *narrative sound artefacts*. The three methodologies had different goals and understanding their origins can help in clarifying their distinct methodologies.

2.1 Designing Functional Artefacts

The EU FET Closed project [8] explored many aspects of sonic interaction design including the creation of functional artefacts as shown in Figure 1. It looked especially at kitchen sounds and how to integrate basic design practises together with interaction design to create functional artefacts. An example of this type of artefact is the *Spinotron* [11], which explored the link between sound objects and pumping actions. It used rolling and wheel/ratchet parameterised sound synthesis models [2] linked to real-time sensor data. The synthesis model design was based on the concept of a ratcheted wheel, where the motion or pumping of the device controlled the rotation of the wheel. The methodology promotes a complementary use of basic design methods to formalise and structure ethnographic approaches. The evaluation aspects in this methodology incorporate the ideas of material analysis and of interaction gestalts as shown in Figure 1. The goal of this methodology is to integrate these aspects to help products fit within their contexts of use by providing broader views of evaluation. This wider view includes holistic measures of experience and takes the functional performance of end users of the device or interface into account.

2.2 Designing Interactive Public Spaces

The Shared Worlds project [9] explored designing for interactive public spaces, in particular public transport spaces and market spaces. Shannon airport in County Clare, Ireland was the site of one of these interventions. An interactive portal was designed to allow travellers in the departures lounge the ability to send electronic postcards home using either stock photos or their own digital images. The sonic aspect of this installation was used to help travellers browse the collection

[2] SDT impact and rolling models - http://closed.ircam.fr/uploads/media/SDT-0.4.3b.zip

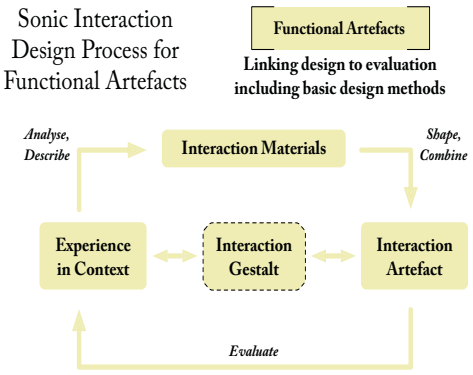

Figure 1: *The design process developed by the CLOSED project [8] for creating functional artefacts.*

of images. The scenario and further details are discussed by Fernström et al. [12]. Brainstorming and mood boards helped generate the initial ideas. These were then sketched and video prototyped or role-played to help evaluate the concepts. The most promising concepts were evaluated and tested using rapid audio prototyping tools such as PureData. This approach and the rapid audio prototyping tools allowed for the creation of four different iterations and evaluations within the space of a month. The process is illustrated in Figure 2.

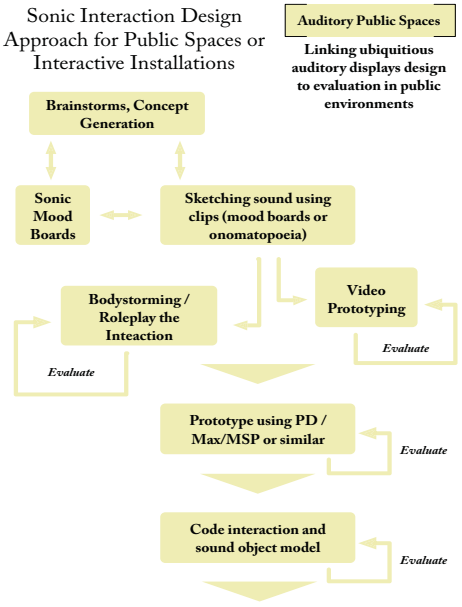

Figure 2: *The design process developed for interactive public spaces [12].*

2.3 Designing Narrative Sound Artefacts

The concept of narrative is important in both film and game design and inspired this methodology proposed by Hug [10]. It applies a design oriented research process to explore narrative approaches in the creation of interactive sound artefacts as shown in Figure 3. The view in this methodology is that artefacts are socio-cultural components within everyday life and are dynamic rather than static things. This approach creates exemplar prototypes for possible future scenarios and evaluates them using wizard of oz prototyping in a workshop setting. The studies in this approach generate a set of metatopics that can help create new scenarios and ideas.

Figure 3: *The design process for designing narrative sound objects [10].*

2.4 Shortcomings of the Existing Methodologies

The three methodologies show the focused nature of the existing methodologies in sonic interaction design. They are often heavily design biased and aim at creating or prototyping artefacts for evaluation. This approach typically fits within a sound creation view and often does not focus on the analysis or empirical investigations of the created artefacts. our framework attempts to bridge the gap between sound creation and analysis while ensuring the empirically inspired methods remain accessible and useful for interaction designers.

