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Abstract

The Morph Table is a new music interface designed for collaborative music making. It comprises a software system that generates transitions and variations (morphs) between MIDI-based musical material, and a table-top hardware design on which cubes representing algorithmic parameters are moved around to control generative music. Like other table-top interfaces the size and multiple objects afford social interaction. The generative music system of the Morph Table makes it particularly suited to installations and use by inexperienced users. This paper outlines the design and usage features of the Morph Table.

Introduction

The Morph Table is a collaborative musical system which allows participants to morph between predefined sets of music through physical moving cubes on a table top surface. The design of the Morph Table involved some new developments, both in the areas of table-top interface and note-level morphing algorithms. Firstly, we will outline some of the previous research into both table-top interfaces and morphing algorithms. Following this is an overview of the musical morphing software, LEMorpheus and an outline of the design of the Morph Table. The design of the table and cubes is given priority, as the morphing algorithms have been described previously (Wooller and Brown 2005). Finally our informal observations and experiences of interacting with the Morph Table will be provided.

Previous research

Blaine and Fels (2003) claim there has been a history of electronically mediated musical collaboration from the earliest days of electronic music, citing Stockhausen's *Mikrophonie I and II* (1963/1964) experiments with professional

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percussionists, choirs and ring modulators. In the fifty years since these initial experiments involving electronics, the rapid and radical development of computer technology has had significant consequences and implications for musical composition and interaction potential.

There has been a strong movement in the past two decades towards developing new ways for people to interact with music via computers and non-traditional interfaces; evident internationally in the popularity of the NIME conference series, and locally with the Australia Council's SoundingOut grant scheme that resulted in web sites such as Digital Instrument Building (Brown et al. 2003) and Clatterbox (Bridgeman 2004) and numerous new instrument designs. This trend has seen the development of a wide range of new musical interface designs, many based on table-top and/or video-tracking interfaces like the Morph Table.



Figure 1. The Morph Table in use.

Table-top interfaces

There have been a range of previous table-top interfaces for music, and the target audiences and

interface designs have varied widely amongst them. Kaltenbrunner and Bencina (2007) provided a comprehensive review of these, however, we will summarise some of the work to provide a context in which to situate our Morph Table project.

Tabletop interfaces have been quite popular in recent years and they generally shared the feature of direct manipulation of objects on the table to control music or sound structures or parameters. The types of objects and methods for monitoring the movement of them have varied somewhat and include video tracking of objects, imbedding buttons and triggers in the table surface, such as in Composition on the Table and Jamodrum (Blaine et al., 2003).

One of the earlier table-top interfaces was the Audiopad (Patten et al. 2001) that used Radio Frequency tracking of objects on a tabletop surface. A projector mounted above the table provided graphical animations that showed the effect of and relationship between the objects. A variety of synthesis controls were simulated by the interface, as it controlled the playing of electronic dance music.

Music Table (Berry et al. 2003) used an overhead camera to track markers on cards laid on the table using the Augmented Reality (AR) Toolkit system. A computer monitor displayed the video camera image with graphics overlaying the card markers. Each marker represented a musical pattern. The user could structure the work by adding, deleting and arranging cards on the table.

The ReacTable featured a translucent round table, on which are positioned objects of different shapes. A video camera situated beneath the table tracked the objects position and orientation. Object position was mapped to the “topological structure and the parameters of a sound synthesizer” that controlled connections between and parameters of various audio signal processing patches (Jorda et al. 2005).

While these projects may have similar goals or use similar technologies to ours, the Morph Table uniquely combines musical morphing algorithms and a table-top interface for users with limited previous experience. While these systems often used projections to provide user feedback, the Morph Table relies on simple mapping and object labelling to enable the object position to be self-descriptive. This also simplifies the system installation, and cube lighting effects were an alternate visual stimulus that enable operation in dimly lit environments.

Both the Morphing Table and the ReacTable utilise the ReacTIVision (Kaltenbrunner & Bencina 2007) video tracking system, working with fiducial markers and live video data streaming. As a result they have similar potential gestural approaches, however the Morph Table differs from the ReacTable on a number of key factors.

