EXPLORING AMBIENT SONIFICATION OF WATER TOXICITY

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ABSTRACT

We explored the possibility of using ambient auditory display in the context of sonification of water toxicity. We looked at the existing work procedures carried out in an aquatic toxicity laboratory and developed a design that could replace or complement existing periodic visual monitoring of samples. The design was further developed as an art-science installation in a public exhibition in the Science Gallery in Dublin, Ireland, where visitors experienced through hearing the life and death of small aquatic crustaceans in real-time.

1. INTRODUCTION

With the proliferation of recent water contaminations in Ireland [1], we set out to explore possibilities to contribute to the public awareness of the underlying problems as well as to engage with environmental scientists handling the day to day monitoring of water quality in Ireland. The project reported in this paper is mainly situated in the artistic domain, but with a direct connection and potential for applications in science using auditory display.

There have been several interesting contributions in the ICAD community that have inspired our work. Cohen's *Out to Lunch* system may be one of the first to create and ambient auditory display [2][3] and Gaver, Smith and O'Shea's ARKola simulation also had ambient aspects [4].

Bly's work on multivariate mappings and auditory display showed clear possibilities for scientific use [5]. Paine's *Reeds* installation had both artistic and scientific dimensions and was situated in a public space [6]. Sturm's sonification of ocean buoys can be listened to both from a musical as well as scientific perspective [7][8]. In previous work we, the authors, have also explored auditory display at the boundary between art and science [9][10][11].

2. BACKGROUND

After an open call for contributions from the Science Gallery in Dublin in Ireland under the exhibition title *Infectious*, we submitted a proposal for collaboration with Enterprise Ireland's Aquatic Toxicity Laboratory (ATL) in Shannon, Co. Clare. Over a couple of months, we visited the laboratory in Shannon and learned about some of their methods for measuring and monitoring the toxicity of water samples. One of the main methods used is to use living organisms, *Daphnia magna* (hereafter called *Daphnia*). They are small, planktonic crustaceans, between 0.2 and 5 mm in size. *Daphnia* are members of the order *Cladocera*, and are one of several small aquatic crustaceans commonly called water fleas because of their saltatory swimming style. They live in various aquatic environments ranging from freshwater lakes to ponds, streams and rivers. These tiny crustaceans are very sensitive to their environment and are also used in laboratory research for analysis of water and soil toxicity. Because *Daphnia* may be used to test the effects of toxins on an ecosystem, this makes *Daphnia* an indicator species, particularly useful because of its short lifespan (typically 1 to 3 months) and parthenogenetically reproductive capabilities (they become mature in about 2 weeks and can then produce offspring every ten days).

To test a sample for toxicity, varying amounts of the sample is mixed with amounts of pure water with a small *Daphnia* population. The population is then observed for some time to check the mortality rate of the *Daphnia*. The toxicity is defined as Lethal Concentration for 50% mortality (LC50).

In addition to the testing, the ATL has to breed and maintain a healthy population of *Daphnia* under pure conditions. The breeding and feeding has to be monitored to assure that there always is sufficient supply of *Daphnia* available.

Currently, the laboratory staff in Shannon monitor samples by periodically visually inspecting beakers and counting the number of live *Daphnia,* see Figure 1.

3. CONCEPT

In collaboration with the laboratory staff at ATL, we proposed to use a simple web camera to monitor movement of *Daphnia* magna in a beaker and to sonify the movement of the living *Daphnia* as an ambient auditory display. The term ambient here refers to the ideas of Mark Weiser and John Seely Brown, as outlined in their paper on Calm Tehnology [12]. The advantage with such a display would be that the staff wouldn't have to do so many visual inspections and counts, and instead hearing in the periphery of their awareness when the *Daphnia* population deteriorated to a level when it would require more frequent and detailed monitoring. The same technique could also be used for monitoring the breeding of *Daphnia*.

We suggested using a simple mapping between the *Daphnia* movement and audio. The field of view of the web camera would be mapped to musical notes with the vertical mapped to pitch and the horizontal to note duration. This was

an intuitive choice, largely based on the saltatory movement of *Daphnia* looking like an aquatic ballet. We could then use different timbres to help the staff segregate between different samples in progress at the same time.

This proposal for an exhibit at the Science Gallery in Dublin was approved and we were commissioned to develop this concept into an installation in a public gallery.