3 An empirically inspired framework for sonic interaction design

The framework we propose is aimed at providing designers with accessible tools and methods in a manner that allows for the easy bridging of the semantic gap between low-level perceptual studies and high-level semantically meaningful concepts. Our framework takes the view that the sonic interaction design process is split into two stages, sound creation and sound analysis. The sound creation stage is where a real sound is adapted or designed to meet the needs of the designer. It includes where the designer creates a new sound that is specifically tailored to the auditory design or context. The second stage, is the sound analysis stage where the sound or group of sounds are examined to ensure their suitability for use or to gain further insights into them from the perspective of potential listeners. In the cases of the *functional artefacts* [8] and of the *interactive public spaces* [12], the methodologies are both somewhat contained within the first stage of sound creation. The *narrative sound artefacts* [10] methodology is situated within the sound analysis or second stage of the framework. The approaches from these methodologies are tailored for specific goals, while the framework presented here aims to be more generalised. This means that there is a certain overlap from these methodologies that is implicit in the framework. A further caveat is the focus of the methods is at an individual level rather than at a group level, however the framework could easily be combined with group oriented techniques such as rich user cases [13] or the descriptive analysis process [14] to address this issue. The focus on the individual level is because time is a practical consideration for many designers and individual techniques are much less time consuming than most group oriented approaches [14].

3.1 Framework of Sonic Interaction Design

The implicit view we used as the method for evaluation of auditory icons selection in the early conceptual stages of design is shown in Figure 4. This approach consists of a number of successive steps, beginning with a definition of the context and purpose of the auditory display and ending with an actual evaluation of the auditory icons. The framework is open and adaptable to include new types of sounds or methods. The foundations of this framework are presented in this paper, as it is hoped that future research will improve its potential and practicality for interaction designers. The existing methods used in the framework include repertory grids [15], similarity ratings/scaling [16], sonic maps & '*earwitness accounts*' [17], '*earbenders*' [18], the context to basic design approach [19], in addition to aspects from the three earlier methodologies. A deeper introduction into these techniques is given in our earlier research [20].

3.1.1 Sound Creation:

The first stage is the definition, selection, creation, and adhoc evaluation of the sounds. This workflow creates and rapidly assesses the sounds within the design group or by the designer on their own. This approach depends on the skill of the designer as incorrect combinations or choices of sounds may occur, in addition to inappropriate mappings for the domain. The second empirically inspired stage can

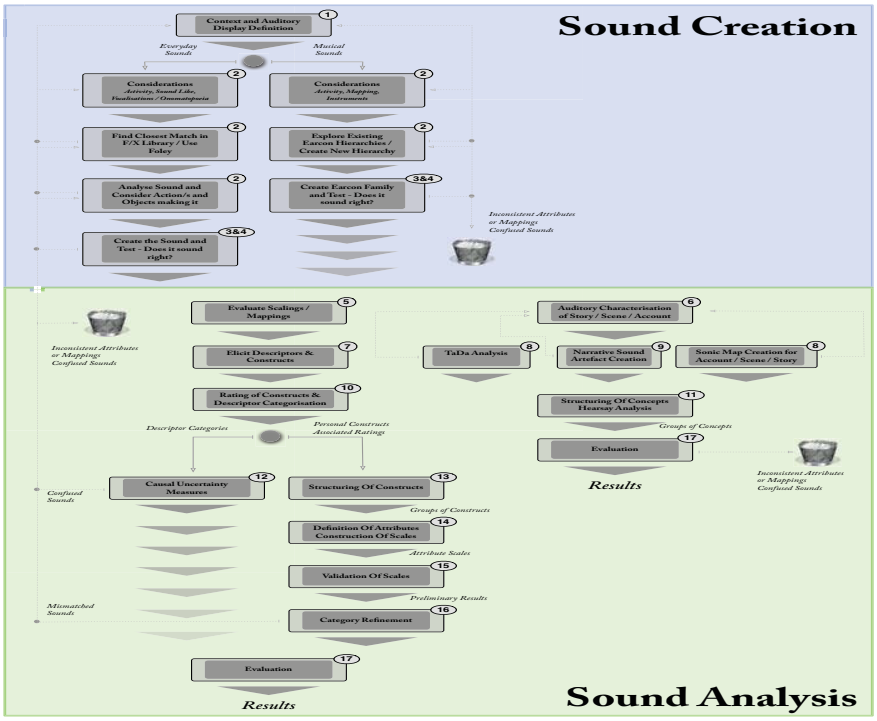

Figure 4: *Two stages in our sonic interaction design process.*

help designers build on this stage to ensure the best sound selections are made for the particular context. This stage is shown as the top part (blue highlighting) of Figure 4.

- *1 - Context and Auditory Display Definition*: The purpose of the auditory display is defined, the context is determined, the initial conceptual design including possible sounds and mappings are created.
- *2 - Selection of Sounds*: A pool of sounds that can fit the selected mappings are gathered and organised for evaluation. These sounds can be real, synthetic or a mix of both.
- *3 - Create the Sounds*: If necessary edit the existing sounds or create new sounds. These sounds can be real, synthetic or a mix of both.
- *4 - Listen to the Sounds*: If they do not sound right for the mapping or events, try again with other sounds.

