MAT 200C: Pattern Formation	**May 5, 2015**
Spring 2015	**Final Project**

Due: Tuesday, June 9, 2015.

For the final project, select one of the topics from class and significantly expand upon it. You are **encouraged** to connect this project to any other projects you may already be working on. Possible avenues for exploration include:

- **Alternative input modalities:** How can we drive one of the programs from class using a camera, an accelerometer, or a Kinect? More interestingly, how can you modify the underlying algorithm to this new source to generate more interesting patterns?
- **Alternative output modalities:** The programs from class all produce some sort of coherent visual structures. How these be used to create structure in other forms, such as sonification and fabrication?
- **Improved performance:** Many of the programs, such as Newton fractals, can be quite slow. What methods can be used to accelerate them, so that larger resolutions are available for interaction? This type of project should take a step past straightforward micro-optimizations of existing code.
- **Extension to 3D:** All of the programs that we have written have meaningful extensions to 3D which we have not explored. What new structures can be generated with 3D DLA, the Mandelbulb, or a 3D Game of Life? Some of the programs we have explored, such as Newton fractals, do not have immediately apparent 3D versions. How could a third dimension be incorporated?

Note that these are only suggestions. I would **strongly** prefer that you propose something specifically tailored to your interests.

Timeline

- **Preliminary Proposal:** Write up a proposal of your project and send it to both myself and Aaron by midnight on **May 12th**. The proposal should be at least 500 words. Include a weekly timeline of how you will implement what you propose, and what final deliverables you propose to submit upon completion.

  The proposal is the most critical part of your project. Take it seriously. Select a specific project with a well-defined goal, and plan out as many of the details as possible. Past experience has shown that poorly thought out proposals lead to embarrassingly simplistic results, total garbage, or no results at all. ***Save yourself the stress and embarrassment later on. Plan your project now.***

- **Progress Reports:** During the **May 19th** class, everybody will give a 5 minute overview of their proposed project, and show a preliminary result. Be careful to tailor your timeline so that you have something to show by then.

- **Final Presentation:** Everybody will give a 10 minute final presentation during the final exam time, **4 PM June 9th**, and submit their proposed deliverables over email by midnight on the same day. One of your deliverables will a Tumblr posting that summarizes or represents your results. This is due by midnight on the same day.

Grading Breakdown

- Preliminary proposal, including timeline and list of deliverables (20%)
- Progress report, including some sort of working prototype (20%)
- Final presentation (40%)
- Final deliverables (10%)
- Final Tumblr summary (10%)

Examples to Avoid

Please avoid making the same mistakes as these past proposals.

Example 1: *I am going to show the growth of several distinct virtual specimens that are designed using several pattern formation algorithms, such as DLA, diffusion-reaction, noise, etc. The specimens aggregate, disperse, grow into more complex structures, or die over time based on certain parameters of the environment. The data from several sensors such as touch sensor, photocell, microphone, etc is fed into their algorithm as parameters that determine their rate of growth or decline. Therefore their behavior, while under observation, is determined indirectly by human interaction. Through this interaction, the spectators become a part of this synthetic bio-system.*

This proposal does not actually propose anything. It says it will take some of the algorithms from the course and attach some inputs to them. That is a restatement of the project parameters, not a description of an actual project. Which algorithms will be used? What inputs? What are you trying to produce that we have not already seen in class? Be specific.

Example 2: *Today moreso than ever before, it is of the utmost importance that we human beings develop more holistic perspectives regarding our selves and the universe in which we dwell. This is essential in every aspect of our existence from our art, to our relationships with others, to the way we treat our planet. There is no singular entity separate from the rest - all is connected in a permanent web of interrelation. Every action affects everything else, and nothing goes unnoticed in the eyes of the cosmos. For my final project, I wish to portray this truth by integrating the physical and digital realms with a combination of anatomical movement, visual pattern formation, and sound.*

Nothing here is relevant. This is not a book report to pad out with bizarre ramblings until you hit 500 words. If you find yourself coming up short, think the details of your project through more thoroughly, and write those specifics down.

