PATTERN DESIGN IN THE CONTEXT SPACE
A METHODOLOGICAL FRAMEWORK FOR AUDITORY DISPLAY DESIGN

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ABSTRACT

Common practice in the design of auditory display is hardly ever based on any structured design methodology. This leaves audio being widely underused or used inappropriately and inefficiently. We analyse the current status of research in this context and develop requirements for a methodological framework for auditory display design. Based on these requirements, we have created a framework of methods to capture, transfer and apply design knowledge based on design patterns - **paco ad**. We present the context space as the organising principle to conceptualise the design space facilitating the matching of design knowledge with solutions and the workflow. Finally, we elaborate on how we intend to evaluate the framework and how it can be supported by tools.

[Keywords: Design theory, Design patterns, Framework]

1. INTRODUCTION

In the bigger picture of human-computer interaction or interaction design auditory displays have been widely neglected as an alternative to visual means. Although research has shown that auditory displays can improve usability of existing interfaces (e.g. [1]) or even outperform visual displays in certain contexts (e.g. [2]) it has proven to be difficult to identify transferable qualities in these prototypes that could be used in different design problems. For auditory displays as a field of research this means that building effectively upon other's findings is not easily achieved. For the average designer the unavailability and/or the inaccessibility of common design knowledge prevents them from taking full advantage of auditory displays. Looking at most of today's technology supports this case. The Apple iPhone, for example, claims to revolutionise the way we communicate by integrating a variety of personal devices and providing new paradigms to interact with it. However, for what we know, auditory interaction will play a marginal role. Lumsden et.al. hypothesise that the reason why sound is little used in most user interfaces is *"that designers typically do not know how to use sound effectively [3] with the result that, where used, sounds are often employed in ad hoc and ineffective ways"* [4].

Hence, what is needed to advance the scientific field as well as the application of its findings in practice is a comprehensive framework for designing auditory displays that unifies the expertise that was built up and is easily accessible for the average designer (see also [5]). The work described in this paper is an attempt to create such a methodological framework. After having approached the auditory display design process by adapting design patterns [6, 7], it became obvious that although design patterns can provide the container for design knowledge, a methodological framework was needed to put them into action. Therefore we developed **paco ad** - a methodological framework that intends to guide expert designers as well as novices in creating and applying design patterns for auditory displays.

The following provides a review of existing guidelines, principles and design theory in the context of auditory displays and highlights the requirements for a methodological framework. The remainder of this paper presents **paco ad** including the key concept of the context space and a description of the workflow. An outlook on future work concludes the paper.

2. PRINCIPLES, GUIDELINES AND DESIGN METHODOLOGIES

The first principles on representing data with sound were compiled by Kramer [8]. He investigated perceptual mappings and their inherent relationships and provides some fundamental principles for parameter mapping. His focus is clearly on using sound to perceptualise data and while still being valid in the HCI domain the principles address sonification design rather than providing interface designers with guidance on how to effectively include audio in the interface. Gaver in the same book provides methods to create auditory icons with a clear focus on computer interfaces [8]. He proposes to parameterise them, not along the usual physical dimensions of sound, but along the properties of the physical object causing the sound. However, while opening a design space he says little about its usage.

Blattner et.al. created guidelines for composing and combining earcons based musical motives [9]. She derived a good part of these from analogies to visual icons. Later, Brewster would refine these guidelines and connect them to a method in HCI that reveals hidden information in interfaces. Adapting the event status and mode analysis technique he suggested to use sound to make this hidden information accessible to prevent human error [10]. Together with McGookin he also investigated the use of concurrent earcons [11] and more specific guidelines for the enhancement of graphical widgets such as buttons were provided by Lumsden and

Brewster [4].

A case-based approach to auditory display design was introduced by Barrass [12]. His Task & Data (TaDa) Analysis is a formalised way to describe the information to be represented by sound. He then uses this description to match it with sounds stored in a database (EarBender). Barrass also proposes the creation of auditory design principles based on principles for generic information design like directness or the level of organisation by linking them to the properties of auditory perception. As a result these principles are very low-level and more useful for sonification of data than for user interfaces. Similarly, his sound design space - the equivalent of the colour space for graph design - is more tailored towards data representation then human-computer interaction. More recently Barrass also investigated the use of design patterns [13]. By proposing to "cultivate" design patterns in a collaborative community effort Adcock and Barrass hoped to create an extensive collection of common knowledge [14]. The efforts, however, stalled and few patterns were written. A possible reason might have been that the community has not yet developed a sufficient number of proven-to-work prototypes for patterns to emerge from common practice.