Music generation: The ReacTable is an interface into an audio DSP patching environment whereas the morph-table operates on the note-level and

enables separate parts within the music to be morphed independently between pre-composed patterns.

Cubes: The ReacTable uses ‘pucks’ – each puck displaying a single fiducial while the Morph Table uses cubes which have at least four fiducials on different sides of the cube allowing for change and variation by rotating the cube.

User Feedback systems: The ReacTable uses a highly complex system for user feedback involving a frosted, curved tabletop to display projected graphics generated directly from the players gestures. The Morphing table, however, relies purely on the placement of cubes and aural feedback.

An example of a table top interface that uses blocks but does not use video camera to track them is the BlockJam project (Newton-Dunn et al. 2003). In this system one block was connected directly to a computer and there were physical connections between blocks as a way of structuring musical sequences. Blocks were functionally homogenous on a broad level (either a ‘play’ or ‘path’ block), and heterogeneous in their potential musical role as the user could ‘dial’ or scroll through different instruments or sequential directions in each block.

BlockJam requires blocks to be physically connected, created a series of binary states between blocks. It relies on sequences and encourages the user to think sequentially and two dimensionally. The function and state of the blocks, and the musical paths created by their arrangement were visible in the positioning blocks relative to each other on the table.

The Morph Table software directly addresses one of the key challenges unable to be addressed with the BlockJam system; continuous control of musical expression. Unlike block jam, which is “an alternative means of controlling a sequencer” (Newton-Dunn et al. p. 392) the morphing software is able to work with continuous control and gesture to allow for greater musical sensitivity and expression.

Previous note-level morphing algorithms

The Morph Table is used to control note-level musical morphing algorithms. We have published a comprehensive survey of compositional morphing algorithms at ACMC (Wooller 2005), however, a short summary of this will be provided here.

A number of morphing and morph-like algorithms have been developed previously, the most significant projects are: GRIN (Mathews and Rosler, 1967), HMSL (Burke et al. 2005), DMorph (Oppenheim 1995) and The Musifier (Edlund 2007).

GRIN is of particular historical significance, being the first attempt at algorithmically morphing between one note sequence and another. Mathews used a pen interface to draw envelopes representing note parameters. Polansky, using HSML, developed a number of specialized morphing algorithms for various compositions

(Polansky and McKinney 1991; Polansky 1987; *ibid.* 1991; 1992; 1996; 1996b).

Oppenheim's DMorph had some unique features such as the separate morphing of rhythm and pitch as well as n-source morphing. Interestingly, DMorph uses a 2D Cartesian plane (like a table) to control the morph index between four different sources (Oppenheim 1995; 1997; 2006).

The Musifier introduced the ability to morph between two different MIDI instruments by sending note information to each and fading the source out while fading the target in. Another significant feature is fact that the tonal representation is morphed separately to the note-level information.

The LEMorpheus morphing system used for the Morph Table builds on many of the features of the previous approaches, while also making some new contributions. Crucially, LEMorpheus utilizes an evolutionary approaches to morphing, which has remained relatively unexplored. The morph table is the first of these systems to incorporate a physical interface for controlling a morphing algorithm in realtime, and to allow collaborative control of the morphing algorithms.

Musical Morphing on the table

Morphing is defined as a hybrid transition between two pieces of music, called the *source* and *target*. In the morph table, there are four different voices in the music – drums, bass, lead and pads – and each of these can be morphed independently by moving the cube that relates to that part along the length-wise axis of the table. For any particular voice, when the cube is on one side of the table the *source* pattern is played, while on the other side of the table, the *target* is played. Moving the cube from one side to another will elicit a note-level or “compositional” morph between the two patterns, a process typically involves automated key-modulation, cross-fading of the different timbres as well as mutation, selection and substitution of note patterns. Moving the cube breadth-wise across the table controls the level of audio effects that are applied to that voice. Other morphing algorithms may also be used, including linear interpolation between pitch, duration, note-onset and velocity envelopes; as well as probabilistic generation of material based on analysis of source and target.