Example 3: *The title and focus of this course is "Pattern Formation", referring generally to visual patterns, such as waves, diffusion-limited aggregation, fractals, and so on. Auditory and musical patterns offer an interesting extension of this, since humans are particularly enamored with patterns and repetition with variation in sound and music – in fact, it could be said that patterns are fundamental to the structure of music as we perceive and enjoy it. As someone who enjoys both listening to and creating music, and has an interest in digital sound synthesis and composition, this is an area I would like to explore.*

A visual system – such as a fractal, reaction diffusion, wave equation, or similar – presents a number of aspects which can be used to control or influence parameters for sound synthesis. Each pixel can have a value, or a set of red, green and blue color values, the overall image can have frequency-domain components, and systems like the Game of Life and Diffusion-Limited Aggregation can record the number of times a cell has been "walked" on.

Sound synthesis, accordingly, presents many parameters that can be controlled. For each oscillator (of which a synthesizer can have, at least in theory, an arbitrarily large number, though in practice this is limited by memory and computational power), one can control the waveform, frequency, and amplitude. Filters, such as the low-pass Butterworth filter common in musical applications, can be applied to the signal, and parameters such as their cutoff frequency and resonance amount can be controlled. The audio signal can be panned to the left or right, affected by reverb, an amplitude envelope, or similar. In conventional synthesizers, these parameters are generally controlled by (physical or virtual) knobs, sliders, MIDI input, et cetera.

In my project, I would allow aspects of the visual system, such as pixel values, to control parameters of the sound synthesis system. The visual systems we have studied in this course can become very complex, and change significantly from moment to moment, which should provide for very dynamic and unpredictable variation of sound-synthesis parameters, potentially leading to new and unexpected sounds and musical expressions.

There is tons of irrelevant padding in this text. Please do not tell me what the title and the content of the course is. I assure you, I already know.

This proposal is slightly better than the previous examples, but still not specific enough. It proposes to do something sound related, presents a list of algorithms from class, and then a list of sound control parameters from another class. Plugging a bunch of things together and hoping the result is not random garbage is not a specific goal.

Example 4: *The following is my timeline. Week 1, I will get it working. Week 2, I will experiment with it. Week 3, I will experiment with it some more. Week 4, I will present the results.*

No, this does not count as a plan.

Examples to Follow

Yoon Chung Han's Proposal (2012): This proposal is very specific. The high level goal is to generate a desert-like virtual world. Obviously we have not seen anything like this in class. The goal will be specifically accomplished by using a Kinect, a sandbox, and DLA. Additionally, it will also be possible to destroy DLA aggregates using the sand, which we also have not seen in class.

Aaron Jones' Proposal (2013): This proposal is also very specific. Möbius transformations could be used in a way that is similar to the Mandelbrot set and Newton fractals from class. The high level goal is to find out if they also give interesting patterns. It is fine for experimentation to be a significant part of this proposal, as it is here.

The difference is that experimentation should not be the *entire* proposal. There is a big difference between "I propose to implement the Möbius transform and then experiment with it" and "I propose to experiment with an algorithm from class. I don't know which one. I'll decide later." Again, please be specific.

Alexis Crawshaw's Proposal (2014): This proposal does a very good job of integrating concepts from the class into existing interests, e.g. Alexis' pre-existing project on vibro-tactile devices. I usually need some convincing when non-trivial hardware is being introduced into the project, but the proposal does a good job of convincing me that she already has some experience with these devices, and will not be starting from zero.

MAT 200C Spring 2012
Final Project Proposal

Yoon Chung Han (1st year MAT Ph.D student)

Desert bloom

Using improved and modified Diffusion Limited Aggregation, my final project will be an interactive installation and artificial nature environment called *Desert bloom*. I was fascinated by the creation of DLA and I discovered possibility of generating algorithmic nature structures by using DLA. I would like to apply the algorithmic results as artificial nature creatures and environment, which will be virtual blooming trees/flowers in dry desert.

There will be a sand box, a Kinect camera, and a mini projector in this installation. (Please see an installation plan image below) Kinect camera can measure the depth of 3D object so I will get the data of 3D surface and depth of sand in the sand box in real time. When audience plays with sand, and change the depth and shape of sand surface, the artificial creatures (trees, flowers, or unnamed creatures) will be appeared and projected at the deep lower sand hole. The creature will be bloomed at each sand hole, and it will bring unique experience to audience; they can become to God to create artificial nature environment by hands. When audience recovers the hole, the creature will be gone as the same manner in real desert; sand storms, desert devastation or human's industry/development destroys all the creatures and end up them in death.