Mitsoupolos created a design methodology for auditory design combining Foley's framework for dialogue design with findings in auditory perception and attention theory [15]. The methodology has three levels on which the interface is designed: the conceptional level, the structural level and the implementation level. In each level he intends to narrow the design space by ruling out solutions that would violate psychological rules. Notably, he argues for two fundamental modes of presentation of information by audio: fast presentation i.e. 'at a glance' and the interactive presentation for more detailed user interaction. Although properly founded in theory, the methodology was not evaluated for its usefulness for designers.

Another design methodology based on existing HCI techniques was presented by Pirhonen et.al. [16]. They adapted use case scenarios to design sounds in a series of panel sessions with experienced designers. Rich use case scenarios, as they call them, are used to draw a compelling picture for the panellists of the context in which the sounds are to be used. The results, however rely on the quality of the panel and may be biased by the author of the scenario and the implied indication of when sounds should be used.

3. REQUIREMENTS

We shall hypothesise why the above methodologies have not made sound more popular in user interfaces and subsequently will derive requirements for our approach to a design framework: Myers et.al. identified a number of qualities in user interface software tools that made some successful and others not [17]. Although we are not yet dealing with tools for auditory display design, design methodologies can be seen as a prior stage to those. Most importantly, successful tools feature a low entry barrier, but high potential, predictability, flexibility in manipulating objects and provide a high level of affordance that leads to increased usability. An obvious obstacle for many designers is the high entry barrier. Many of the above methodologies demand a substantial understanding of the background. Furthermore, the diversity of fields involved further complicates the matter. In terms of predictability and flexibility, auditory displays also raise difficulties. While most existing concepts are tailored towards a very specific context, the solution in a slightly different context could sound very different. Surveys have shown that the way of least resistance dominates the current practice of designing audio [3], which leads to an inefficient and inappropriate use of audio. This has also been supported by the results of a, not yet published, survey on common practice in auditory display design amongst 86 HCI designers, conducted by the authors recently.

Another lesson to be learned from previous attempts to create a design methodology is that it requires a critical mass of design knowledge. The community has not yet produced many "killer applications". Proven-to-be-working solutions are scarce, the material to draw upon scattered in the design space. Also, the size of the community makes it difficult to spark a community effort without highly ambitious individuals. Another aspect is the interdisciplinary composition of the community causing misunderstanding or information loss due to different terminology and focus areas.

It is to be expected that future design of user interfaces has not only to deal with a single modality, but will demand the use of every human sense. This means, that a design methodology for auditory displays will have to fit into the bigger picture and support, if not incorporate strategies for multi-modal design.

With this context in mind and based on a literature study and an online survey on current practices in auditory display design, we specified the following core requirements for our approach to develop a design framework:

- easily accessible and productive for novices and experts
- support for smaller communities providing means to conceptualise the design space
- context aware design that may also accommodate multimodal design
- support for creativity and designer's craft
- encouraging collaboration

Based on these requirements we developed **paco ad** to be presented in the following section.

4. THE FRAMEWORK

paco ad is a framework for creating, applying and managing design knowledge based on design patterns. Design patterns have proven to be adaptable to various design disciplines such as Architecture, Object-orientated programming and web design. Compared to guidelines, principles and other forms of guidance, design patterns have distinct properties which make them particularly suitable for the envisioned framework: *"First, patterns offer solutions to specific problems rather than providing high-level and sometimes abstract suggestions. Second, patterns are generative, helping designers create new solutions by showing many examples of actual designs. Third, patterns are linked to one another hierarchically, helping designers address high-level problems as well as low-level ones."* [18]. Additionally, the contextual form of patterns make them suitable as a lingua franca for all stakeholders in the process [19] and they are able to reflect 'values' of good practice which may cover subtle issues like privacy or æsthetics [20].

