Kinetic Sand Garden: Initial Design

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DESIGN GOALS

Our project consists of building a kinetic sand garden coffee table. The project will utilize a variety of materials such as sand, marble and incorporate design elements such as lighting and sound -- to enhance the user's experience. The result, an innovative and interactive way to enjoy a cup of coffee as you start your morning.

For this project, our main goal is to create a kinetic sand garden coffee table that can create diverse designs using a metal ball and to showcase the designs without the ball by removing it when a design is done. Another one of our goals is to give the user a personalized experience by adding LED lights to customize their experience with a range of colors. In addition, using our radial pulley system in the third level of our mechanism, we want to create articulate and a wide range of designs. Additionally, we are thinking of having the legs of the coffee table to be *removable*, to further enhance the user experience.

Since our previous assignment, we have moved from a circular structure to a square-like one to incorporate all of our designs.

CURRENT DESIGN

The following is a third iteration from our initial designs after consulting with our TA.

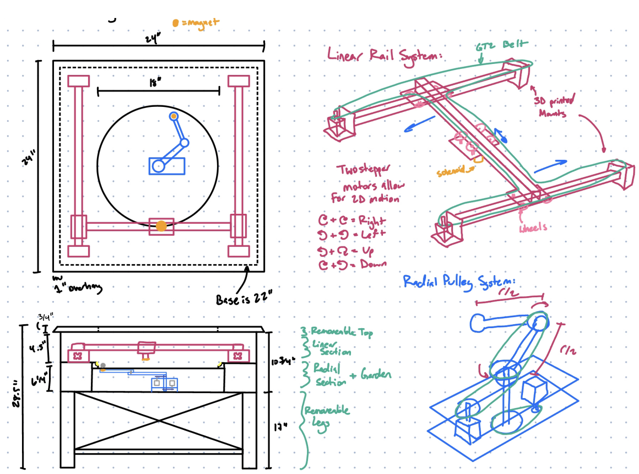

Figure 1. Overhead view of the sand table, including a further look at the linear rail and radial pulley system.

High-Level

Our current design is significantly different from our V2 design, mainly due to weekly TA meetings and brainstorming on how to make our design more efficient. The product of those meetings is this version of the table: A square table with a center circular sand garden piece. The table is split into three functional sections: a linear rail system to be placed above the sand garden so the ball can be picked up, a radial pulley system underneath the sand garden to act as the Ball's main movement, and a high quality table frame to bring the piece together. These three sections were split based on the amount of work required for each, and the ability to work and test each of these blocks independently of one another (that is, until they are all combined at the end of the project). Further detail on how we arrived at these designs will be explained in the following sections.

CARDBOARD PROTOTYPE

Before getting into the detailed descriptions of our functional blocks, we first explain our cardboard prototype. Our cardboard prototype was broken into sections that correspond to functional blocks as stated previously. Pictures of each functional section are included in this document for reference.

Figure 2. Prototype of the radial pulley system below the base.

The bottommost section can be seen in figure 2. The main dual arm mechanism is positioned in the middle of the box, so it can reach the entire circular area of sand. The magnet at the end of this arm will drag the magnetic ball bearing around to create beautiful sand patterns in the layer above. The two boxes represent stepper motors. A more detailed explanation of the mechanics of this system is presented later on in this document.

Figure 3. Prototype of the linear rail system and placement of the kinetic sand garden.

The next section includes the linear rail system and the sand itself. The circular rim of cardboard represents the area where the sand will be contained.

Note that the lower radial system is hidden from view giving the appearance that the ball is moving on its own. The cardboard rails represent the 2D linear axis system. This system positions itself over the sand and grabs the ball via an electromagnet to produce more complicated patterns. When not in use, this system is retracted to the side of the box hidden from view, as seen in figure 3.

Figure 4. Prototype of the final level to our table, the removable top.

The last section is the topmost wood finish of the table, which allows the viewers to enjoy the stunning sand patterns from above. This can be seen in figure 4. Note that the circular hole will be a transparent material, such as glass or acrylic.

