The Shannon Portal: Designing an Auditory Display for Casual Users in a Public Environment

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ABSTRACT

We developed an installation for a public environment and casual users where auditory display was a significant element to facilitate user interaction. We used an iterative design process, starting from simple onomatopoeic representations, to complex sound object models in Pure Data. The system was evaluated at each stage, from the lab to the final public setting. The problems addressed covered the representations of left-right, up-down, and the amount of movement by the user or groups of users. In addition to this, it was important that the auditory display would attract attention when users were within control range of the system, i.e. an affordance that invited and allowed users to discover functionality.

1. INTRODUCTION

In our *Shared Worlds* project we explored designing ubiquitous computing for public environments. Part of this exploration was to design, build and evaluate installations in public environments. The work reported in this paper is about the Shannon Portal, a complex interactive installation in Shannon Airport in the West of Ireland. The overall design is described in [1], while in this paper we focus on the design of the auditory display element of the installation. One of the issues that we wanted to explore in the project was the use of large ambient displays and public interaction with such displays. As the installation at Shannon required an interactive image gallery to be displayed, we designed a purpose-built back-projection system. An overhead camera tracked users' movements in front of the display, allowing the users to move a virtual magnifying glass across the image gallery on screen, by moving their body in front of the display. See Figure 1 and 2.

Over several iterations we developed hardware and software for the display and explored different mappings of users' actions to movement of the virtual magnifying glass on the projection screen. For reasons outside the scope of this paper, it was decided that it was not the users' location that would control the movement, but the users' movement. The rationale for this was that as there was only one virtual magnifying glass but there could be multiple simultaneous users, this mapping would encourage collaboration and engagement.

While testing and evaluating the system in the lobby outside our lab in the Interaction Design Centre at the University of Limerick, we noted that users who occasionally passed by the display were not aware of that the display was interactive. Furthermore, due to the nature of the mapping, some users found it difficult to understand that it was their movement, not their location, that controlled the virtual magnifying glass. To remedy this, we decided to design an auditory display element for the system.

Figure 1: Shannon Portal installation

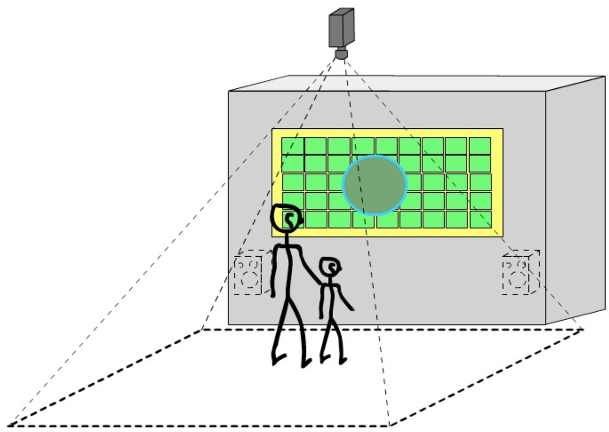

Figure 2: Back-projection, loudspeakers and video camera

1.1. The challenge of auditory display in public environments

Is has been noted in numerous papers (e.g. [2-4]) that auditory display can be annoying. A location such as the transit hall of an airport has an inherently high background noise level, at peak-time often over 85 dB. In the transit hall in Shannon airport, the main contributors to the soundscape are people walking, talking, handling luggage, eating and drinking, mobile phone ring tones, tills in the Duty Free shop, all the activity in the Sheridan Bar and bursts of announcements about flights over the PA-system. Having analyzed the airport soundscape and the nature of the interactivity that we wanted to support, it was obvious that traditional auditory icons and earcons would not be suited for the design. Auditory icons would easily be confused by all the normal activities in the space. Earcons would easily be confused with mobile phone ring tones and the bleeps and pings from PA announcements and tills. Due to this we tried a number of different auditory displays based on a more abstract approach but with consideration of psychoacoustic issues of masking and loudness. The basic requirements of the auditory display were that it should:

- Only sound when users actively moved in front of the image gallery.
- Indicate the positioning of the virtual magnifier glass in the projection: up, down, left and right. The parameters from the overhead motion tracking camera system were the amount of movement, left-right position and front-back (closeness to display) position.
- Be audible and not be easily masked by the airport's existing soundscape.
- Be audible but not too loud or masking other sounds, in particular speech.
- Be able to attract the attention of people passing close to the display, without being intrusive.

