A Spherical Tape Topology for Non-linear Audio Looping

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Abstract

There have been many physical design formats used in the field of audio recording. As audio has an inherently a linear, time-based structure, these have generally followed logical layouts such as tape, or grooved records and cylinders. This project explores magnetic recording technology and digital analogues for recording and playback that are instead on spherical topology. This instrument expands the concept of the audio loop through a more tangible and randomized approach than traditional record playback techniques of tape, while maintaining a familiarity with historic techniques of audio looping and scrubbing. Through it, one can not only create linear time-loops but blends between different times of the recording non-sequentially. The size and mass of the spheres enhances the performative elements through the physics of inertia. The movement possibilities allow for non-linear circles, circuits, spirals and other patterns of sound not traditionally possible through linear tape or digital loop, including accelerations and decelerations – akin to a turntable, but with greater freedom of direction, thus offering surreal record/playback possibilities.

Keywords

loops, playback, spheres, non-linearity

1 Introduction

1.1 History and Related Work

Not long after the development of magnetic tape, musicians began experimenting with its unique characteristics to manipulate recorded sound into novel musical composition. Indeed, the novel abilities this medium provided allowed not only the preservation of a sound, but also one that could be erased, rewritten, and variable overwritten. In tandem with this *sounding paper's* ability to be spooled, spliced, and looped, magnetic recording opened wide new avenues for experimentation.[9] The opportunities to splice sounds into new sequences, loops of repeating audio expanded the simple temporal manipulations of forward/reverse/speed available to prior fixed media through experimentations featured prominently in sound collages such as those produced by the *Groupe de Recherches de Musique Concrète* (GRMC).[7] In such experiments the loops themselves became used as recurrent compositional elements. With the addition, or manipulation of the play, record and erase heads these loops could be further expanded to produce a variety of delay effects.[3] Over time, further practices explored more surreal means to read the recorded sounds, most notably as one of the explorations of Nam Jun Paik's "`Random Access Information`"[12]. In this work, a series of tape strips were mounted on a wall in multiply intersecting patterns. A floating tape play head could then read across the recording in a number of directions, creating non-linear, (or multilinear) dissociative playback. Such experiments in magnetic media were not limited to tape. More recent examples can be seen in works such as those by Wouter van Veldhoven[11], exploring spiraling audio recordings on magnetic plater, akin to the format of a record player, but providing the ability to scratch laterally in addition to the rotational axis. Meanwhile, expansions continue in the performative possibilities of the original tape medium as apparent in works such as the Tape Bowing in Ei Wada's "`Open Reel Ensemble`"[16] or creations such as the Parasampling multi-user device.[5] Within the digital realm, loops have taken on their own forms, with a wide array of tools to move through, adjust and rearrange the audio. These techniques expand from simple repetitions, delays and feedback loops to include the foundations of wavetable[14] and granular[15] synthesis. These histories, however, have generally kept to topologies that can easily be unwrapped into a linear or rectangular form. From recording cylinders, to platters, to tape, to wavetables we find the same thing. As has plagued cartographers since the recognition of the spherical world, the means to stretch a sphere to a rectangular format is plagued with distortional anomalies. Even today's mapping software frequently relies on multiple mapping strategies at different zoom levels, relying on the sphere at global scales and shifting to a grid at local ones.[4] It is thus that recording upon a spherical medium could produce the ability to create novel intersecting and spiraling audio recording and playback possibilities.

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1.2 Intended Outcomes

This project is an exploration of the possibilities of recording and playback on a spherical interface. The original intent was to create a spherical, magnetic element that could be manually manipulated with one or more recording and playback heads to produce novel sound and give the musician a new means to directly interact with the sound loops being performed. Through the non-planar topology and the interactive potentials it represents, this work seeks to explore how the movement and sounds interact and expand from typical tape methodologies. Among other elements is the ability to create multiple loops simultaneously, but that are accessed through non-linear temporalities.

2 Development

The production of the interface went through several stages. While, as above, the intent was to produce a magnetically based analogue recording and playback device, several difficulties resulted in a reconfiguration to a digital interface with similar, although not identical, function, to the planned version - with certain tonal motions unavailable, but some additional functionality thus opened.