Kinect projection mapping is necessary, and due to use of Kinect camera library, I will use Processing (http://processing.org/) as a main programming language to implement this project. Main algorithm will be DLA but I may use Newton Fractal and Reaction-Diffusion as ways of generating other various creatures. Also, DLA 3D will be possibly considered.

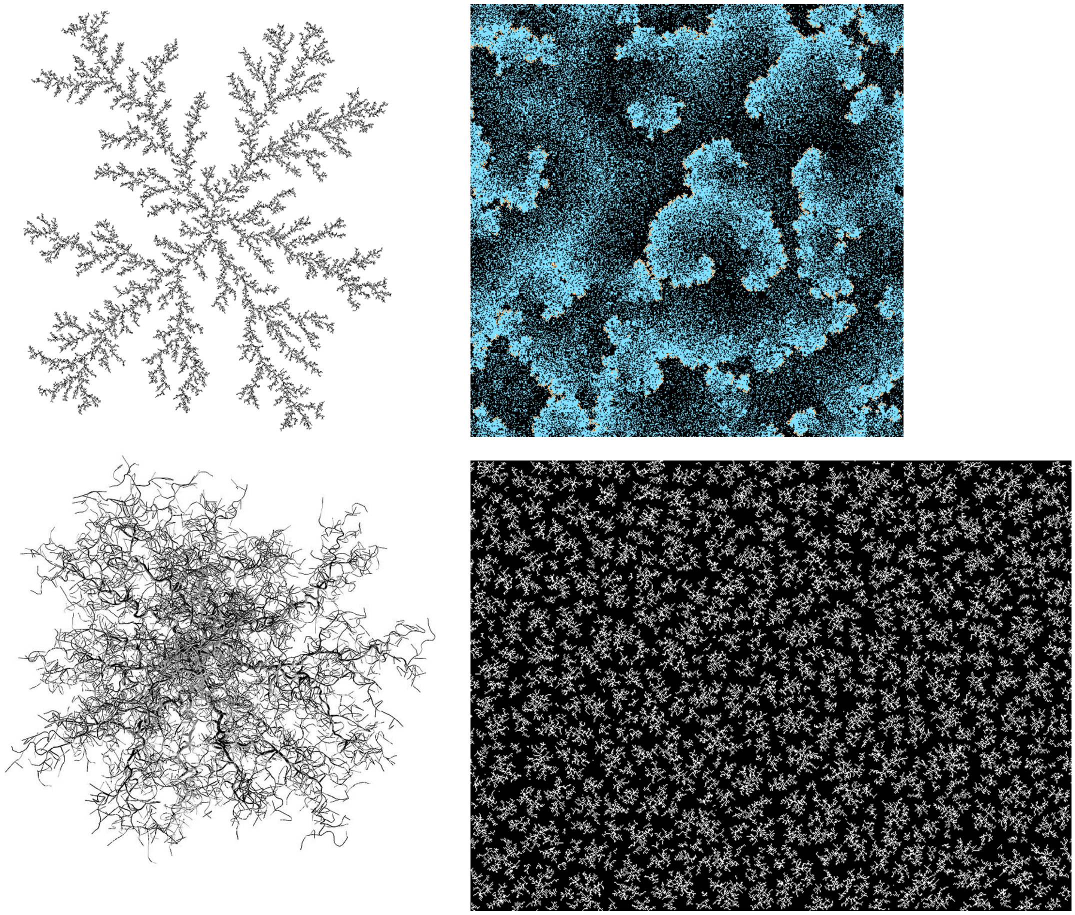

Fig.1. Reference images of Diffusion Limited Aggregation

Time schedule

May 14th – 20th: Create basic DLA and many variations in Processing, test Kinect projection mapping, and buy/borrow a sand box and mini projector

May 21th – 27th: Create a prototype of Desert bloom – simple interaction with Kinect camera and DLA processing sketch