We extensively tested our cardboard prototype to ensure that it met all of our performance targets. We created a video highlighting our testing and further explanation on our prototype. [1]

One of the main things we learned from testing was that we should make the casing of the table smaller. Right now, there is still a significant amount of excess space around the circle in the middle, which takes away emphasis on the sand patterns. We also learned that making the table able to be disassembled is very helpful for maintenance and troubleshooting. As a result, we incorporated this into our design for the actual table.

Ultimately, we were satisfied with our prototype's performance. We now proceed into explaining each of the functional blocks more in depth and the respective tests that were performed on them.

BLOCK 1: UPPER LEVEL LINEAR RAIL SYSTEM

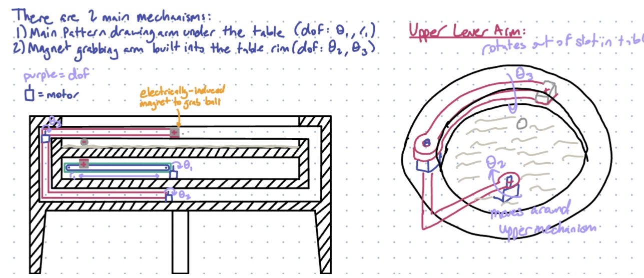

Figure 5. Initial sketches of the upper lever arm/crane.

Initially, we created a system that consisted of an upper lever arm that rotates around the circular sand table (see Figure 5). This would have been the grabbing mechanism that rotates above the table itself, using an electrically controlled magnet to grab the metal ball when it is over it.

We wanted to implement this part into our designs to have a way to pick up the metal ball after a design is done. However, we weren't sure if the material used would be strong enough to support the arm. In order to go forward with these designs, the upper level arm would have to go around and on top of the table which would not fit the aesthetics of our table.

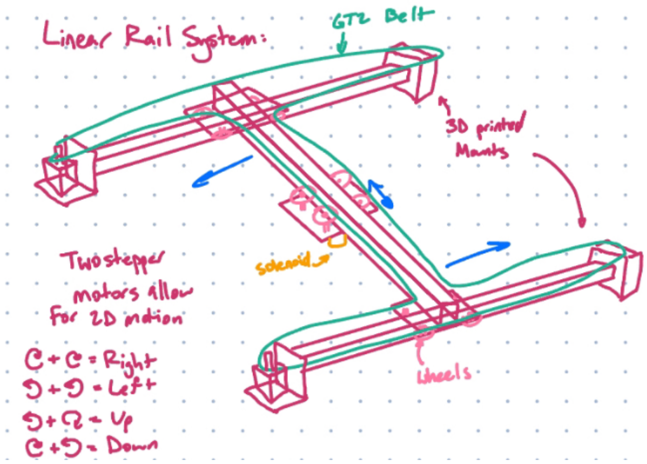

Figure 6. Revised sketches of the linear rail system.

We began to think of different ways to implement this feature into our project. We still wanted a way to move the metal ball after designs were done. As mentioned before, we shifted from having a circular table to a square table with a center circular sand garden piece.

In Figure 6, the linear rail system utilizes a GT2 belt and wheels to control how the magnet in the middle can move both horizontal and vertically. The two stepper motors allow this 2D motion to occur. By modifying our designs to use this linear rail system, we are able to keep our table aesthetically pleasing and tackle mechanisms that are more feasible.

BLOCK 2: LOWER LEVEL RADIAL SYSTEM

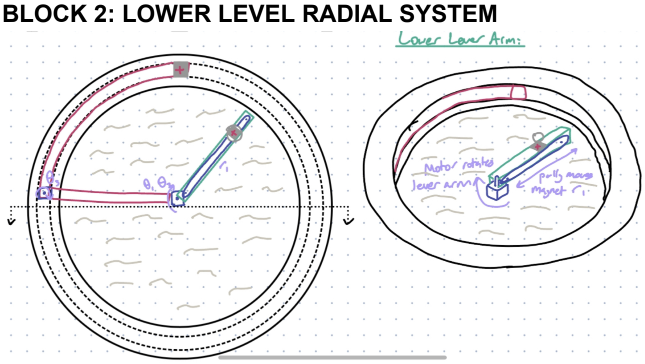

Figure 7. Initial sketches of the radial system.

