GrainPlane: Intuitive Tactile Interface for Granular Synthesis

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ABSTRACT

GrainPlane is a prototype design build of a highly intuitive tactile interface for granular synthesis. The granular synthesis software engine's parameters are modulated by the manipulation of small, physical objects. The sound of the grains as they interact with a resonant surface and with each other is analyzed, from which audio grain triggering, grain duration, amplitude, and sample position can be calculated. This provides a flexible platform upon which the musician can easily and intuitively modulate the granular synthesis in real time through a direct link between the tactile and auditory manipulation of the grains.

Keywords

Granular synthesis, haptic feedback, multisensory

1. INTRODUCTION

Our interaction with everyday objects is incredibly multisensory. Many day to day experiences, often forgotten, are full of a vast amount of auditory and haptic information. In shaking a salt shaker, we feel the heft of the salt crystals shifting inside, we see the grains spilling out, and sometimes we can hear the pitter patter of the crystals hitting our plates. The actual quantity of salt applied (and the rate of its application) is embedded in all of these sensory phenomena. Despite an intuitive grasp of these parameters however, the travel and interaction of each individual grain of salt is wildly unpredictable. The grains each scatter and bounce; a great complexity arises from simple physical laws. This behavior is common to all classes of small objects, as well as distinctly unique to each type of object; while salt scatters, coins may jangle, marbles roll, and glass beads will bounce. This paper attempts to harness the link between this everyday, intuitive, multisensory control and the highly complex series of events that follows to build an instrument that engages both musician and audience through accessible, multisensory metaphor.

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In this paper, a methodology originally presented by Essl and O'Modhrain [2] for linking the behavior of physical grains and that of sound objects is built upon and extended, presenting a novel design for an instrument with highly expressive control of granular synthesis. Not only are the grain events and basic amplitudes captured, but a spatial control element is introduced as well, adding new dimension and flexibility to the interface. In addition, a new design and build for a highly playable instrument, suited for real time performance and improvisation, is presented.

2. BACKGROUND

Granular synthesis has long been a focus of research and application in the computer music world. In brief, it is a musical synthesis technique that chooses small segments of audio from a larger source (in this paper a pre-recorded input sound file is used). These pieces are called audio grains. Often many grains are layered over each other to create a rich musical texture. There are a number of parameters that can be used to control the characteristics of each grain, including but not limited to grain density, length, playback speed, amplitude, and sample position. The literature on this topic is too extensive to be reviewed completely here; the interested reader is forwarded to Roads' excellent treatment on the subject [4] [5].

There has been some amount of previous work investigating methods for real time control of granular synthesis. [2] [3] While there has been much exploration of various granular controllers with some haptic element, only a few have explored the direct link between objects' physical granularity and the granular synthesis model. Most notably [2] proposes a system in which the granular object metaphor is used to translate the haptic sensation of physical object manipulation into control over a granular synthesis engine. However, this system lacks certain qualities which allow it to be truly expressive in a performance context which are described in the following section.

3. DESIGN GOALS

While previous controllers in this design paradigm successfully couple the sound and feel of granular events [2], they suffer from several limiting factors that prevent rich expressive control.

Principally, there is a disconnect in the audience-performer loop; while the performer receives haptic feedback the system is relatively opaque to the audience. As described by Gadd and Fels [3], transparency in the instrument metaphor is paramount not only for the musician but also for the au-

Figure 1: Piezo passive transducer

dience. This paper aims to introduce an interface based on metaphors that are both haptically and visually engaging. The design also aims to accommodate modes of interaction that are rooted in daily experience in order to further increase the level of transparency in the instrument metaphor.

Pragmatically, this paper also aims to introduce a design that can easily accommodate changing materials and quantities. While [3] uses the well-adapted pouring metaphor to control grain rate and quantity, it lacks the direct link and interaction with physical grains. Meanwhile [2] provides no convenient way of modulating the material or quantity used mid performance. This paper's design combines the two paradigms and focuses on the flow of granular objects, on the tumbling streams of complexity that arise when grains are collectively dropped or rolled onto a surface.

Finally, no previous controllers for haptic real time granular synthesis utilize an important paramater; the spatially distributed nature of the granular events. This paper aims to introduce a design that incorporates these elements in an affordable and ergonomic package.

4. CONTROLLER DESIGN

The GrainPlane is designed to allow for both manipulation of objects on, as well as the dropping or pouring of objects onto its surface.

The design consists of a sheet metal plate encased in a wooden enclosure. Attached to the back plate are four passively powered contact pickup microphones. These microphones (see Fig. 1), when attached to the plate, will pick up audio information in a very limited range, ie only those events occurring directly on the plate. These typically include the sound of grains dropping onto and hitting the metal surface in addition to the sound of grains sliding or rolling on the same surface. These sounds are then used to control the granular synthesis engine.

The planar surface allows for some simple actions from day to day life to take on a new meaning. These actions retain their elements of tactile and visual feedback, but produce a novel and interesting auditory feedback that is nevertheless linked to the tactile and visual sensations of the performer.

