Replication of System: explorations in kinetic sculpture

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Introduction

Replication of System is the culmination of many years of conceptual thought and research. The idea of recreating organic life and behaviors through art and technology forms the foundation of my work. This subject matter is still primitive and is difficult to advance with limited resources. My work discusses infinity in terms of a spatial void and repetition in technology arts as they relate to evolutionary nature. These themes began as a personal curiosity in natural sciences; however, many artistic influences have shaped my work. These influences include but are not limited to: Ken Rinaldo, Peter Vogel, M.C. Esher and Karl Sim. These artists have similar subject matters or have inspired the technological solutions in my projects. The mechanical system in my Bendybots project is one such solution. Bendybots consists of twenty small robots. The robots were made out of simple materials and electronics that featured Flexinol wire as the movement driver for each robot's mechanics. Custom mechanisms were also designed and used in my Infinity Gliders project. Infinity Gliders consisted of small robots, a two-way security mirror, a metal-backed glass mirror and white foamcore enclosure. Natural magnets kept the robots lightly attached to the metal-backed glass mirror. Placing the two mirrors parallel to one another creates an endless spatial void through infinitely repeating images.

Repetition continued to inspire me and was apparent in my thesis project. Replication of System is an interactive electronic sculpture. The sculpture used intercellular communication between brain cells as a functional model. Replication of System was constructed out of readily available crafting materials and electronics. I collaborated with a computer scientist from the Electronic Visualization Laboratory to aid in programming the project. This collaboration culminated in a highly successful thesis show. The show spanned two days and was meticulously designed and installed by myself. Bendybots, Infinity Gliders and Replication of System were all positioned to have ample viewing space in the north gallery; located in the Art and Design Hall, CUPPA building, on the University of Illinois at Chicago campus.

Conceptual Ideas

Over the past three years, my artwork has gone from scattered subject matter and mismatched mediums to a solid body of work rooted in technology. My conceptual depth has developed and expanded through originality. The pieces displayed at my thesis show all held common threads of philosophical and artistic ideas. The first, being how to replicate the behaviors of organic life through art and technology. The second would be how to explore the conceptual correlations between technology and the expanding universe. Lastly is the use of repetition in art. Bendybots were the embodiment of replicating organic life and instinctual behaviors. Repetition is very obvious in the Bendybots. The project makes use of twenty identical robots in a straight line. “Used dynamically in art, repetition can go beyond rote articulation to invoke experience and memory, in turn involving reproduction and reflection” (Levy, 1996). Levy’s idea was very active in the Bendybot’s audience experiences. Almost a week after the thesis show, friends were still mentioning how much they enjoyed the Bendybots. The robots used electronics and simplistic materials to recreate oceanic plants that sway in water currents. These robots metaphorically spoke about the future of organic robotics movement. Presently, the most fluid robotic replication of organic movement are biomedical (highly experimental) limbs made for amputees. This technology is not accessible for use in creature recreation. It is used for humans to control as an extension of themselves. Therefore, I was inspired to use biomedical electronics and re-purpose them into artistic expressions.

Infinity Gliders takes advantage of both the organic life and expanding universe ideas. I feel that much of society is very centered on their immediate spaces and lives. Therefore, I wanted the Infinity Gliders to remind the audience of the infinite world around us. The universe revolves around something much larger than personal relationships, family events or work deadlines. Infinity Gliders asks its audience to stop, let go and enjoy a moment of endless thoughts.