A methodological framework for auditory display, however, must be more than a straight forward adaptation of design patterns as Barrass's attempt has shown. A framework has to take into account the requirements as outlined in the previous section. A key concept to organise design knowledge in **paco ad** is the context space, which is introduced in the following section.

4.1. The context space

The context space is the organising mechanism in the framework. It is a multi-dimensional space in which design problems, design solutions and design patterns can be classified according to their context. The introduction of the context space benefits the design process in various ways: 1) It provides means to conceptualise the design space and the problem domain and allows for navigating these. 2) It functions similar to a map and reveals gaps and clusters in research. 3) As it provides a common space for problems and solutions, it facilitates efficient matching of those. 4) It also facilitates new ways of creating design patterns as we will show in the following section and 5) it emphasises the importance of the context for design in human-computer interaction.

Similar to the ontology used in model-based user interface design the context space features the user, the environment and the platform (together the context of use) as key dimensions [21]. To be able to "localise" designs (i.e. assigning descriptors into the context space) and organise them meaningfully, it is also necessary to introduce the purpose of the design. This not only includes the functional purpose (i.e. the task of the user of the artefact), but in a wider sense the desired user experience and social context.

While aspects of the context of use (user, device and environment) can be represented by a set of ordinal dimensions, this is hardly feasible with the remaining dimensions. Hence, nominal dimensions like the task are represented by keywords. One of the features of the context space as an organising principle for design knowledge is to define the proximity of descriptors. With nominal dimensions, however, this is difficult and we have not yet settled on a solution to this problem. A promising approach might be to create hierarchical trees of keywords in which the proximity is simply defined by the length of the path between items. However, the diversity also demands the possibility of free text associations or a similar concept to the tagging paradigm, popular with an increasing number of applications with the need of organising a large amount of diverse information. A complete overview of the dimensions of the context space is provided in table 1. The representation of and the navigation in the context space will have to be designed carefully in a design tool. The multiple dimensions and the amount of non-ordinal data to be depicted are significant difficulties to be solved. However, sonification of the context space might be a promising candidate to navigate the space the possibility to map multiple dimension on different perceptual dimensions of sound. "Localisation" in the context space could be facilitated by a Wizard-like question and answer paradigm. For example: "Which sound capabilities are available on your target platform?" - 0 for one channel, mono-phone sound output like in old mobile phones. Very limited processing power and poor programming facilities. ... 3 for mobile device with stereo, poly-phone sound cards. Limited processing power, but high-level sound interface. ... 5 for full featured desktop PCs with multi-channel, high quality sound cards, high processing power and good support through programming environments.

4.2. The workflow

The framework provides methods for the whole life-span of design patterns - from creation to application and refinement. This section illustrates these methods by describing a typical workflow using a concrete example: the auditory menu navigation in an Mp3 player.

4.2.1. Creation of design patterns

The motivation of an experienced designer to create design patterns from her designs is driven by the possibility to share the design knowledge and - like a portfolio - to build up a profile and make solutions re-usable for future projects. The starting point is a working prototype to the design problem of making the menu of an Mp3 player accessible by auditory means. The solution is based on the designer's experience and was empirically evaluated. The specific solution is "localised" in the context space by assessing the values for each of the dimensions (i.e. defining the context by creating a descriptor into the context space). Subsequently, the solution is described in a textual pattern format supported by audio examples and the rational for the design (see also [7]). The pattern gets rated with 3 stars out of 5, because it was positively evaluated, but there are no other implementations yet that would justify a higher rating. The designer then takes every dimension and seeks to widen the potential context in which the proposed solution might work. In the course of this process the pattern might be revised to accommodate the new context. In our fictional example, the "Menu" pattern that emerged the prototype gets rewritten to fit not only Mp3 players, but also PCs and finally the name changed to "Hierarchical navigation & selection" to make other uses possible. The rating decreases, as there is no evidence that these solutions work (e.g. to 2 stars for strong indications, 1 star for guesses). All changes to the pattern are stored in a history, like with version controlled source code. This creates a multitude of patterns and versions that reflect the expertise of the designer and provides an additional source for the reasoning of how more abstract patterns were developed.