Figure 2: GrainPlane Overview

Figure 3: GrainPlane Detail

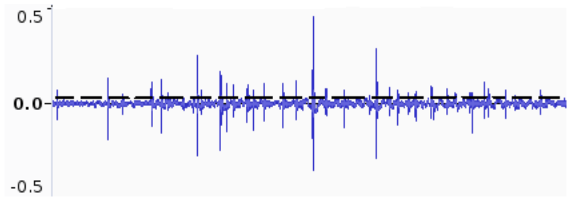

Figure 4: Rice dropping events with thresholding shown

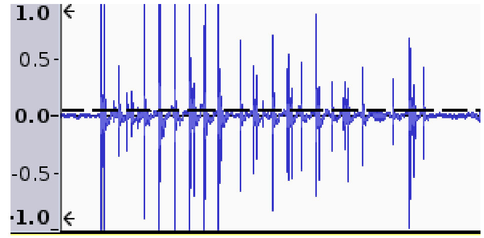

Figure 5: Kidney bean dropping events with thresholding shown

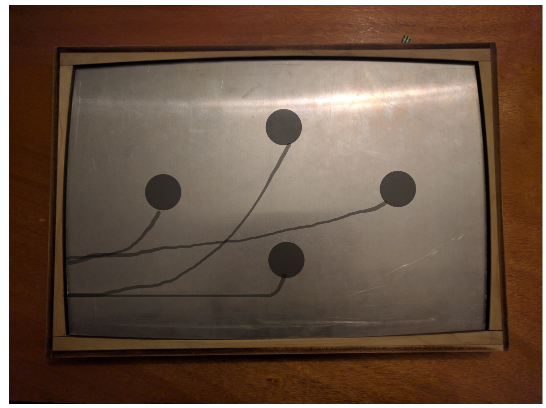

Figure 6: GrainPlane Mic Placement Detail

Importantly, the planar surface also allows for the manipulation of any collection of small objects for any amount of time. By propping the plane at an angle, the dropped grains naturally clear the surface making way for the next granular gesture. In this way, a constant stream of small grains is possible, as well as the immediate ability to rapidly change the granular material used. An alternative method of play is to hold the plane flat, for interaction with spinning coins or rolling objects. For more examples and applications see section 7.

The audio connection is maintained by a pair of 3.5mm stereo audio cables which can be disconnected from the wooden casing for portability.

5. AUDIO DRIVEN GRANULAR SYNTHESIS

From the four audio streams,

1. Granular events are detected
2. Event amplitude is determined
3. Event spatial position is determined

This design is bound by the real time nature of the event. The delay between the perception of a physical granular event and an auditory one must be low; processing is limited by the bounds of human perception (0.05s).

5.1 Event Detection

A very basic algorithm is used for event detection, implemented in Max/MSP's gen feature and roughly described by [2]. Incoming audio samples are examined one by one in real time.: when an absolute sample value larger than some threshold is found, an event has thus been detected. For the next r samples, a new state is entered in which new events cannot be detected. This minimizes the chance for a false retriggering caused by the decaying oscillations of the initial signal. This value r is called the *retriggering delay*. It is important to choose an appropriate value for r. A low value will increase the odds of a false retriggering, while a higher value will increase the latency of auditory feedback. This design uses a value of 256 samples, which at an audio rate of 44.1kHz creates a 5ms delay which is well below human perceptibility.

5.2 Event Amplitude

During the retriggering delay period, the signal's root mean square (RMS) value is calculated and used as an indication of the grain's amplitude. Previous work make certain assumptions about signal character; chiefly that of decaying envelope events, and thusly are able to simply take the first gradient amplitude as a reliable measure of grain strength [2]. However, these assumptions do not necessarily hold under the GrainPlane's design paradigm, as grains may roll continuously over the surface. Hence, a more general and flexible strength computation is required. The implementation is eased by the design of thresholding algorithm; the value can simply be calculated during the retriggering delay.

The careful reader may note that under this scheme, spurious RMS values could arise if a second physical grain event occurs within the retrigger delay window of a first. This poses no major problem. In effect, the strength of the earlier grain event will be summed with the second. It is important to remember that this window is shorter than the human limit of perception, and thus even the natural sound will also be perceived as a single, stronger event. rather than two individual ones.

5.3 Spatial Positioning

The spatial positioning algorithm was designed under the working hypothesis that the strength of the audio signal was inversely proportional to the distance of the grain event from the microphone.

The four microphones are placed in a 2-axis configuration, thus allowing two axes of spatialization information. A moving window RMS value is calculated for each of the left, right, top, and bottom channels FIGURE and the difference is taken between each channel pairing. From this a left/right offset value and a top/bottom offset value can be obtained, giving a clue to the spatial location of the grain event.

This approach can quickly and reliably determine the *center of mass* of grain activity. This comes with some drawbacks however; it is most important to note that this approach cannot demultiplex concurrently occuring grain activities. In other words, two streams of grains at either end of the GrainPlane but not in the middle will produce the same behavior as a single stream in the center.