Artwork-to-audience communication is emphasized in my thesis project, Replication of System. Keeping in theme, the project mimics the communication system between brain cells. The project uses many different sound sensors, electronics and programs to create an interactive sculpture. Replication of System incorporates all original conceptual elements. The project provides the illusion of evolving and expanding out into environmental space. This reaching for the unknown opens up its integrated interactivity to the audience. The project's interactions replicate how a brain cell reads stimulus and then communicates it to the nucleus. The nucleus then decides how to react. Lastly, is the concept of repetition. Similar to the natural design in nature, the project uses repetition as a means of balance and for eye pleasing aesthetics. "Art, nature and pure mathematics can have a way of proceeding along analogous and sometimes converging paths" (Owen, 2007). One disagreement I have with the previous statement is that it's not "…sometimes converging paths" but always. I believe art, nature and the mathematics are all dependent upon each other. Mankind has developed many explanations for nature and life. The most reliable category of explanation is Mathematics. The mathematics of Nature are visible in all mediums of life. One example is bilateral symmetry, a natural pattern phenomenon which is explained through mathematics. "Bilateral Symmetry will divide an organism into roughly mirror image halves." ("Bilateral symmetry", 2008) (Figure 1) On Wikipedia.org, *Bilateral symmetry* is further described by using a geometrical shape and dividing it on its axes of symmetry, "…if the shape were to be folded in half over the axis, the two halves would be identical: the two halves are each other's mirror image. Thus a square has four axes of symmetry, because there are four different ways to fold it and have

Figure 1. Leaf showing symmetry.

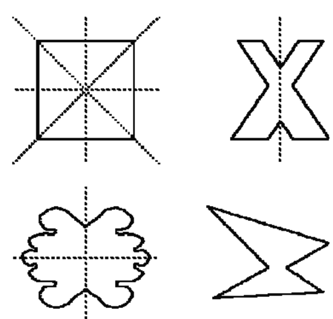


Figure 2. 2D Shapes showing symmetry.

the edges all match. A circle has infinitely many axes of symmetry, for the same reason." ("Reflection symmetry", 2008) (Figure 2) Much of nature can be replicated through mathematics, it cannot be exactly duplicated. Nature has a system of creation but no creature or plant on this planet is perfectly symmetrical. This repetition of patterns is apparent in all my artistic endeavors. There are an infinite amount of natural and mathematical patterning examples ranging from art, to nature, to societies, to space, to technology, etc. These kinds of concepts have largely influences me and my body of work.

Influences

In addition to mathematics, a variety of sciences have influenced me and my artwork over many years. Biology, the study of organisms, has become a major element in my current visual aesthetics. Bendybots are an example of using art to discover and imagine technological biology. Bendybots uses repetition in nature and movement as its inspirational concept. Replication of System, is a cross between biological communication in brain cells and the endless expanding reach of space. Another scientific influence is the endless discoveries in outer space. That ever expanding search for new space objects and how the void of space relates to us, as humans, has captivated me for many years. Space visualization has not only influenced my thesis project but was the conceptual back bone for Infinity Gliders.

A variety of incredible artists have inspired me in my pursuit of my MFA degree. Some of the most influential are the following: M.C. Escher, Ken Rinaldo, Karl Sim, Peter Vogel and many others. Specifically, each inspiration can be seen in my artworks. First, M.C. Escher was a huge resource for me when I was designing Infinity Gliders. In Escher's work, he was interested in the concept of infinity and impossible architectural construction. (Figure 3)

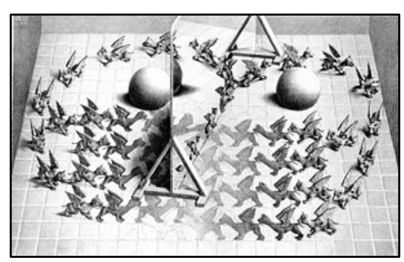


Figure 3. "Magic Mirror", Esher

“Escher's work has a strong mathematical component, and more than a few of the worlds which he drew are built around impossible objects such as the Necker cube and the Penrose triangle” (“M.C. Escher”, 2008). A Necker cube is a line drawing of a cube with never ending insides. (“Necker cube”, 2008) What has always drawn me to Escher’s work is the philosophical thought the work exuberates. I see an infinite trick of optics which forces the mind to repeatedly rethink the scene again and again. Escher’s work creates an endless vortex of thought. This void of logic and thought is what inspired the look and conceptual theory behind Infinity Gliders. I will discuss the technical aspects of the Infinity Gliders later in this paper.