3.1.2 Sound Analysis:

The second stage is the use of empirically inspired methods to improve the selection and understanding of the sounds. The methods present a number of perspectives, depending on whether it is attributes / mappings, confusion metrics, or listeners' narratives being explored. The methods available in the framework are designed to be open for extension to include other adaptions or new methods. This allows for many different perspectives on the sounds and helps inform the designer about the range of possibilities that exist within the given design space. The sound analysis stage is shown as the bottom part (green highlighting) of Figure 4.

- *5 - Evaluate Scaling / Mappings of the Sounds*: The participants listen and compare the sounds and the mappings or attributes being used.
- *6 - Auditory Characterisation of Story/Scene/Account*: This is where a narrative for the sounds and environment are created.
- *7 - Elicit Descriptors & Constructs*: The participants created descriptors for the sounds presented.
- *8 - TaDA & Sonic Mapping*: Analyse the narrative and break it down into the different types and aspects of sounds occurring.
- *9 - Narrative Sound Artefact Creation*: The workshop narrative approach as discussed in section 2.3.
- *10 - Rating of Constructs & Descriptor Categorisation*: Each participant rated the stimuli using these constructs created in the previous stage.

- *11 - Hearsay Analysis / Structuring*: Take the auditory patterns and key sounds to create a short summary of salient points that could be reused in other auditory display contexts.
- *12 - Causal Uncertainty Measures*: The categorisation details can be used to calculate the causal uncertainty of sounds.
- *13 - Structuring of Constructs*: Cluster analysis, multidimensional scaling and principal component analysis of the ratings data can clarify attributes and reduce dimensionality of the data as well as removing redundancy.
- *14 - Definition of Attributes, Construction of Scales*: The construct groups are analysed for their content. The appropriate descriptions for the participant identified attributes are then formulated. The rating scales are defined from these attributes.
- *15 - Validation of Scales*: The scales created can be explored in terms of existing categorisations and taxonomies to test the appropriateness of the scales.
- *16 - Category Refinement*: The details from the earlier causal uncertainty measures and from the scales can help suggest the removal of particular sounds as unsuitable for use in the particular sonic context.
- *17 - Evaluation*: The details and results are further analysed to produce the final evaluation results and summary of the evaluation.

3.2 Simplification of the framework

This evaluation method consists of a number of steps, it is envisaged that in future when auditory icons and their subjective qualities are better know that some stages may be simplified or found to be redundant. The use of several methods helps to triangulation the results and shows where additional steps may be added to incorporate new techniques within the framework.

3.3 How to use this framework

There is no how-to or best practise for using this framework or the suggested techniques either individually or collectively. The most appropriate way to adapt these subjective methods is to adopt one or two complementary techniques and use them in a small exploratory design study to see the value they bring to address a particular design issue. The main goal of this paper is to provide a short review for practitioners of the framework and allow them to make the appropriate choice of technique for their design goal.

While some of these methods may not be as 'rich' as others, they can still provide additional insights on different facets of the sound or sounds. A number of the methods overlap in terms of what is needed from participants and as a result a single experimental session can easily generate data which can be analysed by several of the methods. The listening test approach [21] asks participants to write verbal descriptions of what they have just heard. These descriptions are similar to the personal constructs collected with the Repertory Grid method [15], the key sounds found using the Sonic Map & Earwitness approach [17], and when described in more detail are similar to the short stories in the Earbenders method [18]. Previous studies [4] have shown how the Repertory Grid method [15] and Ballas's causal uncertainty method [22] can be used on the same set of collected responses to analysis different yet complementary aspects. The similarity scaling technique [16] uses direct scaling of sound stimuli and as such it requires a separate experimental session. This can be an advantage as participants focus on a single scaling task rather than being asked to scale and provide written descriptions. The method could easily be combined with a context-based rating [23] task, a sorting task or with a discrimination task [22].

4 Discussion

A motivation in creating this framework work was the lack of support for designers wishing to use empirically inspired methods to answer their design questions. The issue is that a typical design problem is more wide ranging than those typically addressed by psychoacoustic studies. This framework presents an approach that is accessible at a reasonable cost to designers and without the need for dedicated facilities such as listening booths or anechoic chambers.

5 Conclusions

This paper introduced a framework for empirically based design within the domains of auditory display and of sonic interaction design. The two key conceptual stages were introduced and related back to the existing methodologies covered in Section 2. This approach builds upon existing techniques and highlights certain areas of overlap where the methods within the framework can be used to complement each other. This framework is the foundation for an accessible empirical approach that can be easily used by novice designers.

The results of this framework will provide greater details to designers on the salient cognitive attributes of sound and help to uncover pragmatic mental models. The aim of this work is to help guide newcomers to sonic interaction design and help them in determining what methods are most appropriate to answer their particular questions or design needs. This review has provided an overview of techniques which, when applied can help deepen knowledge and contribute to answering the question raised by Hug [24] about how to design sounds for ubiquitous technology.

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