ORBIT

Theresa Bracht (tgb62)
Cuyler Crandall (csc254)
Yiwen Sun (ys657)

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Contents

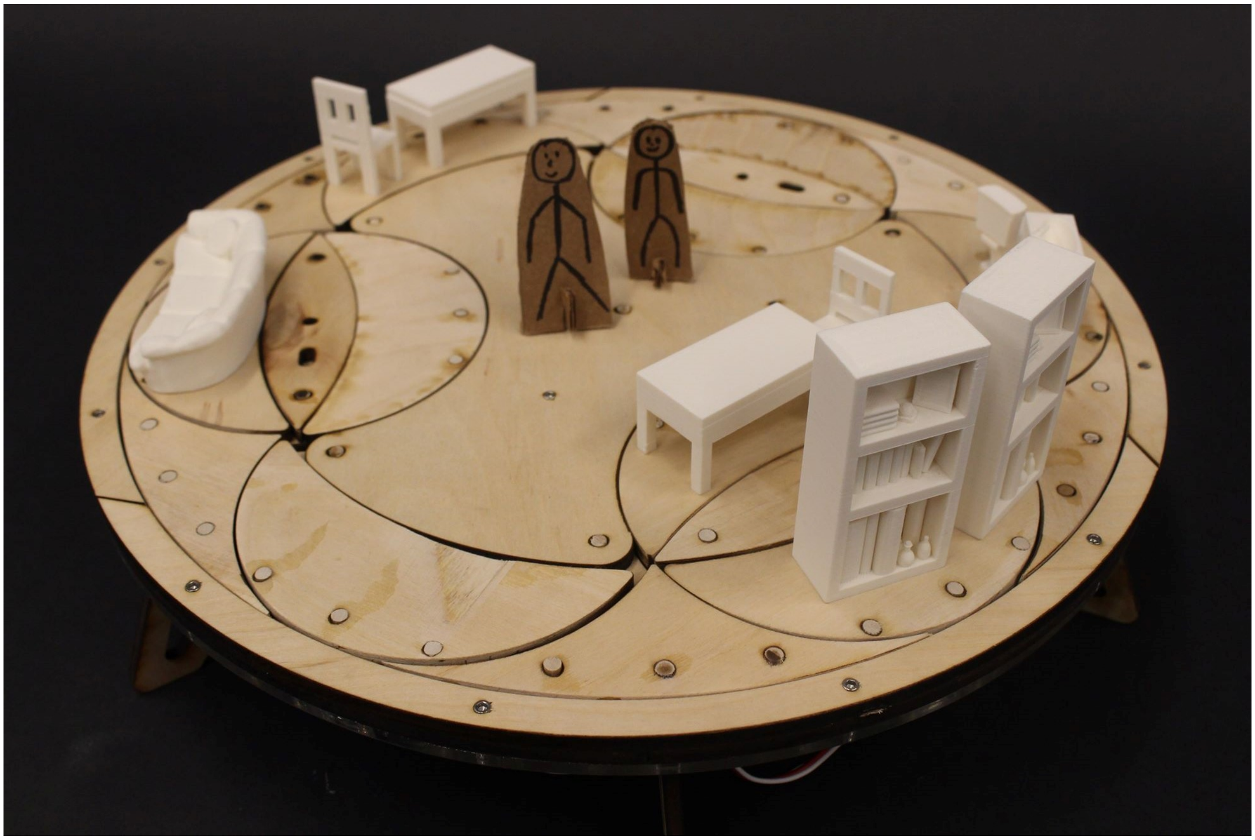

Figure 1: Orbit with furniture and inhabitants

1 Abstract

In this project, we explored the idea of a transformable space that allows different furniture modules to be easily swapped in and out of use. The space consists of a main room, three turntables, and a geared outer ring, that work in unison to shift pieces from wall storage to the living area. The outer ring rotates new modules to the turntables, which are then used to rotate the previous module out of and the new module into view. The modules could use reconfigurable or expandable furniture to further utilize the wall storage and maximize space usage. The designed environment could be used in areas with restricted space or supplies, such as large cities, or remote space habitats.

2 Scenario

It's the year 2034, and the Mars colony is bustling with immigrants from Earth. Zenon, a 27 year old vibrant and absent minded astro-botanist, and her husband Andrew, a 28 year old thoughtful astronomer, have made their home on the upper highlands of the red planet. They, like many Mars inhabitants, live in one of the Orbit pods, connected by a series of tunnels underneath. The costly nature of transport means that brining supplies sturdy enough to withstand the Mars climate is difficult, so the Orbit homes that most Martians live in are designed to have a small footprint and minimal materials, while still being capable of supplying everything the inhabitants need. From a place to sleep, or work, or have company, the Orbit system has everything.