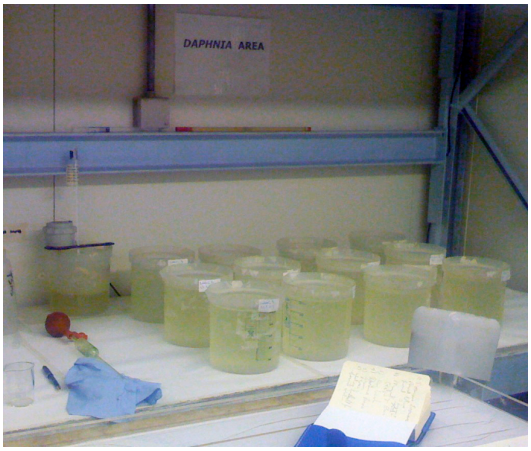

Figure 1: Water toxicity testing at the Aquatic Toxicity Laboratory in Shannon, Co. Clare.

4. DESIGN

For the public exhibition we decided to use four containers with living *Daphnia*. A web camera connected to an Apple iMac computer running *Pure Data* with the *Graphics Environment for Multimedia* (PD/GEM) monitored each container, see Figure 2 and Figure 3. We designed and implemented a PD-patch for capturing the video and using blob detection to track the movement of *Daphnia*. The movement was then mapped pitch pitch along the vertical axis and note duration along the horizontal axis. For timbre, we chose a synthetic human singing voice and the four containers mapped to the ranges of bass, tenor, alto and soprano. As each container typically had ten living *Daphnia*, this resulted in a complex choral polyphony. Our metaphor behind this choice was 'the budgie in the coal mine', i.e. alluding to that when the *Daphnia* die the singing stops and when humans notice this, our own end may be nigh unless we take immediate action.

As we could not use real and potentially toxic samples in the exhibition, we reverted to using a substance used by the ATL for calibration purposes, a solution of Lipopoly-saccharides (LPS). When LPS was added to a container, a proportion of the *Daphnia* population died. This was directly reflected in the ambient auditory display as the number of notes per minute and range of pitches used were reduced and eventually stopped.

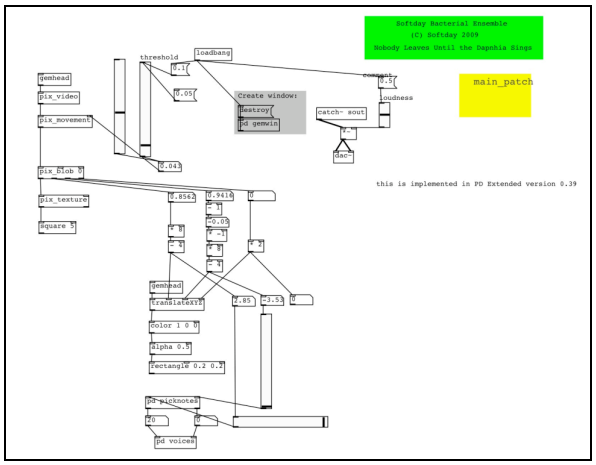

Figure 2: Main PD/GEM patch

4.1. Installation

For the physical installation we were inspired by the look and feel of the ATL in Shannon. We borrowed lab tables, glassware and various props and configured the installation into four stations, each with its own Petri-dish with *Daphnia*, video camera and computer with our specially designed PD/GEM-patches. We gave our exhibit the working title "Nobody leaves 'til the Daphnia Sing", and installed the equipment on the first floor of the Science Gallery in Dublin. See Figure 4.

Figure 3: Web camera focused on a Petri-dish with sample of *Daphnia*.

Figure 4: Installation with four stations: bass, tenor, alto and soprano.

4.2. Score

For the opening event in the gallery, we also created a live human performance element. We received a spreadsheet with data from actual water samples around Ireland that covered a period of 18 years. We normalized the data and converted it into MIDI and then further processed into a musical score, see Figure 5. This score was given to our *Softday Bacterial Ensemble*, four young musicians from the B.Sc. Programme in Music, Media and Performance Technology in the Department of Computer Science and Information Systems at the University of Limerick. The score provided a framework for improvisation, as the live performance was to be in conjunction with the sounds coming from the live movements of *Daphnia*. The tonality between the score and our computer vision to sound algorithms was aligned to allow for an interesting and unique musical experience.