2.1 Analog Recording on Magnetic Medium

2.1.1 Testing Magnetic Media. In researching the production of the coating used for magnetic tape, the most common early materials were forms of iron oxide, which later gave way to cobalt-based alloys for greater fidelity. Iron oxide is readily available as iron(III) oxide (Fe_2O_3) and iron(II, III) oxide (Fe_3O_4). Additional elements included in the emulsion include adhesive and smoothing elements[13], but the primary element of iron oxide or rust has been shown sufficient merely by fine powdering and applying to common stick tape.[6] Chromium Dioxide ($Cr0_2$) is more commonly used in modern tape it also carries with it greater risk.[2] The two iron oxides are not only safe, but also common forms of red and black pigment in paint. In testing it became clear that, at least with the tape heads in use, the greater the Fe_3O_4 content, the better the audio fidelity. The primary additional component to fidelity was producing an appropriate bias signal, for which I eventually used off-the-shelf pre-amps with bias generators intended for standard tape decks such as the TA7668 "`magnetic tape head audio preamplifier board`".

2.1.2 Hardware. Arcade trackballs were always the intended format for the device. First, at 80mm they can be of a size much larger than those designed for computer interface (34-55mm)[1]. This provides greater surface for recording, space for tape head placement and capacity to interact with them. Their greater mass further allows an inertial element to become a part of the interaction. These models are robustly built to handle abuse, thus if a performer wants to aggressively use the device to use the inertia to continue spinning for a moment, they need not be concerned with that they damage the device.

2.1.3 Assembly and Results of the Analog Revision. The first hurdle in the conversion of the trackballs into magnetic recording media was determining a proper technique to evenly coat them with oxide paint. The slow but simple process of continuously rolling each sphere in a small pool of paint on fine cloth until it had received an even coat and was no longer tacky to the touch was followed by brief baking at low temperate on silk layered over thicker fabric provided a surprising high quality and even coverage. Sanding with progressing finer grit sandpaper and emery cloth sufficiently eliminated remaining imperfections if used gently. Even with this smooth finish, the mild imperfections of thickness created difficulties in developing a mount for the tape heads that provided consistent and even contact, without dramatically dampening inertia, and with sufficient rigidity that it would not shift with the sphere's variable directions of travel. This problem was superseded, however, by issues of grounding. While there were successes in live recording and reproduction, the static charges accumulated by the movement of the sphere beneath produced irregular loud pops presumed to be voltage arcs into the audio head. As yet, I have been unable to determine a grounding configuration to mitigate this. One consideration may be looking into something similar to the smoothing coat used on tape in hopes of diminishing charge build-up, or antistatic brush before the tape heads.

2.2 Digital Development

The above limited successes and continuing difficulties led to the decision to rework the interface as a digitally based device. As the trackball hardware was pre-fitted with rotary encoders to provide x and y digital output, this seemed a more promising route to the goal.