Bendybots took inspiration from two artists, Ken Rinaldo and Karl Sims. Studying Rinaldo’s pulley-system robots in Autopoiesis helped me realize a solution to creating the movement in each robot. Rinaldo’s robots are much bigger and much more sophisticated than mine, but the concept of artificial life and using a pulley system was influential to me. Artificial intelligence is the main research in almost all of Karl Sims’s artwork (Figure 4). Instead of creating physical intelligent objects, he created original primitive virtual creatures and studied their discovery of movement. Sims was very interested in creating evolution within programmed virtual creatures as a form of education and study. Evolved Virtual Creatures is “...a research project involving simulated Darwinian evolutions of virtual block creatures” (“Sims”, 1994). All of these projects taught me different interesting ways to solve problems and inspired me with my own work.

Figure 4. “Evolved Virtual Creatures” Sim

In my thesis project, I again called on all these influences to figure out how I was going to create Replication of System. Rinaldo was a staple resource in designing my semi-intelligent interaction

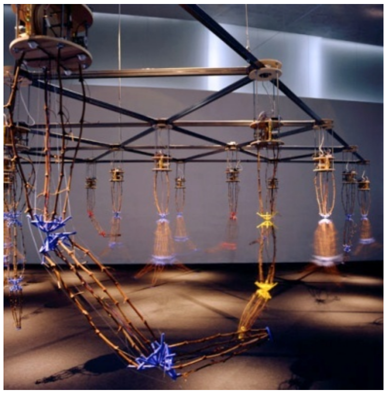


Figure 5. “Autopoiesis” Rinaldo.

and communication system for the project (Figure 5). Rinaldo's Autopoiesis "breaks out of standard interfaces (mouse) and playback methodologies (CRT) and presents an interactive environment, which is immersive, detailed and able to evolve in real time by utilizing feedback and interaction from audience/participant members" ("Rinaldo", 2000). This type of rapid response was critical in keeping the interest of my tech savvy audience.

With the interaction design set, I then needed to decide what kind of aesthetics I wanted the project to have. I could have made a solid primitive physical object using Karl Sim's creature as a spring board, but my committee and I did not feel that was original enough. So, we looked further back into art technology history and found Peter Vogel. Vogel began as a German electronics artist in 1969. His works were open-air circuits complete with fully functioning electronics (Figure 6). The pieces are painstakingly exact from a graphical perspective and mind-boggling from an electronics perspective. However, Vogel displays a sheer appreciation for the components he uses to create the sculptures. He acknowledges the normally hidden medium driving the functionality of the project by displaying all the components. "The interactive sensitivity of his constructions utilizes photocells and microphones that react to spectators, creating an experience of seeing and hearing unique improvisations triggered by light and shadow" ("Bitforms", 2007). His interactive open-air circuit was the right kind of visual inspiration I needed for my sculpture. Leaving the materials and so called "electronic guts" of the project on display to the public was the right direction for my thesis. In the following chapter, one will see that I did not keep the painstaking graphical layout of the components as Vogel did.

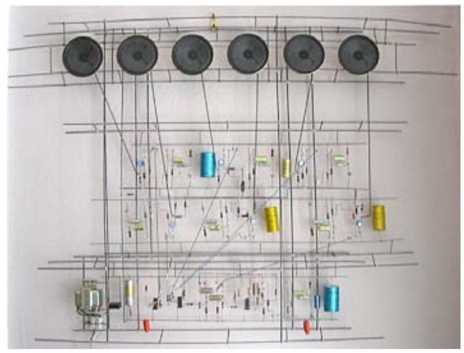
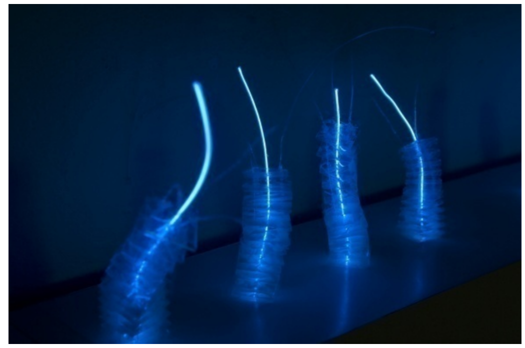


Figure 6. "Two different series" Vogel.