The first design we created for the lower system can be seen in figure 7. This design involved a lever arm (shown in green) that could rotate radially around the center of the table powered by a stepper motor.

A small carriage carrying the magnet could then run linearly up and down the arm via a belt drive. We really liked this design because of its simplicity of motion. Given a polar coordinate in the form of an angle and a radius, we could easily move the arm and carriage accordingly. However, one of the problems we envisioned was being able to sufficiently support the arm at the center so that it would remain level and not sink toward the end. In addition, we also struggled to think of ways to ensure that the wires would not get tangled due to the radial motion. As a result, we created a new design.

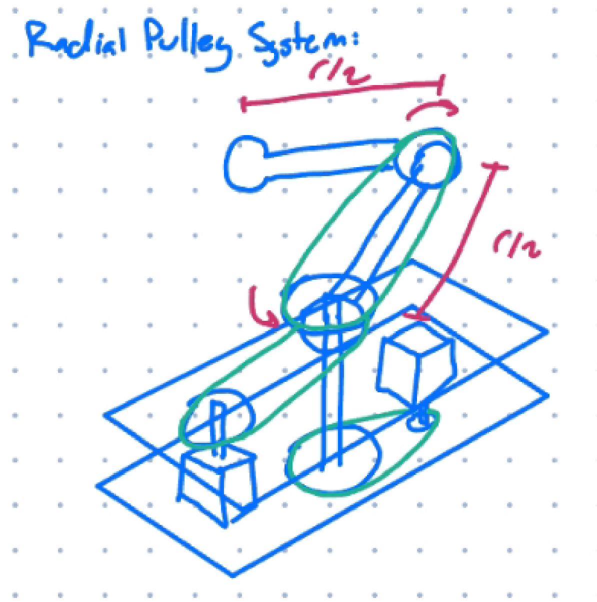

Figure 8. Closer look into the sketches of the mechanisms and scaling of the radial pulley system.

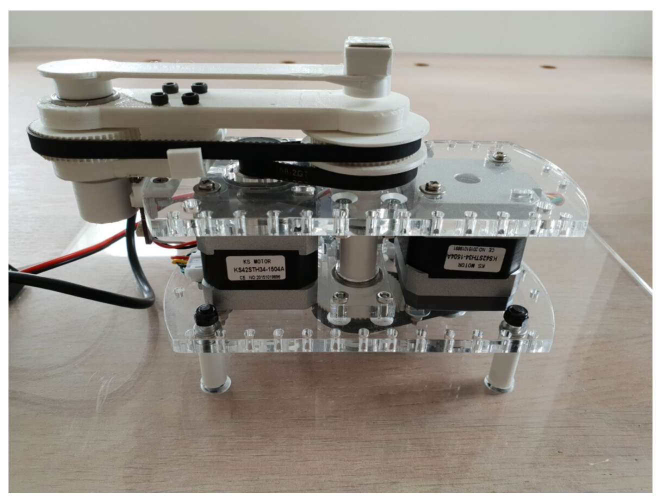

Figure 9. Inspiration for the radial pulley system, *a new sandbot.*

A picture of our second design can be seen in figure 8. The main idea behind this design is to model a human arm. The entire arm apparatus can spin about the axle in the middle, while just the lower arm can bend at the kink or "elbow". Each portion of the arm is controlled by a separate stepper motor and belt drive. The stepper motor facing downwards spins the center axle via a gear on the bottom of the platform, which in turn spins the entire arm apparatus. The stepper motor facing upwards powers the lower arm to rotate about the elbow joint. It does this via a two-belt system, which can be seen more in-depth in figure 7. We did not build the device in figure 9, but rather it served as inspiration for this new design. [2]

By controlling these two stepper motors, we can position the magnet located at the end of the arm into any position within the circular area of the table. Admittedly, the dynamics for movement are not as simple as in our first design. However, we felt this was admissible because this design alleviates the problems in our previous design (i.e. dealing with tangled wires while spinning and having a droopy arm). It's also more space efficient.