2. EVALUATION

All our designs throughout the design process were evaluated. Initially we used heuristic evaluation, considering issues such as masking and mapping. We then evaluated the designs with 3 to 5 people in our own laboratory. The installation was then, temporarily, put up in the lobby area outside our lab, a semi-public space. In this space, 9 people participated in the evaluations. They were first observed in free casual use of the system and then interviewed. When we finally moved the installation on-site to Shannon Airport, over 500 people used the system. We captured approximately 50 hours of video of real use that was later analyzed. We interviewed 20 users about their subjective experience.

3. DESIGN

In this section we look at the general design process that we used in the project (see Fig. 3). As in most creative design activities, the process starts with brainstorms and concept generation. During this stage, one needs to have samples at hand that can be discussed and critiqued, but also help driving the creative process forward. In other design disciplines, mood boards are commonly used to gather ideas for stimulation and as exemplars. For sonic interaction design, one possible tool is the *Sonic Browser* [5, 6] that can be used for grouping and listening to collections of sampled sounds. It is also possible to use for example *Apple iTunes* to hold examples of our sound collections and use the playlist function to create auditory mood boards. In any case, the important issue was to have plenty of relevant sound examples at hand to support the creative process. At this stage of the process it is also valuable to have sound collections that have been tested in terms of *causal uncertainty* and with background information about what users participating in testing the sounds in isolation believed they heard [7, 8]. The short sentences written by participants can support us in finding and building possible metaphors for an interaction. Another possibility is to just act out the imagined use of the system while making the sounds live, i.e. *bodystorming* [9], and record it as a placeholder for a concept.

We can then choose sounds and interactions from the previous stage and create a first rapid prototype using tools such as for example *Pure Data* (PD) and connecting the sonifications via network sockets to the rest of the system, in this particular case the computer vision system. As PD is Open Source, the final sound designs could potentially be extracted and rebuilt by taking the relevant source code snippets from PD, integrating it with other source code for the system under development.

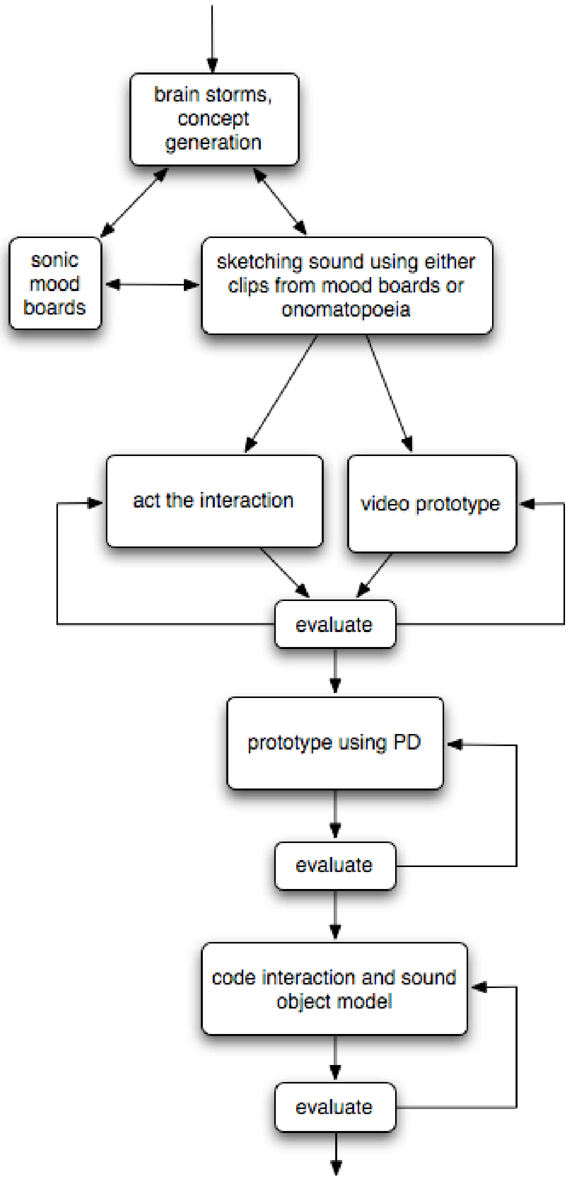

Figure 3: Design process

As the visual metaphor of our installation had a certain science-fiction feel and the setting was in an airport, we decided that an aerospace-inspired sound design might be appropriate. We used PD as the sound designer's sketching tool to rapidly generate possible sonifications. All four sound designs described below were created and evaluated over a four-week period, allowing instant access to adjust parameters, or quick modifications based on comments from the participants.