As the sun rises, Zenon and Andrew get out of their bed modules, which fold up and rotate into the walls to swap with a shower and sink, allowing them to get ready. Eventually, those trade out for a kitchen table for breakfast, and then work stations for each of them, saved from their previous day's work. After a long day of work, the stations save their spots, and flip themselves back into the walls. In their place is a couch, and a chair that swings into the center of the room so Zenon and Andrew can relax and catch up, taking in the sight of the double moons through the skylight.

3 Operation

The prototype is a scale model (roughly 1:20 scale), and shows the correct aspect ratio and fit of the floorplan. One of the three central turntables currently outfitted to rotate to switch out one room component for another. This is done using a positional servo controlled using three buttons connected to an Arduino. To ensure the turntable stops at the correct location, the code restricts the movement to a 180 degree range. The two black buttons, shown in Figure 3, allow for clockwise and counterclockwise movement, while the central green button swaps the controls to control the outer ring (not yet functional). LEDs on the breadboard indicate which buttons are currently active. As the servo moves the turntable, the room modules are forced to rotate, as the main room floor constrains its location.

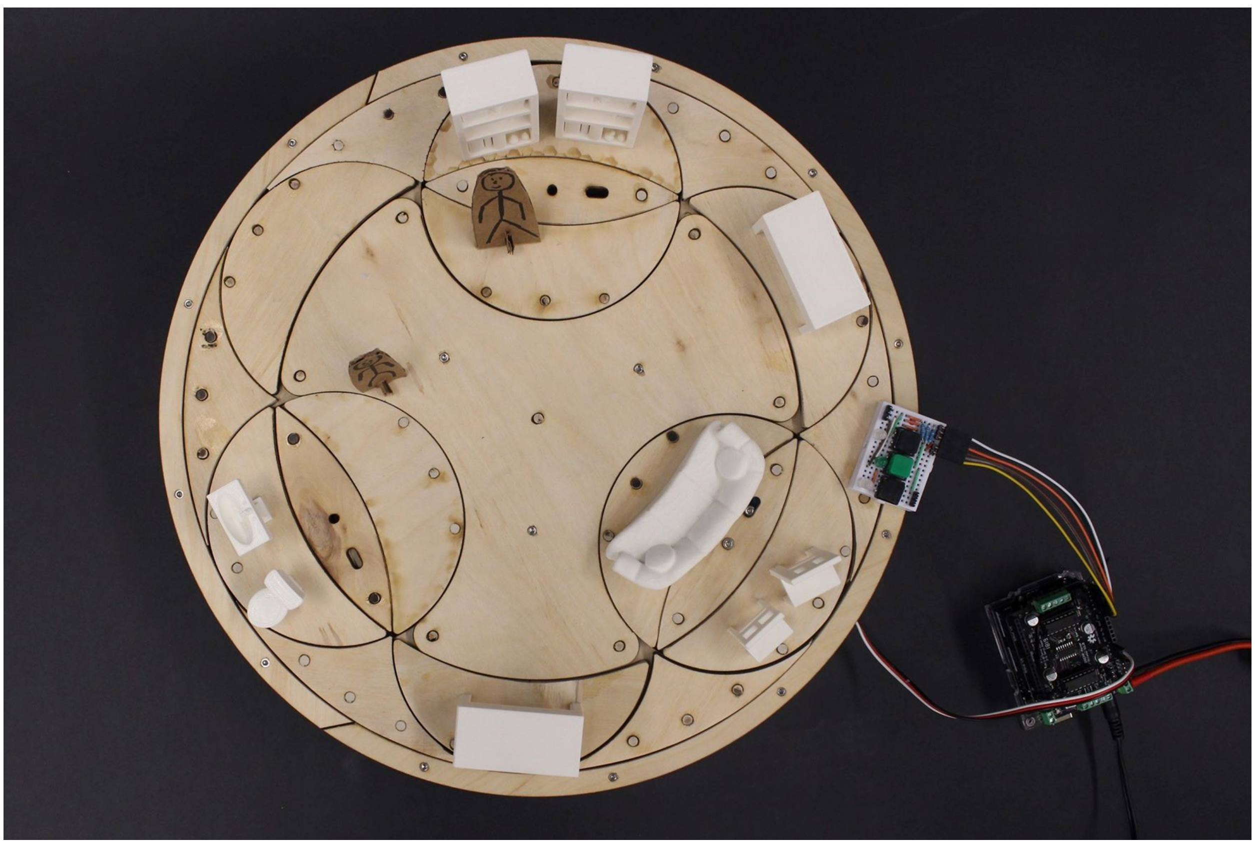

