MAT 200C: Pattern Formation	May 6, 2014
Spring 2014	**Final Project**

Due: Tuesday, June 10, 2014.

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 Sahar by midnight on **May 13th**. 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 20th** 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 10th**, 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.

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.

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.
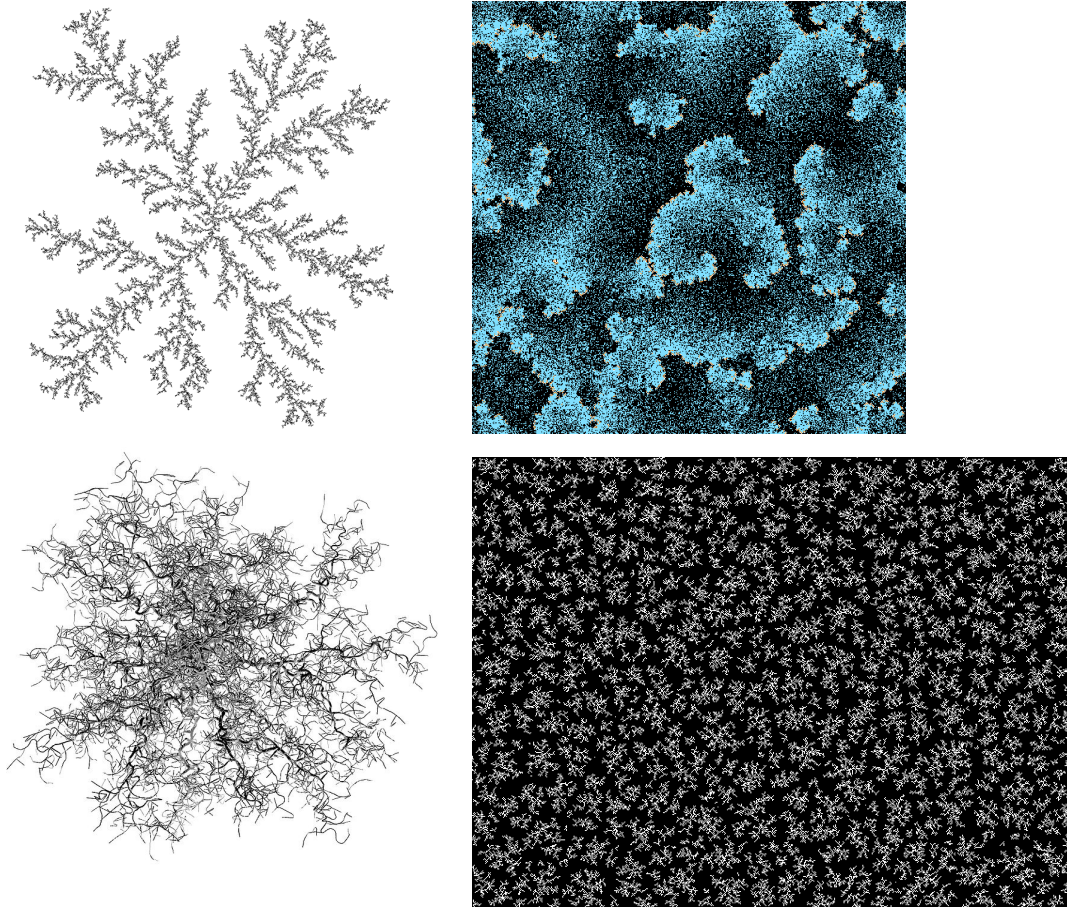
Fig.1. Reference images of Diffusion Limited Aggregation

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

Kinect camera

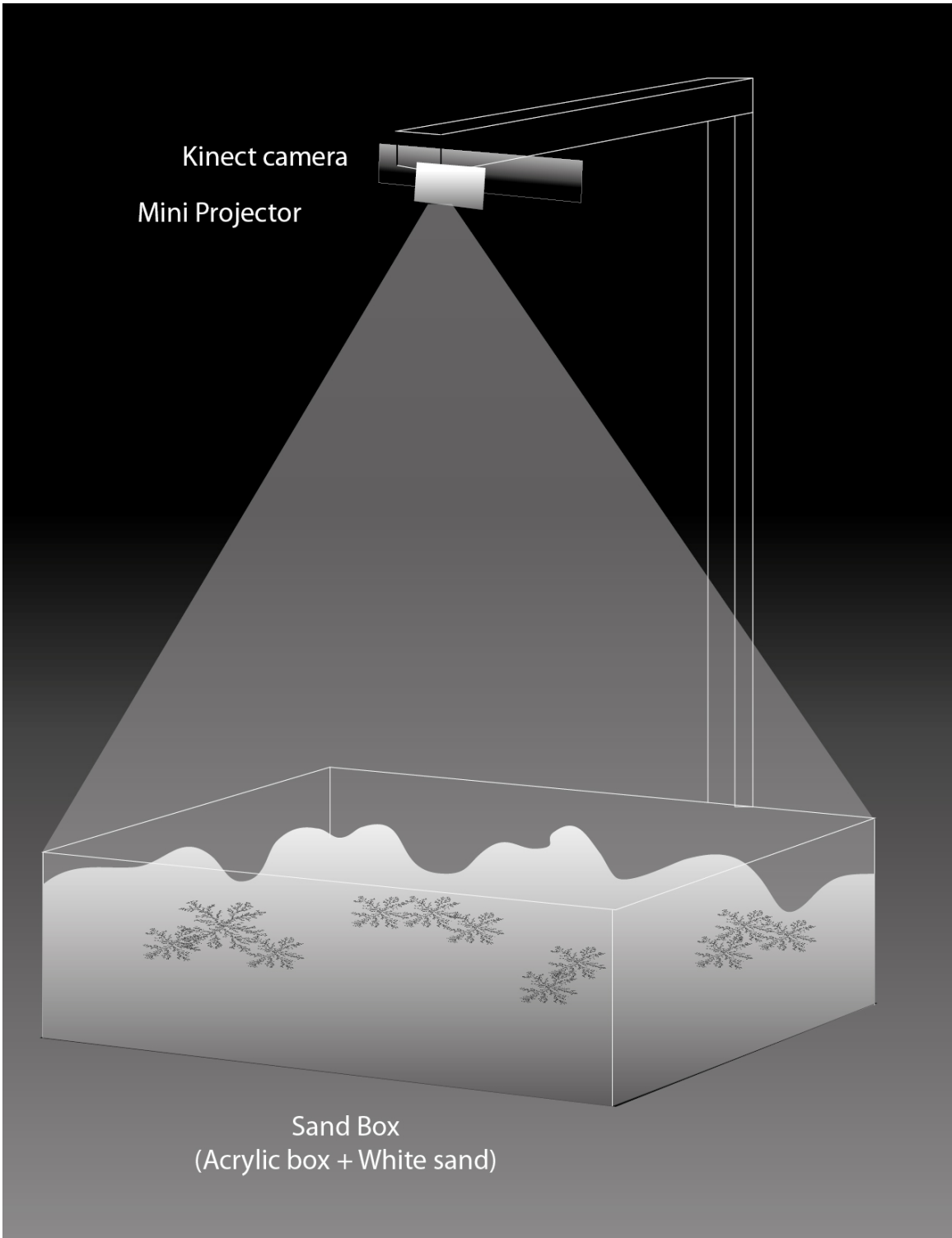Mini Projector

Sand Box
(Acrylic box + White sand)

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

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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.