May 28th – June 3rd: Develop more advanced, and detailed DLA creatures, finish Kinect projection mapping on sand box

June 4th – 6th: Final test, set up all installation, and fix bugs

June 7th: Final presentation

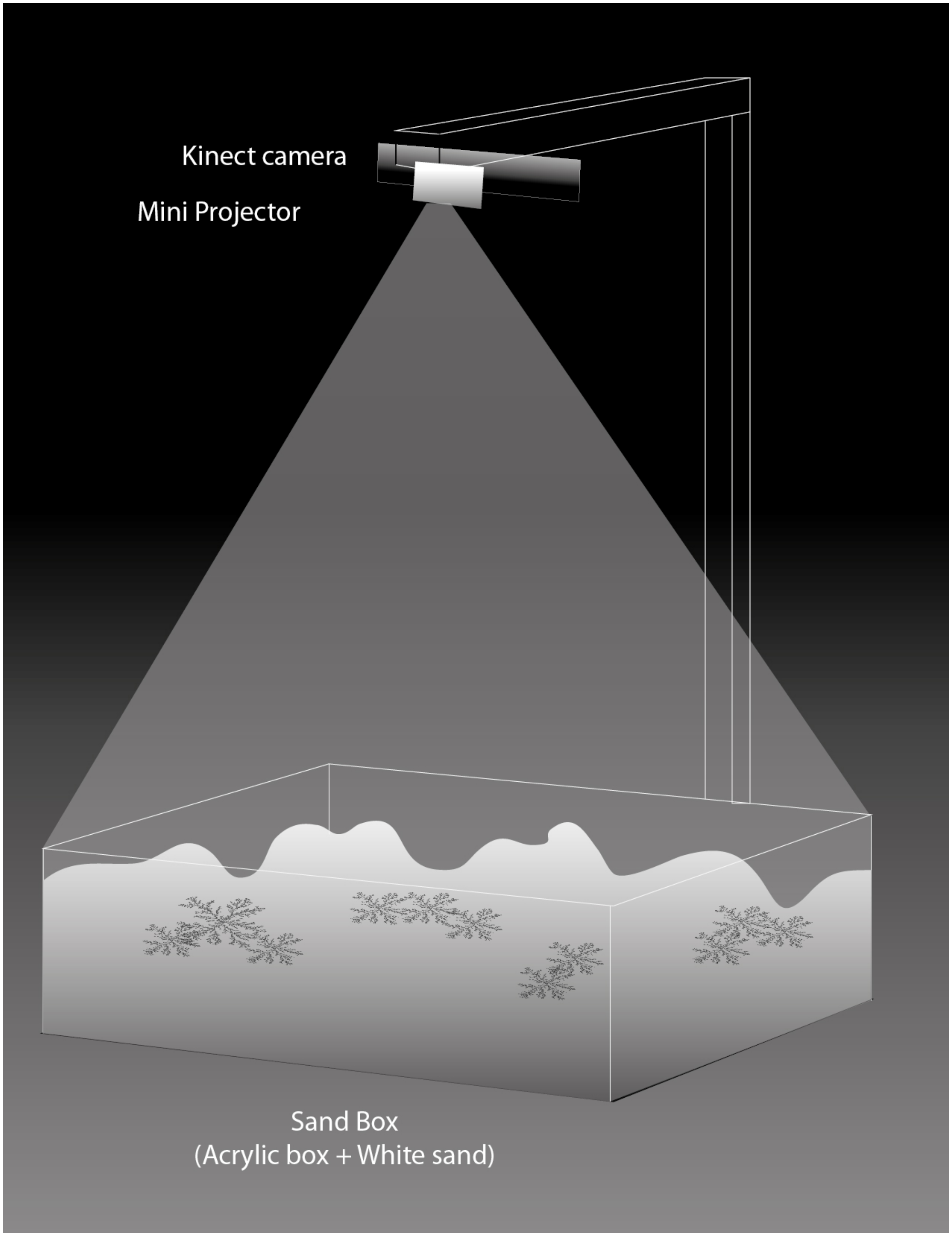

Fig.2. Desert bloom installation plan

200C Final Project Proposal

Aaron Demby Jones

May 14, 2013

In complex analysis, Möbius transformations are functions $f\colon C \to C$ defined by

$$f(z) = \frac{az+b}{cz+d}, \tag{1}$$

where $a, b, c, d \in C$ such that $ad - bc \neq 0$. Conceptually, a simple way to understand Möbius transformations is to consider them as the composition of several basic geometric transformations: translation, dilation, rotation, and inversion. In fact, every Möbius transformation can be decomposed into some combination of these geometric operations. It follows from the fundamnetal properties of these simple transformations that the composition of Möbius transformations is also a Möbius transformation. Hence, Möbius transformations form a group under composition and are of interest algebraically as well as analytically.