4.2.2. Application

A novice designer approaches a design problem - e.g. to create an auditory design for the navigation of mailboxes in a desktop mail client. She "localises" the design problem in the context space by assessing values to all the dimensions (e.g. what sound capabilities are available on the platform and what the desired user experience should be like etc.). With the descriptor that is made up by these values she can explore the context space around the problem and retrieve design patterns for similar problems. In our example, she will find the "Hierarchical navigation & selection" pattern as related design knowledge describing vaguely how hierarchical information can be represented by auditory means. The rating tells her that this pattern is a guess by another designer, the history shows the origin of the pattern as being derived from an Mp3 player menu. Design patterns leave a great freedom for interpretation to the designers, which encourages creativity and supports the possibility to tailor solutions for specific circumstances. Every solution the designer derives from the pattern will need thorough usability testing. However, the goal is to get initial prototypes nearer to the required solution, hence, making more iterations possible resulting in better designs.

4.2.3. Refinement

The solution the novice designer arrived at after multiple iterations, applying the "Hierarchical navigation & selection" pattern and instantiating it to her needs, was evaluated and proven to work well. She can now feed back her experience in two different ways: in a top-down approach revising the pattern she used and creating more specific patterns in a reversed process to the creation process or in a bottom-up approach by starting with her prototype and

Name	Desription	Metric
user:askill	Skill of the user in the application domain	ordinal, level 0-5
user:hskill	Skill of the user in human-computer interaction	ordinal, level 0-5
user:vision	Visual capabilities of the user	ordinal, level 0-5
user:hearing	Hearing capabilities of the user	ordinal, level 0-5
env:vision	Restrictions by the environment to vision (e.g. sun light)	ordinal, level 0-5
env:sound	Restrictions by the environment to sound (e.g. noise)	ordinal, level 0-5
env:privacy	Restrictions to the privacy (e.g. office vs. public transport)	ordinal, level 0-5
dev:vision	Visual capabilities of the device	ordinal, level 0-5
dev:sound	Audio capabilities of the device	ordinal, level 0-5
pp:task	Type of user task in the interaction problem	nominal, keyword and associations
pp:experience	Desired user experience	nominal, keyword and associations
pp:social	The social context of the design	nominal, keyword and associations

Table 1: The dimensions of the context space

working her way up to the pattern she instantiated. In both cases a set of new patterns is created reflecting the novice designer's newly acquired expertise. The ratings of the patterns will be set accordingly and the "Hierarchical navigation & selection" pattern steps up too, as it now has two authors and more example implementations. Similarly, if the evaluation reveals faults in the pattern (e.g. if a guess is proved to be wrong), the rating system can reflect this by decreasing the number of stars. In both cases, it is important to keep track of the history of the changes as it reveals how a pattern arrived at a certain version with a certain rating.

Figure 1 illustrates the complete workflow described above.

4.2.4. *Benefits*

The methods described in the sections above enable designers to share their design knowledge in a re-usable form. The introduction of the context space not only allows the designer to conceptualise the design space and find relevant design knowledge, it also facilitates the creation of new design patterns. The methods not only allow for capturing well established and validated good practice, but also supports unproved solutions. The rating system and the history make possible a natural selection of working solutions while bad practice is dying, or can still be used as anti-patterns to showcase bad practice.

This methodology satisfies our requirements stated in section 3. The use of design patterns ensures flexibility and the freedom of designers to exercise their creativity. The context space allows for conceptualising and navigating the design space and effective matching of design knowledge and design problems. It is expected that many design patterns, as their descriptors in the context space (i.e. their intended contexts) grow, will become more and more mode-independent. This can be the beginning of a multi-modal approach that goes beyond auditory displays (i.e. **paco** alone can serve as generic concept), but connects to them by using the same organising mechanism. For creating a momentum in the community and encouraging a collaborative effort towards building a shared body of knowledge, the methods in **paco ad** must be supported by tools. The following section discusses what such tools might look like and what the next steps in research will be.

5. FUTURE WORK

5.1. Evaluation

To evaluate a design framework implies systematical difficulties. The vague definition of what it means to produce 'better' designs or of the 'usefulness' of methods for designers undermine any empirical evaluation. Furthermore, in a field like auditory display in which current practice is little attached to any structured design methodology and draws mostly on research literature and experience, it is difficult to find a control setting which the framework can be evaluated against. However, similar studies in other domains like ubiquitous computing have shown how such an evaluation might be approach, although the process of creating design patterns was never included in such studies [18].