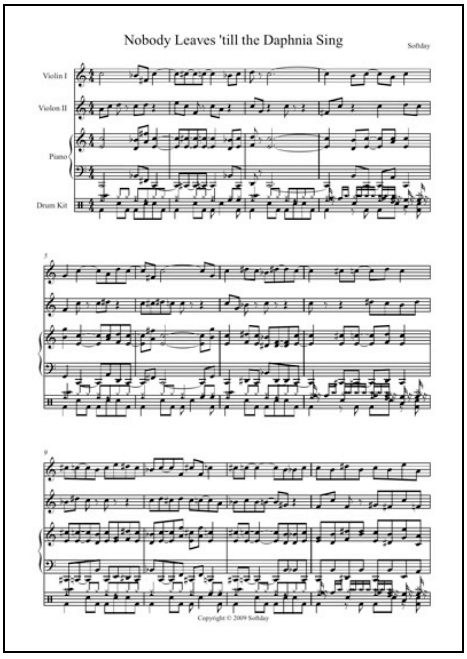

Figure 5: The first page of the musical score.

5. EXHIBITION

On Saturday the 18th of April 2009, we premiered "Nobody leaves 'til the Daphnia sing", as a live performance of a unique multimedia sound art work, as part of the Infectious exhibition at the Science Gallery, Trinity College, Dublin.

The computer generated music composition that the *Softday Bacterial Ensemble* performed was constructed utilizing a variety of *Daphnia* data sources. This composition formed the basis for an improvisation between the human musicians and the ambient auditory display of *Daphnia* populations.

After the opening event, the installation with the ambient auditory display was open to the public until the 17th of July 2009. Over the three months, approximately 45,000 visitors experienced the exhibition.

We didn't carry out any formal scientific evaluation of our exhibit, but we received ample media coverage and communications from visitors via email and phone calls. The intense general interest may also have been due to that the outbreak of A/H1N1 coincided with the exhibition – titled Infectious.

6. DISCUSSION

Based on what exhibition visitors and staff informally told us, and from discussions with staff at ATL in Shannon, it is clear that this kind of ambient auditory display can be used for a peripheral awareness about the health of multiple small populations of *Daphnia*.

Originally we had planned to use a separate sound reinforcement system in the Science Gallery, but during our initial testing on-site we found that the built-in loudspeakers in the Apple iMac computers were fully sufficient for this particular exhibition environment.

While the use of synthesized human voices helped to emphasize the relation between the health of *Daphnia* and humans, if this kind of system would be further developed for used in laboratory contexts similar to ATL in Shannon, other timbres are likely to have to be explored for improving segregation between auditory streams. It is also likely that systems like this cannot be applied in all laboratories, as other kinds of equipment may be using auditory display needing more urgent attention. Still, it is interesting to note that segregation between synthetic voices was quite good, probably due to the physical constraints of a circular container being viewed by a web camera with a rectangular field of vision. This resulted in the probability being higher for mid-register and medium duration notes being generated more often then very low or high-pitched notes. The mappings in the extreme corners of the camera's view could never be triggered, see Figure 6.

It is unfortunately not possible to try this system in the ATL in reality, as their certification and routines are based on existing international conventions regarding the procedures for measuring LC50, i.e. using periodic visual monitoring. To introduce new procedures would require approval of a separate and purely technical and scientific project.

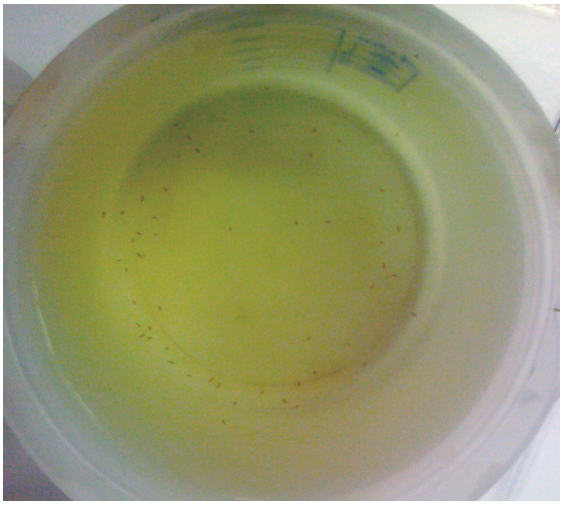

Figure 6: Web camera view of daphnia in container.

7. Technical Details

Our PD/GEM patches can be downloaded from www.idc.ul.ie/mikael/hack/Softday_Bacterial_Ensemble.zip

Video of the performance and more information about the exhibition and be found at www.softday.ie/nlutds/

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