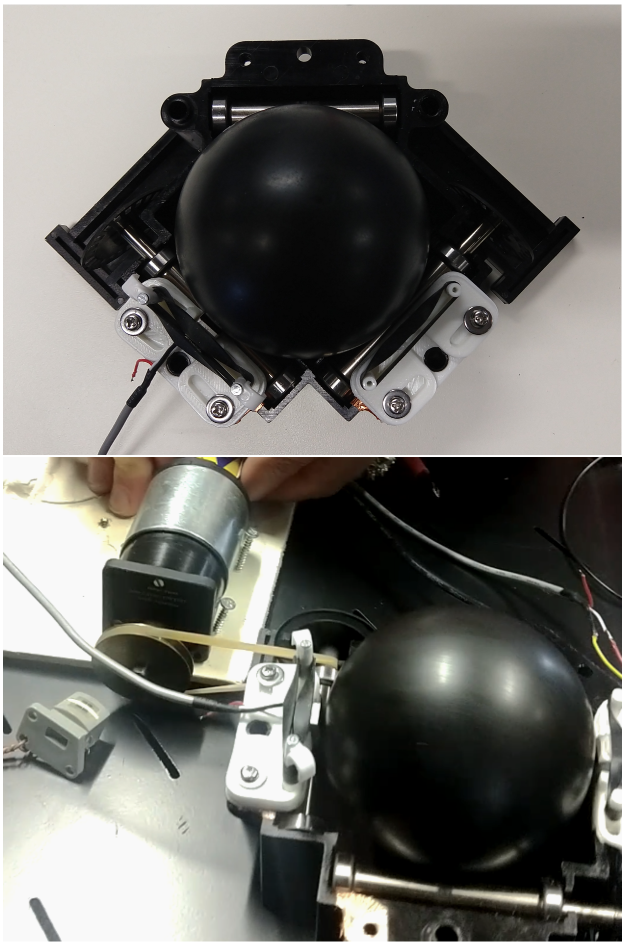

Figure 1: Above: Head mounting apparatus to maintain soft, consistent pressure on a disassembled and coated SuzoHapp trackball. Below: A motor is used as a belt drive to test fidelity on apposing playback and record heads.

2.2.1 Code Design. As mentioned, mapping a sphere to a grid poses a unique set of challenges. The rotary encoders themselves provide a resolution of about 1 tick per degree. While this is easily sufficient for high velocity motion in video games, it quickly becomes apparent that it is insufficient for finer grain motion. In testing, the spheres do not consistently hold to an exact number of tics per rotation, especially when being manipulated in diagonal trajectories. This is presumably due to a small but meaningful degree of slippage between the ball and the bearing rods on which it rests. With the prior in mind, it seemed best to ignore the original ideal of a perfect spherical mapping as none such would be possible. Such a mapping could still exist imprecisely, but even then another issue arises. Based on interaction response, it was decided one circumfrencial loop of the sphere should be approximately one second (at a presumed average rate of performer motion). This also simplifies the thought process in coding. At 44.1kHz and 16bit sample rate, the math for computing the area of a spherical surface yields nearly 2.5GB. Changing to a simple x-y grid yields even more at almost 4GB. As the Bela[10] platform had been selected for development, this is far too large for its local memory and would produce lengthy boot times when pre-loading a sample map. This strategy was then abstracted to something similar to a wave table. Originally, this produced 360 loops (x-axis) of 1 second at 44.1kHz, 16bit (y-axis). In performative testing, this resolution along the x-axis proved too high. Attempts to play what was just recorded became too fine-grained an area to reliably target and the complexity of blending several loops together, too much. Additionally, when starting from an empty track, it requires a great deal of time before enough was recorded for interesting playback. Through trial and error, a resolution of 90 loop arrays along the x axis was chosen as a good compromise between resolution and playability. Due to the resolution of the rotary encoder, an instant 1:1 of movement to playback/record was not ideal. At low speeds, this led to a form of clicking or chirping in playback and further created aliasing artifacts in recording as it could not average between enough samples at low speed. Eventually a sliding window, based on average speed, was decided upon with a temporal smoothing. This introduces a slight lag, but one acceptable to performance. To break down the final algorithm more directly:

- Y motion (forwards/backwards) is an average of a number of audio frames (n=1024, 0.03sec), the sliding window stretches or averages the audio input buffer contained in those frames (or the reverse in writing record audio to that buffer)
- X motion (left/right) selects the current record/playback array index. Again, the windowed averaging of speed allows a smooth transition between these arrays to prevent popping on each jump. These cross-fades are linear. Sigmoid fades were experimented with as well, with no significantly noticeable variation to quality. At almost all times, the playback is some blend of two overlapping x-arrays.

Motion of the interface thus results in pitch effects only on the forward and reverse motion with the left/right action providing smooth granular shift between the buffers. Diagonal motion reproduces sounds similar to the originally intended magnetic device, but the more lateral the motion becomes, the less true to that ideal as the audio becomes more a granular fade at lower effective pitch.