5.4 Granular Synthesis Engine

The granular synthesis engine is also custom implemented in Max/MSP and is integrated tightly with the analysis components described above. Its design is inspired by Ross Bencina's treatment of granular implementation [1]. The software is modularly designed, such that each channel of control information can be mapped to any synthesis parameter. All of the synthesis parameters are controlled in the audio domain using Max/MSP's gen . This allows us to modulate the synthesis parameters in real time at audio rate. These parameter mappings are discussed in the following section.

6. GRANULAR PARAMETER MAPPING

Given this rich methodology for granular synthesis parameter control, the final remaining question is that of how to assign these mappings to control the granular synthesis. While one is relatively obvious (physical grain event triggers an audio grain event), the remaining parameters are not. A performer can modulate the grain amplitude quite dramatically in the midst of performance through choice of grain material as well as the height from which grains are dropped. Spatial positioning on the plane is another parameter to be considered. While of course these control channels can in theory be arbitrarily mapped to any parameter of the synthesis engine, it is important to choose mappings that maximize ease of musical expression and metaphorical transparency

GrainPlane chooses to map grain strength to grain *duration*, rather than volume. In this way, differing grain materials produce significantly different sonic textures that associate much more closely to their physical properties. Smaller, lighter grains thus trigger shorter grains, creating a brittle, delicate sound, while larger grains trigger longer audio segments. Grain volume is instead mapped to the top-bottom axis of the spatial parametrization. In this way the performer has independent control of volume and grain strength.

The left-right spatial parameter is mapped to sample position. Each grain, when triggered, chooses a starting point from the input audio sample relative to the center of mass on the left-right axis as described above. In this way the performer can scrub across the sample forward and backward by simply streaming or rolling grains across the plane.

6.1 Other possibilities

By no means are the mappings described above the only method by which the synthesis engine can or should be controlled. Perhaps the player may wish to be able to automatically rewire the mappings mid performance. Some other mapping possibilities are described below.

- Grain Material/Weight: This parameter is most suited to a timbral or textural element. Although volume or grain duration are excellent candidates, it may be interesting to assign this parameter instead to *sample position*. In this way the performer can determine herself the textural qualities that she may desire. Different grain materials could thus trigger different portions of a specially designed input sample with discrete or continuous changes in grain timbre.

- Spatial axes: This parameter is quite flexible and can be intuitively mapped to almost any synthesis parameter. One possibility that was ultimately rejected in the prototype build of GrainPlane was a pitchbend, or playback speed mapping. While exaggerated changes in pitch detract from the gestalt texture created by the engine, more subtle shifts could have a rich expressive use in performance.

- Spectral analysis: [2] uses a basic zero-crossing count spectral analysis to extract information about the material being used. It was hypothesized that GrainPlane event zero crossing frequencies may not give much unique information, in the sense that the spectral content of the reverberations of the sheet metal would stay relatively similar between different materials used. However, it could still be fruitful to explore the spectral domain, perhaps with a more sophisticated FFT based spectral analysis (spectral centroid, etc.) on the grain event level.

7. EXAMPLES AND APPLICATIONS

Although the GrainPlane was initially designed for use as a slightly inclined surface upon which to drop things, its form allows for a multitude of different methods of interfacing, each with its own character. The grain detection and characterization algorithm allows for extremely sensitive, low latency feedback, establishing a strong and transparent link between the haptic, visual, and auditory dimensions of the instrument. Most compelling are those actions that mimic or reference everyday experiences, drawing attention to their their rich multisensory nature.

- The salt shaker metaphor was explored in the introduction and is a viable and compelling way to play the GrainPlane. The chaotic scattering of the salt crystals produces a similarly chaotic storm of granular events. The performer can shake, for discrete bursts of sound, or pour evenly for a more continuous texture. The link between salt, plate, and the sound produced is highly transparent for both the performer and audience.

- Sand can be pinched in the fingers and let go, similarly to how golfers let blades of grass test the wind. The texture produced is similar to the salt shaker, though the performer has more fine grained control over the rate of grain flow.

- Glass beads, lead balls, marbles, or other small rounded objects can roll freely inside the plane. The performer can pick up the GrainPlane and tilt it to shift the objects inside, controlling the rate of movement (and thus the grain triggering density) as well as navigating the varying spatial parameters.

- Coins or similarly shaped plastic disks can be spun on the flat surface of the GrainPlane, creating their own musical gesture.

8. CONCLUSION

This paper proposed an ergonomic design and implementation of low cost and great playability. The interface invites experimentation and facilitates full exploration of many granular synthesis parameters in a real time performance setting, some of which have no t been combined in such a flexible way before. While this is not the first controller to maintain the fine grained temporal structure of granular events to control granular synthesis while maintaining the original haptic feedback elements of granular manipulation, it is the first to incorporate spatial information. It also does so in a package that is intuitively playable in the sense that it maintains a transparent link between the granular action and the granular sound for both the audience and performer.

The controller was initially designed for a MetaMuse [3] pouring interaction but is flexible enough to support a wide host of playing methods, many of which mimic or reference everyday experiences. This is one of the principle ways in which the GrainPlane maintains its transparent link; by drawing on shared knowledge experience common to both the audience members and the performer.

9. ACKNOWLEDGEMENTS

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