Figure 2: Orbit from above with the control electronics visible

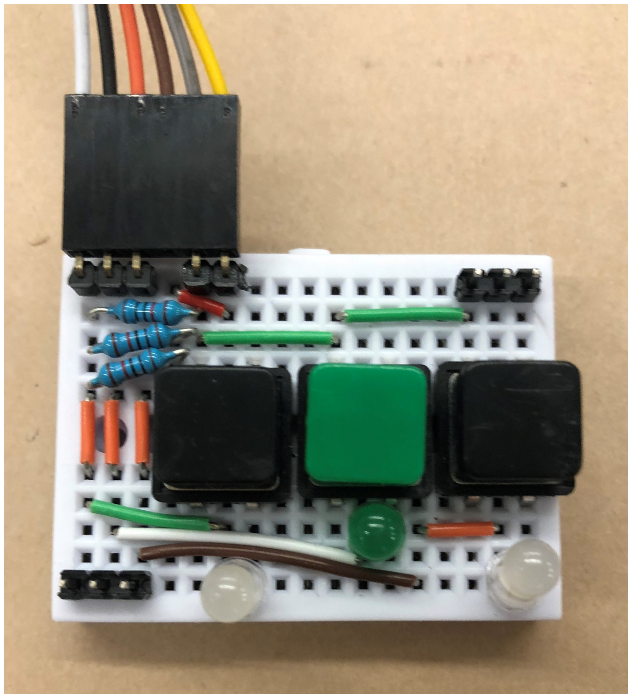

Figure 3: Control buttons on breadboard

The movement of the outer ring would be controlled by an internal gear. The outside ring has the gear profile superimposed on the bottom of both the turntable pieces and the guide pieces. The outer ring is controlled by three continuous rotation servos spaced out evenly on the circle, such that binding between servos is minimized and movement is maintained as the inner gear meshes with a new piece.

4 Construction

The prototype was constructed of laser cut quarter inch plywood and clear acrylic. It consists of three main layers and a base. The bottom layer acts as a platform for the room, as well as mounting for the base and servos. The second layer includes the gear ring and control gears attached to the servos, and the inner turntable pivot pieces, as well as the first layer of the main room floor. The top layer has the final layer of the main room floor, and the floors of the turntables and guide pieces. The servo mounts were 3D printed out of ABS. The gear pieces were assembled to the floor and guide pieces by first aligning using pegs, then using cyanoacrylate adhesive to adhere, and finally sanding down the pegs and outer edges to allow for smooth movement. The acrylic base used heat set inserts to allow it to be screwed onto the wood ring above and the servo mounts, while the legs were adhered using cyanoacrylate adhesive.