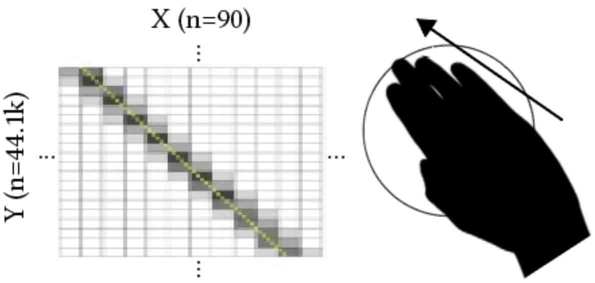

Figure 2: One second audio arrays (y-axis) are arranged into a secondary array along the x-axis. Performance averages the current audio out sample point for smooth transition of secondary arrays. The grid suggests a cropped section of the 2-dimension array with the anti-aliased line showing a presumed sample-averaging path through the indices resulting from the motion shown right.

2.2.2 Physical Design. With the above code, an initial interface could be constructed. This design features:

- Two trackballs: one with record and playback, one with only playback.
- A buffer selection button: The software was written to include ten full-sphere audio buffers with the first of these empty. The remaining nine are samples pre-loaded from storage. Each of the spheres could play from any one these at a given time. If the record sphere and the playback sphere were accessing the same sample, the playback on the second would update with the newly recorded information.
- A record button. Its combination with the buffer selection button allowed selection of the record/play sphere's buffer as well.
- An input balance dial. On the record/playback sphere, the synthetic record head was placed opposite the play head, this allowed the record sphere to create a delay effect by adjusting its playback level mix with the input signal.
- A delay "head shift" dial, providing a second synthetic play head. The dial shifted both the *distance* from the primary play head and the level of the delay.

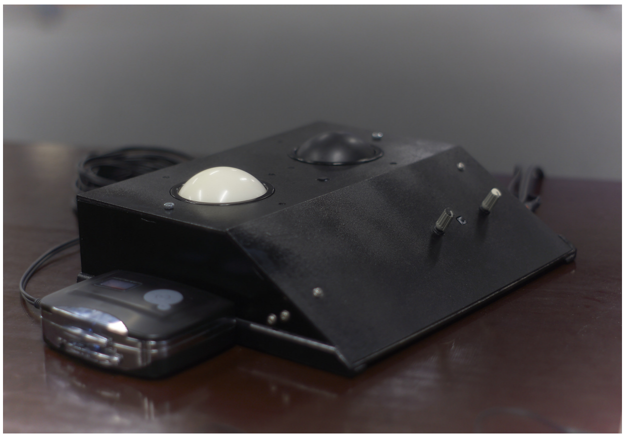

Figure 3: The final device and controls.

3 Performance Patterns

A number of performance strategies were tested for both sample playback and live recording, looping and playback. These included several speeds, directions and patterns. A simplified breakdown of these can be found on Table 1 on the next page.

3.1 Playback Performance

In performance the device proved versatile and intriguing. Performing with pre-loaded sound buffers gives expected results. The files tested included spoken word, looping beats, field recordings, and music. The speech was the most clearly interesting as scrubbing between words yields something nearly, while impossibly, intelligible. The beat loop samples, while allowing scrubbing between beats of the same tempo and thus allowing more variation, was not not appreciably different from scratching on a record with the chosen sample, but can suggested other audio could be more interesting as discussed later. In all cases, more usage of diagonal, circular, wiggling or spiraling in/out produced the most novel results.

3.2 Recording with Playback

This result, when motorized, was exactly as expected, but with some subtle drift between x buffers, presenting a somewhat more

