Tüb - Interactive Sonification of Water Waves

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ABSTRACT

Scanned synthesis is a method for sonifying slowly-changing systems. It has been used, for example, to sonify computer models of mass-spring systems [3], and has also been applied to still images [4]. We present a method for live video raster image scanning using pd and GEM that combines the image-scanning of the latter approach with the real-time interactivity of the former approach. Also presented here is an application of this method to the sonification of water waves. The resulting installation, entitled the "Tüb", allows people to interact directly with water, and in so doing influence the sound being produced.

Keywords

Scanned synthesis, sonification, installation, camera, water, tub

1. INTRODUCTION

We approached this project with the idea of using water as a medium for human-computer interaction. The complexity of the patterns that arise when the water is perturbed lend interest and richness to the resulting interaction. That the interaction is enjoyable is evidenced by the fact that people play in water from young ages. It was our idea to translate this interaction into a sonic / musical result.

In investigating methods for this translation, we found that scanned synthesis provided the detail necessary to capture the subtleties of the interaction.

2. SCANNED SYNTHESIS

Scanned synthesis was developed by Bill Verplank, Rob Shaw and Max Mathews as a technique to sonify vibrations of dynamic systems that are too low to be heard directly [3]. The shape of a vibrating object is scanned along a closed path to create a dynamic wavetable which can be played back at variable rate. We applied this method to the sonification of the surface waves in a tub. A webcam is placed over the tub and circular paths through the image frames are scanned to update the wavetable. The brightness values of the pixels are reinterpreted as instantaneous amplitude values. A similar technique has been used [4] to sonify still images, by scanning images line by line.

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2.1 Processing of Raw Webcam Output

Waves in the water are clearly visible in the images taken by the webcam. By illuminating the water from above, patterns of shadows are created on the bottom of the tub. Yet, some processing of the data is necessary for sonification. The absolute brightness has to be filtered out by a DC blocking filter, since we are only interested in the fluctuations caused by waves in the water. Additionally, environmental reflections and shadows on the surface, such as those caused by people, should not influence the output waveform. It is not sufficient to simply subtract a calibration image from the webcam output, since the light situation changes (for example when people approach or leave the vicinity of the tub). We designed another low frequency blocking filter, which does not operate on the output waveform but on the whole wavetable as a vector.

The filter has the form:

$$y[n,m] = x[n,m] - x[n-1,m] + \alpha y[n-1,m]$$

where $x[n,m]$ are the incoming scanned wavetables with n being the nth frame and m being the mth scanned sample (the index into the wavetable). α is between 0 and 1 and determines the cutoff of the high-pass filter.

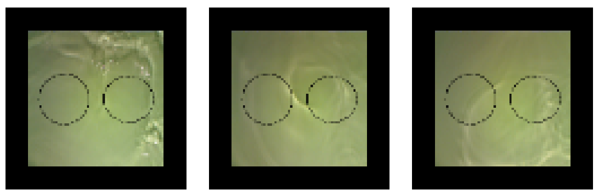

Figure 1: Application windows showing scan paths superimposed on raw webcam output

3. THE INSTALLATION TÜB

An installation, Tüb, was constructed to explore scanned synthesis. The installation was centered around the BeagleBoard [2] embedded system running Ubuntu Linux. A laptop was connected to initialize and shutdown the installation and to display a GEM window. However, a lightweight X server could be run directly on the BeagleBoard, allowing the installation to be completely self-contained.

3.1 Software and Sound Design

Source code for the software used in the installation may be found here: `https://github.com/mikewils/Tuub`.

Apart from the sound generated directly by the scanned synthesis, an additional aspect of the sound design for this installation was the concurrent playback of samples of tuned plastic tubes being struck. The percussive nature of this sound counterbalanced the more continuous nature of the scanned synthesis, resulting in a more pleasing musical texture. The frequency and intensity of these percussive strikes were modulated by the amount of activity in the water, as represented by the summed amplitude envelopes of the scanned waveforms.

Figure 2: Top-down view of the installation

3.2 Hardware

A circular tub was chosen because it allows for greater variation in the curvature of the reflected waves. For instance, as a limiting case, if one creates a circular wave exactly halfway between the center of the circle and its edge, the reflection off of the side of the tub is a flat wave.

Construction of the rest of the installation was done via standard off-the-shelf components: a webcam, computer speakers, power strip, adjustable lamp arm and lamp, and an inexpensive table, towel racks and towels[1]. Colorful plastic tubes, sampled strikes of which were included in the sound design, were available to be used to excite the water. Their presence also added an element of playfulness to the installation, appropriate to the medium of water.

4. FUTURE WORK

One possible future extension of this project would be to project the video from the webcam (with the scanning ellipses superimposed) onto a large screen nearby or behind the installation. Even in an installation setting, where people would have the chance to interact directly with the tub, a video projection would allow others to look on and to understand the relationship between the waves created in the water and the sounds produced.

In terms of developing the instrument proper, a good avenue of exploration would be to create more ellipses along which the image is scanned. With the two ellipses we created, one on either side of the tub, the physical locations of the waves became somewhat audible and thereby part of the interaction. (The two circles were set to different scan speeds, and therefore different pitches, and also the outputs of the circles were mapped to separate speakers.)

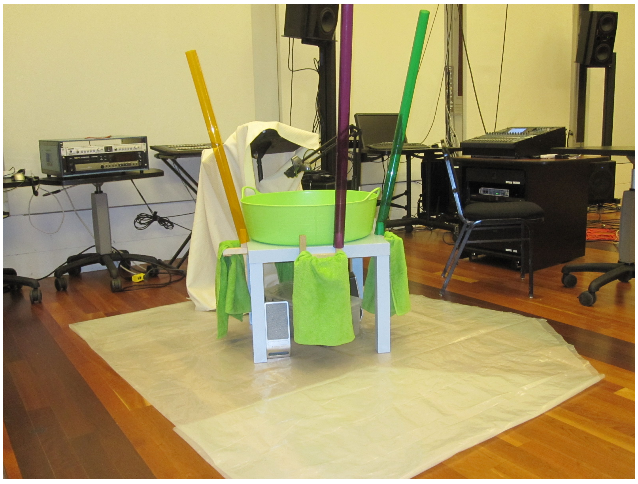

Figure 3: Tüb installed on the CCRMA stage

However, with more, smaller circles spread over the area of the image, this spatialization could be extended, perhaps in addition by mapping the output to more than two speakers and creating a different spatial location for each of the circles' outputs. Expressive and interactive possibilities would also be enhanced by giving each new circle a different scan speed/pitch.

5. CONCLUSIONS

The application of scanned synthesis to real-time image processing has shown to be a viable and fruitful method for sound generation. Scanned synthesis is a computationally inexpensive, yet very expressive, method which makes it well-suited for implementation on embedded platforms. The self-contained nature of the hardware and software platform make it appropriate for a fixed installation. Our Tüb provided an example of such an installation using the natural and expressive medium of water, and demonstrated the potential of applying scanned synthesis to a human-computer interaction through this medium.

6. ACKNOWLEDGMENTS

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