Individual Projects

Bendy Bots



BendyBots are a series of twenty animatronic creatures. The project is an imaginative daydream about what future mergers of technology and nature could produce. The robots were inspired by oceanic plant life. Each robot was on a Flexinol mechanism. I chose to echo the feel of an ocean by incorporating glowing blue electroluminescent wires into the center of the robots' wormlike bodies. The robots sit on a white rectangular shelf, constantly swaying from right to left, as though an unseen current was moving them. I designed small mechanics for each Bendybot. I constructed the mechanisms to have one static resistance arm and two active arms that could pull independently of each other, while still being on one removable unit. I tried to design the project so it could be easily accessible to have the mechanisms replaced, while still being light enough to affordably ship across the country. The entire project was created from easily accessible materials. The housing was carefully constructed from white formcore. Each Bendybot is comprised of two halves, the publicly visible bots and the internal mechanisms driving the bots. The publicly visible part was created from strips of clear plastic and then folded, accordion style, for the body with three pieces of fishing line run up along the edges. A single piece of electroluminescent wire runs up the center of the body. As one can see in figure 7, the internal mechanisms were created out of a small piece of Plexiglas and foamcore for the arms with metal screws and Flexinol wire. Instead of using noisy micro servos motors, I found a silent heat-activated wire to be a better choice. Muscle wire (aka: Nitinol/Flexinol wire) is a metal material which uses the heat of an

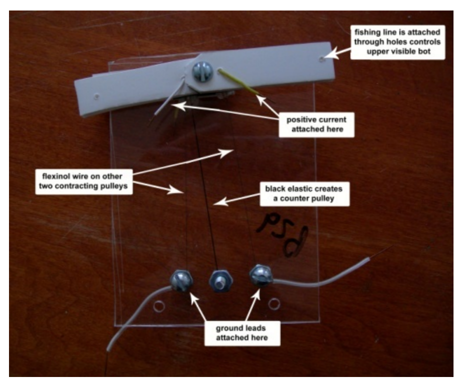


Figure 7.   Bendybot mechanisms.

electrical impulse to contract the metal. “Nitinol belongs to a class of materials called Shaped Memory Alloys (SMA). SMA's have interesting mechanical properties” (“Nitinol”, 2007). SMA metals have been a popular material in bio-mechanical design and engineering. “Nitinol's physical function resembles biological muscle; when activated it contracts. To activate Nitinol it is heated above its transition temperature (typically 70C). An electric current may be passed through the wire to heat it electrically. As the material cools it can be stretched back it its original length” (“Nitinol”, 2007). The most problematic part of making these mechanisms was trying to get the flexinol wire to stay connected between the fishing line and the electrically charged screws. Since the flexinol wire is thin and cannot be soldered to metal connectors because of low heat tolerance, it was very difficult finding a solution. That solution was using hot glue to attach the muscle wire to small solid core wire pieces and finally soldering current carrying wire to those small connector wires. In my application of the muscle wire, the wire takes on a spring like behavior.

A Wiring micro-controller board sends out electrical impulses. These impulses are sent in one second intervals. The electrical impulse sent out is limited to 2 volts; however, my flexinol wires needed 4.5 volts to contract. I created a supplementary electronic component board. This extra board had 40 reed relays on it and each reed relay acted as a switch. The wiring board’s 2 volts would trigger the reed relays to open and allow 4.5 volts to activate the muscle wires which started the mechanisms. Since only one arm would be active, the other arm would be resting and the static resistance arm would become counter-springs. When the flexinol wire started to cool the other straight arms would slowly pull the active arm upright or back to an at rest position. Simple programming code controlled all of the robots’ movements.

Code example:

Programming code was created in collaboration with, EVL Phd candidate, Ratko Jagodic.

The code starts by telling the wiring board that we are using forty output pins that are divided into right side and left side pins. These left and right sets of pins correspond to the right side arms and left side arms on each robot.