Table 1: Performance Styles and Results

Motion	Play Results	Play/Record Results
Simple forward/backward motion	Standard audio scrubbing sound, with variation across tracks.	Speed irregularities of between play and record result in a pitch warbles. More rapid variations result in greater differences. Some playback of recording is missed due to drift.
Forward motion with handheld motor wheel.	Standard sounding playback, however regular lateral drift resulting in variation of which time point of the track was replicated.	As per playback only, but with the addition that the drift could result in either longer times between delay loops which could effectively render no loop depending on patience and alignment.
Lateral motion	Sometimes jumpy erratic audio dependent on speed and buffer contents, pitch variation from inconsistent motion.	As per playback, but can become smoother or more fully chaotic by speed as high speed buffer rewrites across the tracks does not alias as well as the forward pitch modulations.
Complicated motions (circles, swirls, wiggles, patterns)	Mostly perceptually analogous to normal scrubbing, but dependent on audio track. Vocal samples, especially, acquired a style that depicted the characteristics of speech, but was indiscernible as it bled through different segments of the audio.	If kept to one hemisphere, unheard until revolved. If utilizing larger motions, the sound would begin as per playback, but as more was overwritten at irregular speeds and intervals, a wholly chaotic result would emerge. Recording such erratic motion to only one side to then flip to the other became a performance strategy as the unknown result would usually be quite a bit more chaotic than the playback that occured while recording

dynamic version of the traditional loop. Manual control output was highly irregular and often intriguing. This results from the myriad irregularities in hand control while recording compounding with those same irregularities during performance. As the play and record index were offset by 22,050 samples (to simulate physical spacing of a play and record head on opposing sides), motions recording on one side would not feature until fully revolved to the other. Even maintaining a simple linear pattern would not maintain alignment, and the accelerations/de-accelerations would blend into new patterns. When this is expanded to recording in one pattern, and using another for playback, the hoped-for non-sequential and dadaist expectations and intents come through even more-so than intended. While the playback only and record/play spheres were capable of manipulating the same buffer, performatively it was too difficult to find the region being recorded to manipulate on the second hand live.

4 Expressive Capacities

While more experimentation and improvement is still needed, there are a few applications and creative approaches that can be confidently expressed in the use of this interface from the results above. On the fairly simple side, within the realm of the traditional drum loop one can create a series of samples aligning with the lateral arrays such that each forward loop is one complete measure, but permitting a performer to slide between any number of measures to create original beats on-the-fly from a longer rhythm sample, or a collection of hand-picked patterns. Taking this out of clear sync with the design can further this expression through syncopation. Expanding from drum loops, a vocal recording allows a form of scrubbing between multiple time-frames of a conversation. This gives the result of a kind of glossolalia - clearly a spoken language, but somehow incomprehensible. Through design, this allows expansions of musique concrète concepts, as one sphere's sample can be a cut-up of several different recordings - with a now-offered possibility to move among them with relative ease, offering per-performance sequence variability to field recording manipulation. When performing with the recording enabled, the possibilities expand significantly, but the complexity of explanation does as well. From some trials, resampling during performance gets especially complicated, however using a handheld motor to turn one sphere recording and playing back creates both a rhythmic, but inconsistent looping pattern of the performance, moving between different temporal frames of the performance. Using the second trackball to control only playback of the same can layer the surrealist scrubbing effects suggested before. With time, further refinements, and greater practice, these expressions are expected to expand and improve.

5 Discussion and Further Research

While the device does not presently feature the original analog/magnetic recording intent, the results produced are very akin to what was intended for performative purposes. It is perhaps interesting, that in the digital wavetable approach, it again echoes the history of analog tape in it reproduction of a kind of surrealist expansion on the first 8-track *Sel-Sync* machines.[8] The device is now undergoing an assortment of general updates while migrating to a new microcontroller. Beyond general code refinements, this will also facilitate the inclusion of control voltage (CV) output to allow the interaction to expand to modular arrangements. There are considerations to include a motorization option that allows the device some hands-free ability, should the performer want to keep a particular loop in play. While not a problem in most amplified contexts, these trackballs are relatively loud, replacing the bearings with higher quality ones designed for silent operation, as well as some acoustic isolation to the chassis could improve this. The analog device is not actively in development at this time, but it is intended that some of the suggestion from 2.1.3 be attempted to revisit its feasibility. Additionally, having found common and inexpensive paints work quite well as a recording medium opens up an array of possibilities for other expanded forms of recording topologies.

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7 Ethical Standards

The researcher has no conflicts of interest in the outcome or presentation of this research.

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