3.1. First design: Ping

Our first display used an 80 ms decaying pulse from two sine wave oscillators 4 Hz apart, pitched from 200 Hz to 800 Hz. The rate of pulses ranged from 0.3 to 5 Hz. The output was amplitude panned left-right. In essence, one could describe this simple sound design as "a machine that goes ping". We tried the following mapping:

- Amount of movement – Pulse rate
- Left-Right – Panning
- Front-Back - Pitch

Participants found this display to be clear but too intrusive ("sounds like a truck reversing"). Part of the intrusiveness in the sound design is due to the sharp onset, which is strongly attracting attention. The pitch used was in the middle of the background soundscape spectrum, hence would require to be loud to avoid masking. All participants found the mapping easy to understand.

3.2. Second design: PhotonDrive

Our second display used a pulse with approximately 0.3 s attack and 0.3 s release from two sawtooth oscillators tuned 2% apart, pitched from 50 Hz to 650 Hz. The output was amplitude panned. Our nickname for this sound design was *PhotonDrive*. The mapping used in our tests was the same as in the previous trial.

The softer onset and richer spectrum resulted in participants feeling that the sound design was less intrusive. Due to the richer spectrum, the sound could be played at lower loudness level, but was still found to be masked at times.

3.3. Third design: Wind

In our third display we tried a less intrusive sound, a wind-like sound that was based on subtractive synthesis using white noise sources that were bandpass filtered with a certain amount of jitter in the center-frequencies to make it sound more realistic. The average center frequency was mapped to the amount of movement.

This sound was noted as not being intrusive as there was no distinct onset, but due to its naturalness, basically being a parametrically controlled auditory icon, and only two mappings (activity – frequency, left-right panning), also this display was discarded.

3.4. Fourth design: Shepard tones

In our fourth and final display we used a slightly more radical approach. This sound design was based on the Shepard tone illusion (Shepard, 1964). This illusion is perceived as eternally rising or falling pitch and is due to the continuous frequency change and mix of ten or more partials. We carefully adjusted the partials to a quite unnatural timbre (bell-like) to try to avoid masking effects in relation to the surrounding soundscape.

- Amount of movement – loudness
- Left-Right – Panning
- Front-Back – Pitch direction

Participants found this display to be positively intriguing, as it did not sound like anything they had heard before. Due a soft onset, as we mapped amount of movement to loudness, it was noted as both being pleasing as well as attention catching. A participant or group of participants walking past and accidentally being tracked and sonified immediately understood that it was their movement that caused the sound. This finding is similar to Todd Winkler's installation *Light around the edges* [10].

We finally moved the installation to Shannon airport where it was installed for 3 weeks. We carried out both observations and informal interviews during this period. Both passengers and staff at the airport found the sound design contributing to their experience and being non-intrusive, and our previous findings confirmed. Our video analysis of people using the system on site also confirmed that the auditory display served to catch people's attention when walking past the system.

In Figure 4, below, you can see an example sonogram of the soundscape of Shannon Airport with the Shannon Portal installed. Within the white square, you see the partials of the auditory display increasing in frequency. The rest of the sonogram is the background noise. Even in this visual representation, the sonification stands out against the background. The psychoacoustic features we are exploiting are 'common fate' and 'good continuation' [11].

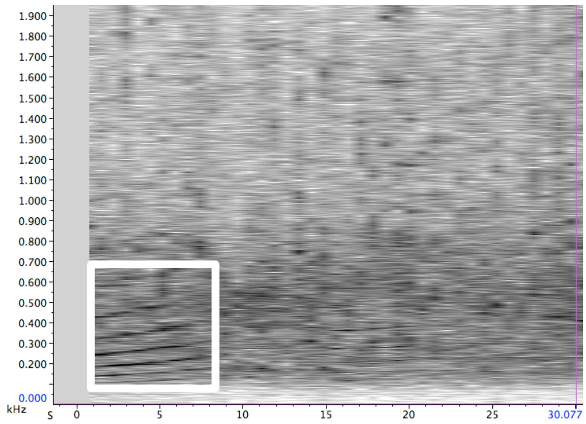

Figure 4: Shannon Portal soundscape sonogram

4. DISCUSSION

There are a number of issues involved in this design. First of all, it was important to create an auditory display that would be somewhat subtle but always audible, but not annoying for the staff working in the area. It also had to be immediately informative, i.e. affordances [12-14] for immediate discovery by casual users. The auditory display also had to be useful, i.e. to actively provide users with information that increased their feeling of engagement with the system.

Our overall design ambition was to develop a ubiquitous computer system for a public setting. Instead of using traditional metaphors, we aimed for a high degree if *virtuality* [15], i.e. that the conceptual structure of the system would be immediately obvious to the users instead of being weighed down by traditional user interface clichés or forcing users to read a manual before trying to use the system. This is always a problem in computing for public environments, as most users would never have encountered a system like this before (at least, not the first time) and within a few seconds the system has to communicate to potential users that it can be interacted with and guide users how to proceed.