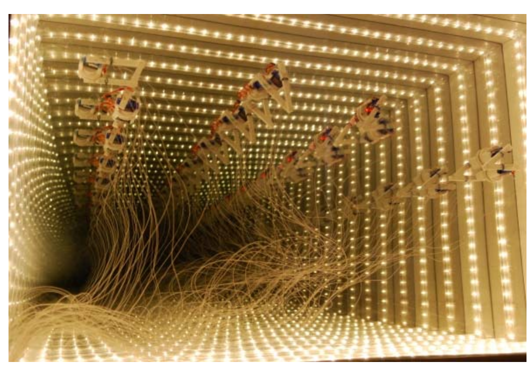
```
int pin;
int leftPins[] = {0,2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38};
int rightPins[] = {1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31,33,35,37,39};
int numPins = 40;
int powerOnDelay = 1000; // in milliseconds
void bend_left()
{
  for(pin=0; pin < numPins; pin++)
  {
     digitalWrite(leftPins[pin], HIGH);
     delay(powerOnDelay);
     digitalWrite(leftPins[pin], LOW);
  }
}
void bend_right()
{
  for(pin=numPins-1; pin >= 0; pin--)
  {
     digitalWrite(rightPins[pin], HIGH);
     delay(powerOnDelay);
     digitalWrite(rightPins[pin], LOW);
  }
}
void setup()
{
 for(pin = 0; pin < numPins; pin++)     //int pin is linked here to the 0-37 pins on the borad
 {
    pinMode(rightPins[pin], OUTPUT);    // digital pins 0 to 37 as OUTPUTS
    pinMode(leftPins[pin], OUTPUT);
 }
}
```

Now the wiring board can continuously loop through the code, creating a waving motion in the project.

```
void loop()
{
 bend_right();
 bend_left();
}
```

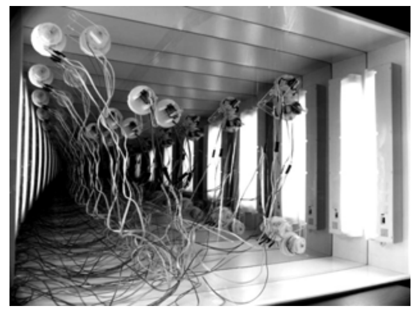
Infinity Gliders

Infinity Gliders is a tangible representation of spatial infinity: small mirror-climbing robots represent the hypothetical life existing between the physical world and an endless spatial void. I used a two-way mirror and a glass mirror to perpetuate an infinite trail of images.



Similar to Bendybots, I designed this project to be easily installed and packaged for shipping. I used simple building materials to create an expansive illusion of space. The housing is made of white foamcore with half inch grooves cut into the front and back of the interior. These grooves lock the mirrors in place. A large groove was also carved into the interior walls for a string of 10ft gold rope lighting. I chose the gold lighting to soften the atmosphere in the installation.

The first rendition of Infinity Gliders had a very different lighting setup (Figure 8). I have had many comments to change the lighting back to the prototype lighting. I understand the former lighting is quite interesting; however, the institutional florescent lighting is not the look or feel I wanted in the final piece. The project is discussing the spatial endlessness existing in the universe, which runs contrary to the feelings evoked by the institutional lighting.



Figrue 8. First Infinity Gliders prototype.

The robotic creatures inhabiting the installation are created from the smallest easily accessible materials and components available to me. Each robot has two Micro servo motors. Foamcore arms are attached to the motors which are connected on one end. These two motorized arms move the robots in a gliding motion across the glass mirror surface (Figure 9). Small natural magnets are buried in a disk of foamcore underneath each motor. A large thin sheet of aluminum is hidden behind the back of the glass mirror to keep the magnets suspended. The importance of weight balance became a very important issue with this project. I had to carefully design a robot that could have all the components needed to move but still be light enough so that the magnets were strong enough to defy gravity. The robot has four extra thin pieces of coated