We approach the evaluation of **paco ad** by conducting two sets of case studies. First we focus on the creation phase of design patterns: expert designers are asked to code design knowledge from their most successful designs by using the methods described above. In structured interviews we seek not only to elicit 'hard' design knowledge, but also to record the particularities in the process of the individual designer. What is the easiest way for them to use **paco ad**? Besides creating a set of design patterns these interviews intend to investigate the requirements for tool support.

Subsequently, in a second round novice designers are asked to solve prepared design problems. They are provided with a design brief for problems close to those elicited earlier by the expert designers. The resulting designs are rated by experts (to avoid bias, these will be different from the ones who created the patterns) and compared to designs a control group created without using the framework. Again, we seek not only to investigate the efficiency of the knowledge transfer, but also to record the individual process to draw conclusions for the development of design tools. The hypothesis is that if we can show that **paco ad** effectively transfers design knowledge from expert designers to novices, we have proven its 'usefulness' to the design process.

The results of this evaluation will be invaluable to refine the methods and concepts in the framework and will also inform the design of supporting design tools as described in the following section.

5.2. Tool support

In order for **paco ad** to be accepted it must be supported by efficient tools. Expert designers in the community have to see benefits

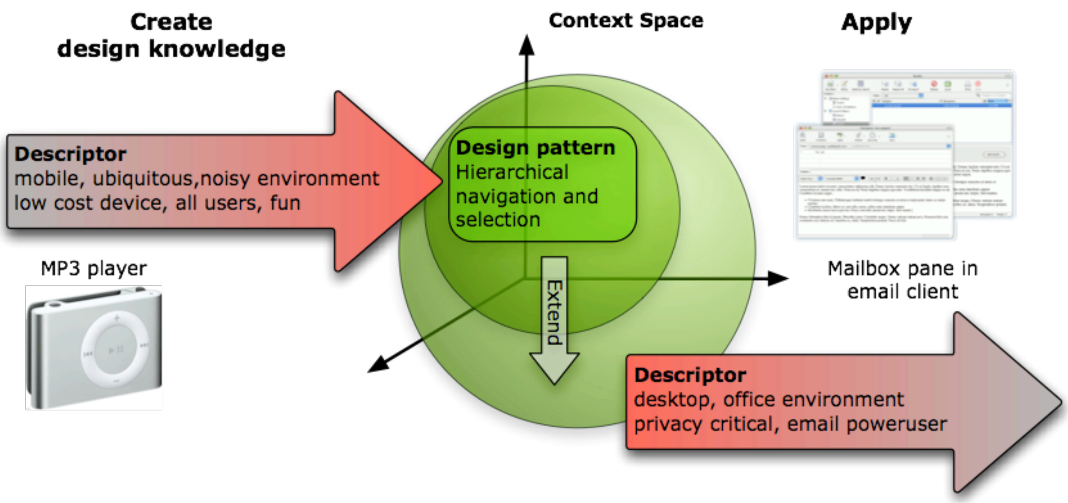

Figure 1: An example workflow: creating design knowledge from a successful MP3 player design, extending it in the context space, generalising and creating new design patterns, applying it to the design of the navigation in an email client.

in using **paco ad** and the system has to be as easily accessible for novices as possible. We intend to develop an online information system that reflects the workflow of **paco ad**. A set of wizards will lead users through the methods and we seek to exploit a common metaphor to convey the organisation of the design patterns in the context space. Such a portal, however, has to be designed carefully to be appealing to the target groups. It has to take advantage of collaborative techniques common with community sites like Wikis, version control, tagging, forums, search functions etc.

6. CONCLUSION

The above sections presented **paco ad** - a methodological framework for auditory display design. Its methods take expert designers and novices through the design process and facilitate efficient knowledge transfer between those groups. The methods are described by a workflow scenario showing the life cycle of a design pattern. The aim of this framework is to provide a systematic approach to auditory display design for experts and novices to promote the efficient use of audio in the user interface. We described a possible direction for developing tool-support for **paco ad** and the steps we intend to take to evaluate the framework.

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