Since several of the concepts we have studied so far (e.g., the Mandelbrot set and Newton fractals) have involved iterating a complex quadratic polynomial, considering the iteration of a different type of complex function such as a Möbius transformation may yield interesting results. However, because of the aforementioned compositional property, Möbius transformations have simpler iterations than quadratics, whose composition is a more complicated quartic. Hence, the first results may not be as exotic or interesting as the Mandelbrot set and Newton fractals. Nonetheless, implementing an iterative visualization of Möbius transformations is a convenient first step toward a more involved final project.

Anticipating that the iterated Möbius transformations will be more of a starting point than an end goal, let us review the Newton iteration procedure we studied in the course to see whether it can be modified. We considered the iteration

$$z_{n+1} = z_n - \frac{f(z)}{f'(z)}, \tag{2}$$

but a more general procedure could be employed by considering the iteration

$$z_{n+1} = z_n - \frac{a\frac{f(z)}{f'(z)} + b}{c\frac{f(z)}{f'(z)} + d}, \tag{3}$$

which combines the concept of Newton iteration with Möbius transformations. Furthermore, besides interactively controlling the zeros of the function $f(z)$, the user could also modulate the four complex parameters a, b, c, and d.

My weekly plan for deliverables runs as follows.

May 14–21: I will implement iterated Möbius transformations and experiment with modulating a, b, c, and d as well as different color schemes. The deliverables will comprise the images and videos of my best results.

May 21–28: I will implement the combined Newton and Möbius transformation iteration and continue to investigate color schemes. User interaction will be increased with the additional option of modulating the zeros of the function $f(z)$. Again, the deliverables will comprise the images and videos of my best results.

May 28–June 6: I will try to 'break' my work so far and branch out into other applications. One possible connection deals with two-by-two matrices—every Möbius transformation $f(z) = \frac{az+b}{cz+d}$ can be put into one-to-one correspondence with an invertible matrix of the form

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix}.$$

Hence, there may be interesting ideas related to an eigenanalysis, or possible generalizations to larger matrices. Another possibility could be to expand the class of functions from Möbius transformations to conformal mappings. Yet another idea would be to incorporate the concept of the Buddhabrot coloring. As time permits, I will try to explore at least one of these experiments. Once again, the final deliverables will be a collection of images/videos demonstrating my most interesting results.

Aesthetically, my goal is to explore a rich area of complex dynamics with the hope of generating interesting or enlightening visual content. Ultimately, my research plans center around visualizing and sonifying mathematical patterns; thus, this project will possibly be the beginning of a more long-term project which would incorporate audio as well.

FINITE DIFFERENCE SPATIALIZATION TECHNIQUES IN VIBROTACTILE MUSIC DIFFUSION

Alexis Story Crawshaw
MAT 200C, UC Santa Barbara
Final Project Proposal

I propose an implementation of the heat and wave equations within the C++-based Gamma to control the gain and spatialized movement of a given signal in multi-channel vibrotactile music diffusion. As with multi-channel audio music diffusion, varying the amount of gain across an array of vibrotactile outs may convey the illusion of a moving *phantom source* or "cutaneous rabbit."[1] Provided the possibility for this perceptual construct in the tactile domain, I will explore the artistic potential of using these diffusion and reaction-diffusion equations to illustrate the displacement of a given tactile signal source when spatialized across a one-dimensional trajectory on the human body.