Throughout the design iterations, the first three designs had some problems to fulfill the requirements, but the fourth and final iteration was found to be a satisfactory solution to the problem. We believe that the important finding here is to facilitate multiple design iterations with evaluation, to help inform an evolving development of this kind of auditory display.

In the design process, we noted that while it might appear to be easy, it is sometimes difficult to get a design team to simply onomatopoetically vocalize ideas for an auditory display in a bodystorming session, probably because they feel it is what children do when playing, adding vocal sound effects to their actions, and as an adult 'we don't do that'. Still, it is the most immediate way to communicate a sound – and what we can vocalize we can hear, and vice versa.

On the issue of annoyance, there is only one way to find out if a particular display is acceptable or annoying, by investigating how users experience the auditory display over a longer period of time.

From a design perspective, there are many possibilities. The difficulty is to quickly hone in on plausible alternatives, in this case sounds that can be played at lowest possible loudness while not being masked by the surrounding soundscape, and still be informative.

As the iterations progressed, it is interesting to note that the first and second design were semi-discrete in a temporal sense, i.e. pulsating, while the third and fourth design were continuous, hence directly responsive to the users movements. We believe that this is an important factor especially for casual users, as the perceived immediacy seems to be better at catching the users attention.

In our evaluation, in the interviews, all users stated that they never encountered a system like this before, but they were all able to use it, immediately.

5. CONCLUSION

In this paper we have reported the design of an auditory display, as a component of a complex ubiquitous computing installation for public use. We have suggested an iterative design process that can involve the entire design team, allowing also non-audio designers to actively reflect upon the auditory display issues.

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7. REFERENCES

[1] L. Ciolfi, M. Fernström, L. Bannon, P. Deshpande, P. Gallagher, C. McGettrick, N. Quinn, and S. Shirley, "The Shannon Portal installation: Interaction design for public places," *IEEE Computer*, vol. 40, pp. 65-72, 2007.

[2] S. A. Brewster, "Non-speech auditory output.," in *The Human Computer Interaction Handbook*, J. Jacko and A. Sears, Eds. USA: Lawrence Erlbaum Associates, 2002, pp. 220-239.

[3] J. Cohen, "Out to Lunch: Further adventures monitoring background activity " presented at ICAD 1994, Santa Fe, 1994.

[4] R. D. Sorkin, "Why are people turning off our alarms?," *Journal of the Acoustical Society of America*, vol. 83, pp. 1107-1108, 1988.

[5] J. M. Fernström and C. McNamara, "After Direct Manipulation - Direct Sonification," presented at ICAD '98, Glasgow, Scotland, 1998.

[6] M. Fernström, "Reflections on sonic browsing: Comments on Fernström and McNamara, ICAD 1998," *ACM Transaction on Applied Perception*, vol. 2, pp. 500-504, 2005.

[7] J. A. Ballas, M. J. Sliwinsky, and J. P. Harding, "Uncertainty and response time in identifying non-speech sounds," *Acoustical Society of America*, vol. 79, 1986.

[8] M. Fernström, E. Brazil, and L. Bannon, "HCI Design and Interactive Sonification for Fingers and Ears," *IEEE Multimedia*, vol. 12, pp. 36-44, 2005.

[9] A. Oulasvirta, E. Kurvinen, and T. Kankainen, "Understanding contexts by being there: case studies in bodystorming," *Personal Ubiquitous Computing*, vol. 7, pp. 125-134, 2003.

[10] T. Winkler, "Audience Participation and Response in Movement-Sensing Installations," presented at International Computer Music Conference ICMC2000, Berlin, Germany, 2000.

[11] A. S. Bregman, *Auditory Scene Analysis: The Perceptual Organization of Sound*. Cambridge, MA, USA: M.I.T. Press, 1990.

[12] W. W. Gaver, "Affordances for interaction: The social is material for design.," *Ecological Psychology*, vol. 8, pp. 111-129, 1996.

[13] J. J. Gibson, *The Ecological Approach to Visual Perception*, 10 (1986) ed. Hillsdale, NJ, USA: Lawrence Erlbaum Associates Inc. Publishers, 1979.

[14] D. A. Norman, *The Psychology of Everyday Things*. NY, USA: Basic Books Inc., 1988.

[15] T. H. Nelson, "The Right Way to Think About Software Design," in *The Art of Human-Computer Interface Design*, B. Laurel, Ed. Reading, Massachusetts, USA: Addison-Wesley Publishing, 1990.