There are four different sets of music, each comprising different pre-composed source and target patterns and pre-rendered morphs. Each of the four sets relates to one of four fiducial positioned on the sides of the cube. Each voice can be switched to any particular set independently by flipping the cube onto the side that (arbitrarily) relates to that set. This changes the timbre, source and target pattern and morph for that voice.

With the possibilities of each cube being either on the source, target or off the table, combined with four different sets of music, there is a total of 6561

discrete musical combinations. This is arrived at because for each cube there are 9 discreet states:

1. not on the table
2. pattern 1, left side (morph index = 0)
3. pattern 1, right side (morph index = 1)
4. pat. 2, L
5. pat. 2, R
- Etc.

Imagine if there were two cubes - for each of the 9 states of one cube, we could put the other cube in any of its 9 states, thus 9^2 . Therefore with 4 cubes we have 9^4 possible discreet combinations, $9^4 = 6561$.

When the near continuous morphing between source and target is factored in, the musical possibilities are dramatically increased further, allowing a substantial degree of flexibility, especially considering the pre-composed nature of the music.

It is not within the scope of this paper to provide a detailed explanation of the morphing algorithms; more detail is available from (Wooller and Brown 2004) and (Wooller 2005).

Morph table design

The Morphing Table is a combination of several interface components. It consists of a flat surface, the tabletop, upon which three-dimensional cubes are positioned. Four of the cube's six sides are covered with fiducials (high contrast pattern markers) and the remaining two sides are used for cube labelling (bass, drums, and so on). The tabletop is Perspex, and a web camera is placed underneath the table such that it can capture the movement of the cubes on the table surface. The table needs to be of a certain height to be both comfortable for the user and to optimise the working range of the web camera. The camera covers an area up to approximately 20 cm inside the perimeter. This area, we call the “beer-resting” zone, can (also) be used for printed instructions, logos, and as a “dead” zone for cubes not currently in play.

The table was also designed with performance and storage in mind, and therefore was able to be disassembled by removing the legs. The screws on the inside of each corner do this and as they fall within the “beer-resting” zone and do not interfere with the camera view.

The cubes are also made of Perspex, and are internally lit by a fully contained LED system. Four faces of the cubes display four different fiducials, and the remaining two faces display text to identify which instrument set the cube is manipulating.

A Mac mini computer runs the reactIVision software to track the location of the cubes and communicates their positions via Open Sound Control (OSC) to a Windows computer running the LEMorpheus morphing software. From the position of the cubes, the required morph indices and sound-FX levels for each part are extracted. The morph indices influence the note-stream that is

generated by the morphing algorithm. Both the note stream and the sound-FX levels are sent to a software synthesiser which renders them into audio. The synthesizer patch itself is quite sophisticated, incorporating 32 separate synth modules (Reason 3 “combinators”), each with a specialised patch of sound-FX.

Table Lighting

Variations in lighting had significant impact on the ability of the web camera to accurately detect and track the fiducials. Tabletop reflectivity required consideration of how external lighting would affect the camera tracking; light from directly above the table could interfere with the camera, light from underneath the table could reflect off the surface making it more difficult to read the fiducials. We decided that lighting the cubes internally would help in making them more durable in a range of lighting conditions. The success of this approach was clearly evident at performances which began in the afternoon and carried through until past sundown. The changing light throughout the afternoon at these venues had little effect on the successful functioning of the table; with only a few minor adjustments being required to the camera settings.

Video tracking

The reactTVision system, used for cube tracking, utilises black and white markers developed by Ross Bencina that he calls amoeba fiducials (Bencina and Kaltenbrunner 2005).



Figure 2. A fiducial marker identifies cube surfaces.

Fiducial Size

For greater accuracy (detection and tracking response) we found that it was best to use quite large fiducials so that the variations were more pronounced, because they were then less susceptible to changes in lighting, and were able to operate over a wider range on the table with ease. The large fiducials also compensated for problems with recognition that were exaggerated by the

“fisheye” effect of the *creative Live! Ultra*’s wide angle (72 degrees) web camera lens used to capture more of the rectangular tabletop area.

Cube design

The Morphing Table cubes have fiducials displayed on four faces, affording more musical potential to each physical object than single sides objects used in most previous table-top systems.



Figure 3. Morph Table cubes.