Specifically, I will use the heat equation to control the *width* of a given tactile signal source— its scope across a given number of channels— mapping the visual parameter of brightness to amplitude, concentrated to one channel initially, and eventually diffused to the entire array. I will use the wave equation to control how a given tactile signal source propagates out from a given starting point along the array, out to the other channels. Time permitting, using the wave equation, I will attempt to impose "borders" of varying *width* that contain and reflect the waves to certain channels. From these starting points, I will experiment with different applications of the equations as well as different aesthetic modifications to the code. The product of this exploration and research will be given in the form of a demonstration of these effects within a short musical étude of about 2-3 minutes in duration, delivered to an audience (one person at a time) via wearable, 6-channel vibrotactile "sleeves."

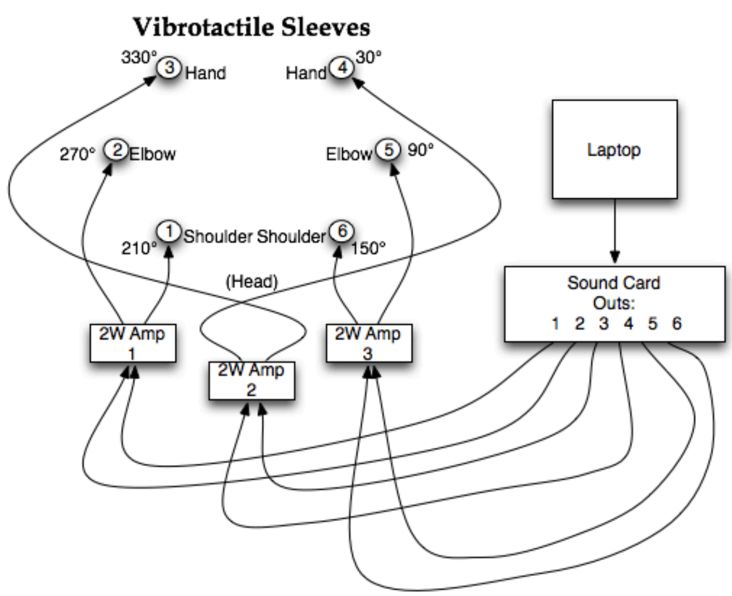

Figure 1: Vibrotactile Sleeves with 6-channel actuator configuration and signal flow chart.

As the sleeves device is conceived, the actuators are arranged in a circular configuration with the spatialization effects occurring across a one-dimensional line, running along the azimuth of said circle. This sleeve is currently in development with the help of the Santa Barbara company Crowson Technologies, and in the event that there would be a problem in delivering the sleeve hardware by the end of the quarter, I have in my possession a 4 to 8-channel vibrotactile board that may be used in its stead. The multi-channel spatialization for this device would also occur along a one-dimensional line: see Figure 2 below.

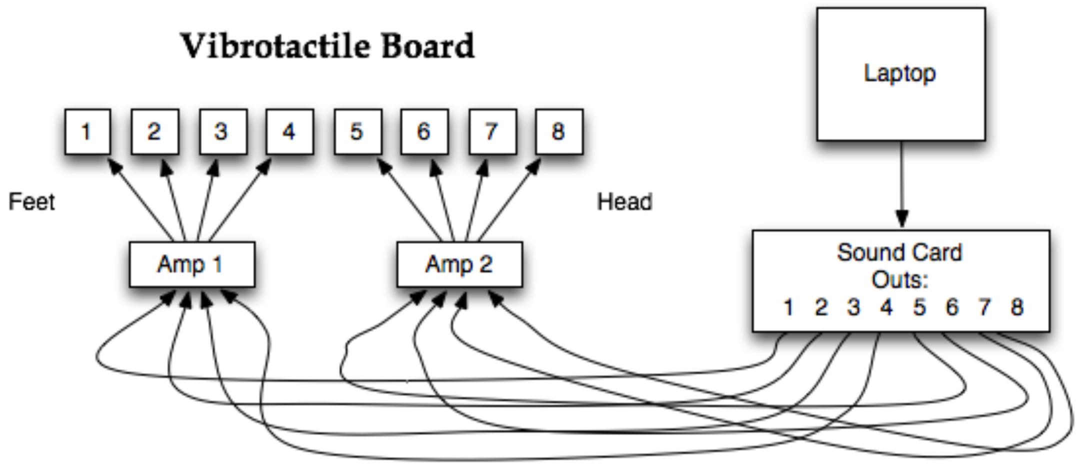

Figure 2: Vibrotactile Board with 8-channel actuator configuration and signal flow chart.