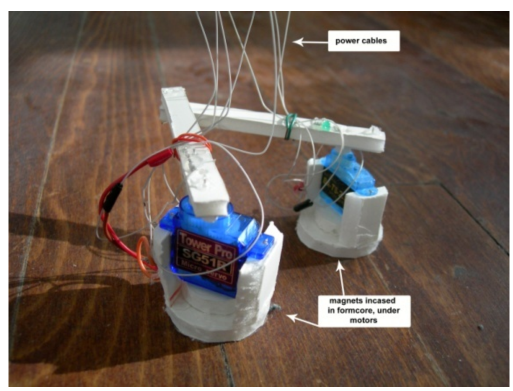


Figure 9. Glider bots.

wire hanging down from them. These spaghetti-like wires carry all the electricity needed to run each robot. The wires run underneath the project to a hidden compartment. This compartment has a Wiring micro-controller board which is controlling each robot. The program turns the motors on or off and reverses the motors' polarities causing them to move in the opposite direction.

Code example:

Programming code was created in collaboration with, EVL Phd candidate, Ratko Jagodic.

```
#include <Servo.h>

#define RUN 1
#define START 2
#define NUM_GLIDERS 2

Servo gliders[2];
long now;  //represents the current time in ms
int pos[2];
int lastDir[2];
int currDir[2];
int state[2];
long nextMove[2];

void setup()
{
  gliders = {Servo(), Servo()}
  pos = {0,0};
  lastDir = {0,0};
  currDir = {-1,-1};
  nextMove = {0,0};
  state = {RUN, RUN};

  gliders[0].attach(32);
  gliders[1].attach(34);

  gliders[0].write(0)
  gliders[1].write(0)
}

void loop()
{
  int i;
  for(i=0; i<NUM_GLIDERS; i++)
  {
        nextStep(millis(), i);
  }
  delay(15);
}

void nextStep(long now, int i)
{
  if (((pos[i] >= 100 && currDir[i]==1) || (pos[i] <= 0) && currDir[i]==-1) && state[i] == RUN) {
    lastDir[i] = currDir[i];
    currDir[i] = 0;
    state[i] = START;
```

```
    // set the next time to move
    nextMove[i] = now+1000; //long(now + random(1000, 2000));
  }

  // start the movement
  else if(now >= nextMove[i] && state[i] == START) {
    currDir[i] = lastDir[i] * (-1);  // invert previous direction
    state[i] = RUN;
  }

  // just move
  else if(state[i] == RUN)
  {
    pos[i] += currDir[i];
    gliders[i].write(pos[i]);
  }
}
```

Video documentation of Infinity Gliders was on display as part of my thesis show. The video was rendered specifically for 4K high resolution tiled displays and is being used as a demonstration video at the Electronic Visualization Laboratory.

Replication of System

Replication of System is a synthetic fungus-like sculpture which passively interacts with its surrounding environment. The project was inspired by cellular communication systems found in human brain cells. Similar to brain cells, the project waits for users to stimulate sensors positioned on out-stretched appendages, and then reacts with visual and audio feedback. This project was also designed to be easily installed and packaged for shipping.

I created the entire project from simple crafting supplies and electronic components. Two large metal rings create the center structure of the sculpture (Figure 10). The metal fungal appearance was created from 4000 feet of copper colored jewelry wire. The very center of the project is a red pulsing core. The core is created from adhering ten red super

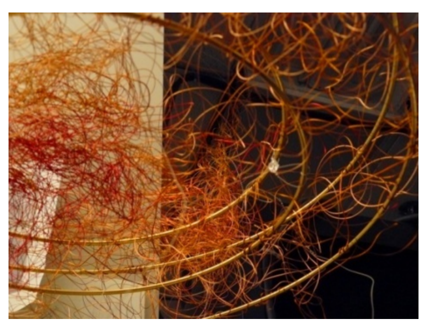


Figure 10. Up close shot of metal rings on thesis

bright LEDs to a clear plastic ball. Outside the core but still inside the metal rings are clusters of high-powered white LEDs. Each white cluster is attached at the base of the sound sensing tentacles. Each tentacle has a set of four super bright blue LEDs. I decided to create a color palette which descended from red hot to cool blue. Many biological science visualizations use this same color scheme.