Cubes operate on multiple faces, and the downward facing fiducial indicates the current state of the block. In contrast to Block Jam which uses two types of blocks (‘play’ or ‘path’ blocks) which have different functions, each cube in The Morph Table is functionally the same, and is mapped to a different instrument. Each cube represents a different musical part (instrument) and each face of a cube represents a different musical riff for that part. When cubes are in view the riff plays, when lifted above or to the edge of the table the part ceases at the end of the currently playing riff.

Cube Lighting

Several obstacles were encountered when designing the internal lighting system for the cubes. A system of LEDs was used after much experimentation. This component of the interface construction was considerably more time consuming than any other aspect, as the design was highly sensitive to the diffusion of light across the surface. Uneven lighting lead to areas of over- and under-exposure which, in turn, resulted in a cube being misidentified, or unable to be detected at all. Experiments to rectify this included printing the fiducials onto paper of varying translucencies, adding a variety of foams and packing materials between the LEDs and paper, using aluminium foil to reflect light from over-exposed areas to darker areas, and adjusting the angles of the LEDs. The most satisfactory result involved angling the LEDs towards the edge of the card, and printing the fiducials onto tracing paper. The fiducials were then darkened with a marker to create maximum

contrast, and the ‘dots’ were slightly enlarged to compensate for over-exposure.

The delicate electronic circuit needed to be durable, compact, and light weight in order to be contained within the cube, and easily serviceable. The final system consisted of an LED circuit on Vero Board, mounted on thick card and was powered by a two AAA batteries. Each side was lit by 9 5mm LEDs, making for a total of 36 LEDs running in parallel. The cardboard provided stability by reinforcing the circuit board. The shape of the card allowed the circuitry system to be fitted snugly into the cube without the use of adhesives or other attachments. It also aided with diffusion, a major consideration, as the white surface of the card reflected the light.

Interacting with the Morph Table

We installed the Morph Table in several public venues around Brisbane, Australia during 2006. In these venues the morph table was used as both a performance instrument and as an interactive installation for the public. Informal usability observations were taken at these events from which we conclude the following preliminary usability comments.

Blaine and Fels (2003) suggest initial negotiation of user roles and protocol that may be mediated by a more experienced player or instructor, particularly in the case of musical novice, however they also highlight that the novelty of the interface may be unfamiliar to ‘expert’ musicians also, and hence require some basic instruction. In the case of the morph table, it was decided that instruction should be minimal to observe transparency of operation, learn-ability and playability of interface. This placement of the camera under the table, as with the reacTable, allowed for more free-flowing user interaction, eliminating the need for the user to consider interference with the video tracking. The use of large, clearly labelled, cubes made distinctions between cubes quite apparent. There were some difficulty in differentiating between sides on the cube; hard to tell which patterns/combinations they had already played.

It was clear that most users enjoyed the experience of playing the Morph Table. Participation was quite intuitive and, with a limited set of instructions mostly relating to how the table axis were mapped to musical parameters and the effect of flipping the cubes, users interacted with the table for up to half an hour. However, we also observed that the length of time spent with the interface varied between users, and that people who were more familiar with the computational arts processes at the heart of the morphing algorithms spent longer with it. This indicates that even more clear instructions and more obvious musical changes may assist novice users. The interaction between users, especially with regard to

passing on learned performance “tricks,” was repeatedly facilitated by the Morph Table.

Conclusion

In this paper we have outlined the morph table project. We have surveyed the research context for table interfaces, and provided a review of the musical morphing software. We have detailed the design and construction of the Morph Table and shown how we have balanced ease of use and simplicity of construction and operation in order to maximise user engagement with music making.

Future avenues for research with the Morph Table include redesigning the project for new contexts and audiences, including installation, performance and possibly as a component of an ensemble. New contexts and audiences could call for further experimentation with musical content and the application of the morphing software, as well as interface considerations.

The development of the physical interface design holds much potential. Refining it towards a more economical and durable model, which would involve further material and lighting experimentation, could create new application possibilities in the educational and commercial arenas.

There is video documentation of the Morph Table available on YouTube.

<http://www.youtube.com/watch?v=nKXhfApKms>

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