We tested this second design by building a cardboard prototype. We recorded a video of us testing all of the table mechanisms. [1] The specific part of testing that addresses the lower radial section starts at 1:50. In the video, we move the arm apparatus to simulate control of the steppers motors. The arm seemed to have good support even when fully extended. Additionally, we confirmed that the arm was able to reach all areas of the circular sand portion. Lastly, we ensured that there was ample room to place other components like a power source, a raspberry pi, and a motor shield.

The result of our evaluation was that this second design passed all of our tests, and thus will be the design we implement moving forward. With this second design we should be able to meet our performance target: that is to satisfy the complexity requirement while still producing elegant sand patterns.

BLOCK 3: THE TABLE FRAME

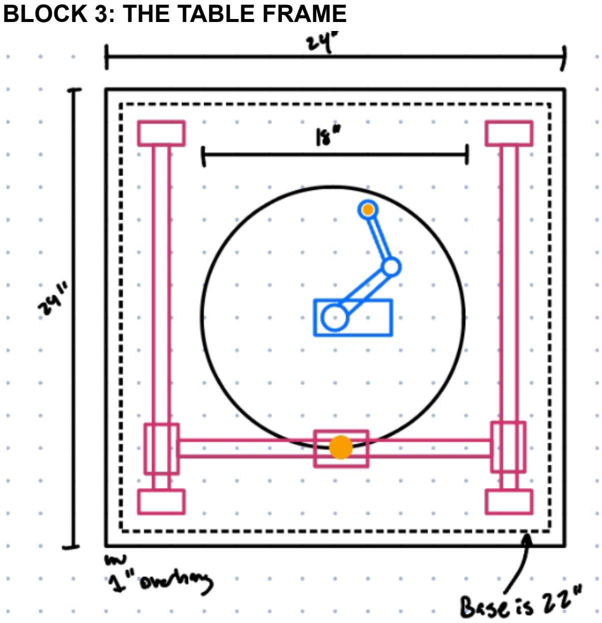

Figure 10. Overhead view sketch of the sand table.

How we arrived at the current design was actually due to us optimizing the movement systems for the magnetic ball. Throughout the design process we had a focus on the circular design of the sand garden table as we felt it lent to more artistic designs than a rectangular table. However we knew that a rectangular table had more space and easier movement systems (a linear system being easier to implement than a radial system).

We decided to merge these two ideas into a square table with a circular garden in the middle. While still looking aesthetically pleasing the square design helps us hide the top linear rail system at the edges of the table. By changing the design of the table we are able to fulfill the complexity requirements of the project without distracting from the main focal point of the sand garden.

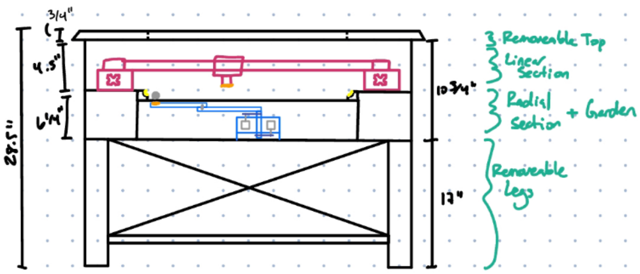

Figure 11. Side view of the sand table, highlighting the three different sections and legs.

The table frame will be split into four sections: A removable top, a box containing the linear rail system, a box containing the radial pulley system with the sand garden, and removable legs. The reason it was decided to make multiple pieces is for device repairability and longevity, because if the machine broke without the user being able to access the insides it would not be able to be maintained over a long lifespan. For how we determined the dimensions, we considered where the table would be placed in normal use. In this case we found the table to be a nice end table for a couch and then found the dimensions of similar couch end tables online. They were often found to be 24" W x 24" L x 24" H. However we decided to make our table slightly taller at 28.5" so the garden can be best viewed from both sitting and standing positions. In addition, using similar pieces of furniture as reference inspired us to add decorative adjustments like the platform and the criss cross wood pieces on the bottom.

REFERENCES

1. Josh Blair. 2023. INFO 4320/5321 Sand Garden Table Cardboard Prototype 1. Retrieved from March 4, 2023 from https://www.youtube.com/watch?v=QMpBKQzrS9g
2. Rob Dobson. 2017. A New SandBot. Retrieved from https://robdobson.com/2018/08/a-new-sandbot/