Figure 4: Test fit of laser cut parts with alignment pegs

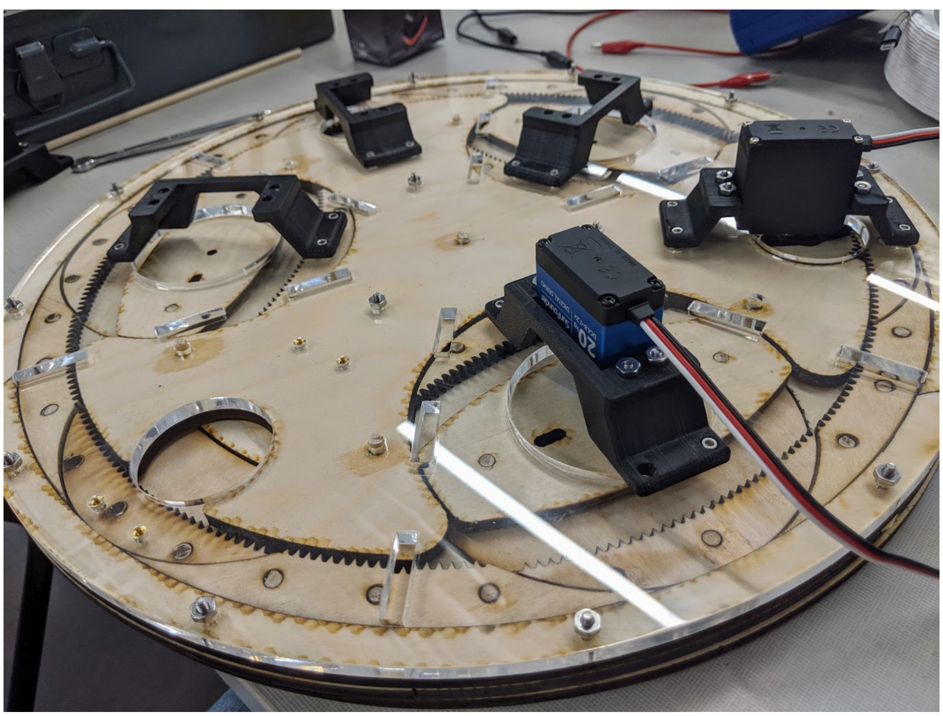

Figure 5: Acrylic bottom mid-assembly

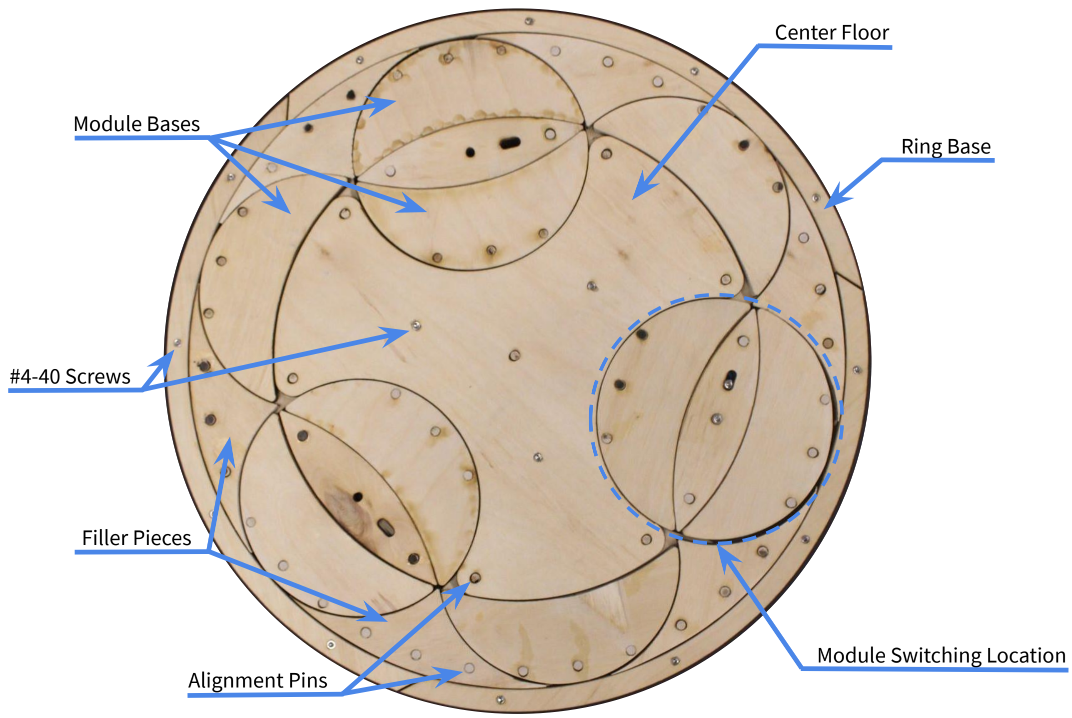

Figure 6: Components on the top side of Orbit

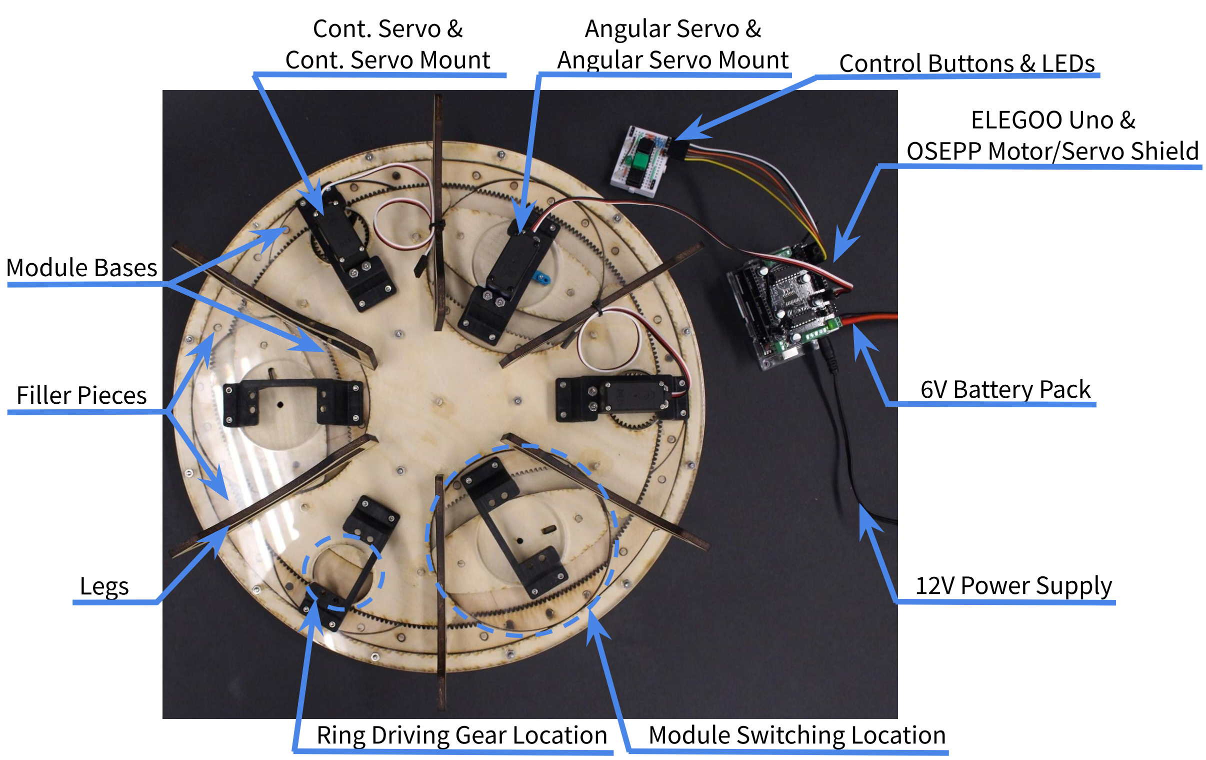

Figure 7: Components on the bottom side of Orbit (and supporting electronics)

5 Discussion

The prototype can smoothly perform the function of switching rooms modules. Even though one of the main purposes of the design is to save space, the outer ring for module storing and turning takes up a lot more space than expected. Relatively large amount of spaces are used as circulation to make sure the modules can rotate successfully. However, transformable furniture like folding out tables and couch enable the users to utilize the circulation space. Empty modules and skylights are added to provide natural light. The entrance of the space is not shown in the prototype. While the rotation of the turntables is able to function (restricted to only one due to limited resources), the outer ring is currently not able to rotate without binding. This is due to the guide and room pieces being able to rotate slightly within the outer ring, which causes binding when they enter engage with the servo gear at the incorrect angle. The pieces had to be sanded down to reduce the friction both within the outer ring rotation and the turntable rotation. However, even this minimal amount of sanding resulted in the unwanted twisting of the pieces.

6 Future Work

For future iterations, we would add a staircase in the middle so that the users can enter the space through the parking garage right underneath the space. Further prototypes could also be constructed that explore different ways to introduce natural light into the space while maximizing wall storage.

The concept of expanding furniture modules could be further explores, and applied to furniture pieces such as beds, sitting areas, tables or workbenches, and more. Specifically, unused living spaces that could be stored during the day in a compact form while work is being completed could be further fleshed out.

A change in materials could also address the binding issues in the movement of the outer ring. Using materials with lower coefficients of friction for the outer/inner ring which guides the modules would lower the resistance caused by the module being torqued out of alignment while a stronger material being used for gear teeth would allow for the servos to force the modules past sticking points without risking shearing off the teeth. As such, a future iteration should probably utilize Delrin or aluminum for gears and HDPE for the guide. Additionally, driving the modules and fillers with a *external* gear profile (as opposed to the currently-implemented external profile) would likely reduce the chance of binding since the rotation of the gear and the rotation for switching modules would have opposite concavity. Such a design had been considered for this prototype, but an internal gear was selected because of its cleaner packaging (all components within the internal ring), since performance was assumed to still be adequate.

A Appendix

A.1 Related Links

A video of Orbit in action can be found on YouTube here.
The CAD files for our model are available on GrabCAD here.
The Arduino code for our project is available on Github here.