Given the heat equation, given as:

$$p_{x,y}^{t} = \Delta t * \alpha * \left[\frac{p_{x-1,y}^{t-1} + p_{x+1,y}^{t-1} - 4p_{x,y}^{t-1} + p_{x,y-1}^{t-1} + p_{x,y+1}^{t-1}}{(\Delta x)^2}\right] + p_{x,y}^{t-1}$$

and the wave equation, given as:

$$A^{t+1} = \left[\Delta t^2 * c_A * \left[\frac{p_{x-1,y}^{t-1} + p_{x+1,y}^{t-1} - 4p_{x,y}^{t-1} + p_{x,y-1}^{t-1} + p_{x,y+1}^{t-1}}{(\Delta x)^2}\right]\right] + 2A^{t} - A^{t-1}$$

one can modify their laplacian components to adapt these equations to a one-dimensional line as follows:

$$\left[\frac{p_{x-1,y}^{t-1} + p_{x+1,y}^{t-1} - 2p_{x,y}^{t-1}}{(\Delta x)^2}\right]$$

These equations will be used in a Gamma program to control a musical signal, using the model of the Gamma instruments/compositional templates used in the MAT 276IA and B courses, Introduction to Micro-Structural Composition and Sound Synthesis, in which I have been and am currently enrolled, respectively. Thus, I am already familiar with Gamma and in creating my own instruments and code for composition within this framework. I will equally have the support of David Adams, the course's teaching assistant, in resolving any programming issues that may arise. Ryan

McGee has equally been assisting me with some of the code for multichannel panning in Gamma.

Although both the diffusion hardware and modality of sensory reception may be novel from an artistic perspective, from a programming standpoint, the task at hand is comparable to spatializing an audio signal within a circular multi-channel speaker array (or with the board, a multi-channel linear array). The devices used for diffusion are tactile (linear) actuators, which, like audio speakers, can transduce an electrical waveform signal into motion. This motion — instead of displacing a membrane coupled to the air, as with audio speakers— is displacing a surface that, when pressure is applied to both sides, can produce vibration through the solid to which it is coupled. When coupled to the human body, this waveform signal is perceived as touch through the skin's mechanoreceptors, specifically as vibrotactility. As such, concerning the vibrotactile "sleeves," six small actuators are strapped onto points along the arms, the actuators pressed against the skin with straps applying an outside force. Regarding the vibrotactile board, eight larger actuators are sandwiched between the ground and a wooden board. The subject may then lie down on top of the board to feel the actuators along the length of his or her body.

I already have experience employing multiple vibrotactile diffusion devices at a time in various live performances, such as *Sur le Chemin…*(Université Paris 8, Ecole Normale Superieure, and La Maison du Portugal: Paris; April-May 2013), *Des Gestes Touchants* (UCSB Music Bowl, April 2014), and *La Perception Transamplithéâtrale* (transLAB, April 2014). Although the signal going to these devices were all mono, the issue of multichannel diffusion— as I mentioned above— is no different than with using the ever more common audio speakers. I will have access to a sound card and amplifiers with the necessary number of signal outputs to enable this.

In conclusion, I hope to offer an original application of these equations in the emerging art form of vibrotactile music and explore what aspects of these equations can contribute to aesthetically salient corporal spatialization techniques within this developing domain.

TIMELINE:

Week of May 12 th: Resolving multichannel diffusion issues in Gamma, writing necessary header panner files, figuring out where in the architecture of the code to best run the equations, initial experimentation, testing out hardware, buying/acquiring necessary cables and equipment

Week of May 19th: Refining implementation of equations, implementing "borders" in the wave equation, refining the strapping mechanisms for the hardware and resolving other hardware issues that may arise

Week of May 26th: Exploration of effects, experimentation, composition of the étude.

Week of June 2nd: Continued refinement of effects and of composition.

---

[1] E. Gunther, "Skinscape: A tool for composition in the tactile modality," Masters' Thesis, Massachusetts Institute of Technology, 2001.