A.2 Bill of Materials

Type	Component	Unit	Qty.
Custom Parts	RingBase_BottomSheet	each	1
Custom Parts	RingBase_RingSlice	each	6
Custom Parts	CenterFloor_Bottom	each	1
Custom Parts	CenterFloor_Top	each	1
Custom Parts	ModuleBase_Bottom	each	9
Custom Parts	ModuleBase_Top	each	9
Custom Parts	RingFiller_Bottom	each	6
Custom Parts	RingFiller_Top	each	6
Custom Parts	ModuleSpinner_Top	each	3
Custom Parts	ModuleSpinner_Bottom	each	3
Custom Parts	Leg	each	6
Custom Parts	Angular Servo Mount	each	3
Custom Parts	Continuous Servo Mount	each	3
Electronics	ELEGOO Uno	each	1
Electronics	OSEPP Motor/Servo Shield	each	1
Electronics	SunFounder SF3218MG Angular Servo	each	1
Electronics	KOOKYE Continuous Rotation Servo	each	2
Electronics	12v Power Supply	each	1
Electronics	6v Battery Pack	each	1
Electronics	Mini. Breadboard	each	1
Electronics	Breadboard Pushbuttons	each	3
Electronics	LEDs	each	3
Electronics	10kΩ Resistors	each	3
Electronics	6 Pin MF Connector	each	1
Electronics	Assorted Wires/Adapters	—	—
Hardware	#4-40, 0.75" SHCS	each	15
Hardware	#4-40, 0.3125" SHCS	each	24
Hardware	#4-40, 0.3125" FHCS	each	12
Hardware	M3, 16mm SHCS	each	2
Hardware	#4-40 Nut	each	27
Hardware	#4-40 Heat-Set Insert	each	24
Raw Materials	0.25" Plywood	ft^2	8
Raw Materials	0.25" Acrylic	ft^2	1.5
Raw Materials	0.1875" Wooden Dowel	each	2
Raw Materials	Cyanoacrylate Adhesive	—	—

A.3 Arduino Code

```
#include <Servo.h>

int clockwise = A5;
int counterclockwise = A3;
int modeButtom = A4;
bool cwState = false;
bool ccwState = false;
bool modeState = false;
Servo contServo;
Servo angServo;
int pos1 = 22;
int pos2 = 160;;
int pos = pos1;


void setup() {
  // Initialize serial communication at 9600 bits per second:
  Serial.begin(9600);

  // Initializes pins to input/output and to needed values
  pinMode(clockwise, INPUT);
  pinMode(counterclockwise, INPUT);
  pinMode(modeButtom, INPUT);
  pinMode(A1,OUTPUT);
  digitalWrite(A1,HIGH);
  pinMode(A0,OUTPUT);
  digitalWrite(A0,LOW);

  // Initializes servo output pins (of the OSEPP Shield)
  contServo.attach(9);
  angServo.attach(10);

  //Initializes position of angular servo (watch your fingers!)
  angServo.write(pos1);
}

void loop() {
  // Read input pins
  for (int i=0; i<5; i++){
    cwState = cwState || (digitalRead(clockwise)==HIGH);
    ccwState = ccwState || (digitalRead(counterclockwise)==HIGH);
    modeState = modeState || (digitalRead(modeButtom)==HIGH);
    delay(5);
  }

  //Cont. Servo Values: Forward = 180, Reverse = 0, Stop = 90
```

```
  //Ang. Servo Values: 22 or 158 (only)

  if ((cwState && ccwState) || (!cwState && !ccwState)){
    // If both (or neither) directions, do nothing
    contServo.write(90); //Stops continuous servo

  } else if (!modeState) {
    //If the mode button is pressed, control angular servo
    contServo.write(90); //Stops continuous servo
    if (cwState && (pos < pos2)) {
      pos += 1;
      angServo.write(pos);
      Serial.println("Rotating␣switcher␣cw");
    }
    if (ccwState && (pos > pos1)) {
      pos -= 1;
      angServo.write(pos);
      Serial.println("Rotating␣switcher␣ccw");
    }
  } else if ((pos == pos1) || (pos == pos2)) {
    // If mode button isn't pressed, control the outer ring
    // ONLY IF ANGULAR SERVO IS IN CORRECT POSITION
    if (cwState) {
      contServo.write(180);
      Serial.println("Rotating␣ring␣cw");
    }
    if (ccwState) {
      contServo.write(0);
      Serial.println("Rotating␣ring␣ccw");
    }
  }

  // Reset pin states
  cwState = false;
  ccwState = false;
  modeState = false;

}
```