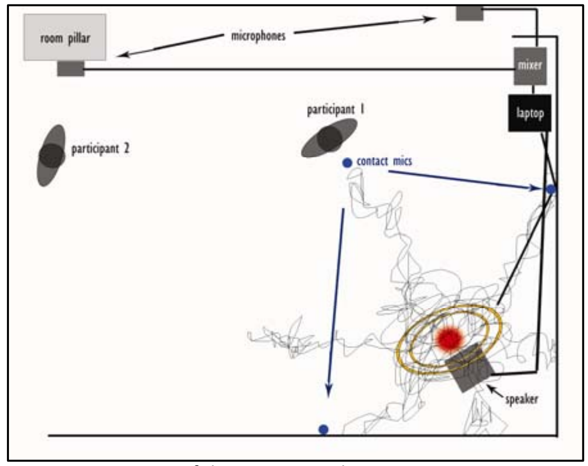


Figure 11. Diagram of thesis space and interaction.

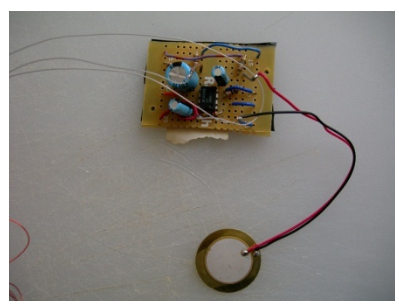


Figure 12. Up close shot of contact mics.

The project uses two distinct sets of sound monitoring systems. Since the project has two microphone systems, it creates an immediate listening space and an environmental listening space (Figure 11). When a participant enters the project's immediate space, a dramatically animated LED sequence is expressed. A single contact microphone component is placed on the floor directly in front of the project (Figure 12). The floor contact microphones are delicately integrated into the sculpture's out-stretched tentacles. The other two walls of the room's corner are identical contact microphone components. The wall contact microphones are stimulated by light tapping on the wall. Each contact microphone causes the associated tentacle to react with an LED sequence. Thus, the sculpture warns to the audience members interacting with the piece that they are getting to close. Since the project is reliant on the room as an environment, the project must also be aware of what is happening in the surrounding spaces of the room. Cardioid, or table, microphones are placed throughout the room. These microphones inform the project about audience members in its outer environment. The project then records the sounds and regurgitates the noises back to the participants. I accomplished this live sound feed by having an open USB port in and out of the control laptop. Then, I used the ESS sound library and serial function in Processing. Processing captured the noise level in the outer environment and passed the information on to the two micro-controller boards. This is displayed through small spawning tentacles. Resembling the larger structure, these spawning tentacles cause the project to appear as if it is reproducing itself (Figure 13). These tentacles visually display the room noise level through a simple blue LED sequence. The louder the environment gets, the faster the spawning tentacles' LED sequences move. When the room is quiet, the spawning tentacle LED sequences move at a slower pace. When the sculpture does not hear any stimuli, the project displays a calm pulsing LED sequence with an accompanying pulsing bass sound.

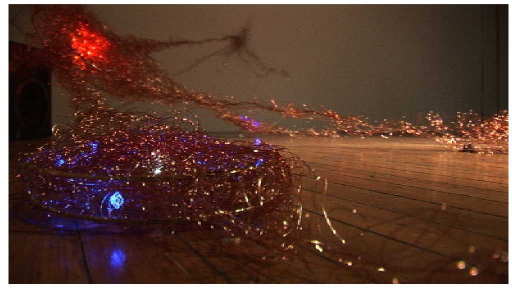


Figure 13. Up close of spawning arms.

The project is controlled by a complex set of cross platform software tools. First, a laptop collects and communicates with all the table microphones and two open-source micro-controller boards (Figure 14). The two micro-controller boards, Arduino and Wiring, receive information from the laptop, and send out electrical impulses which control corresponding LED sequences. The Arduino board controls the red core and spawning cores on the project. The Wiring board controls the core's yellow LED ring, the tentacles' LED sequences and the contact microphone LED reaction sequences. In Figure 15, I have a spatial diagram which displays the elements previously described.

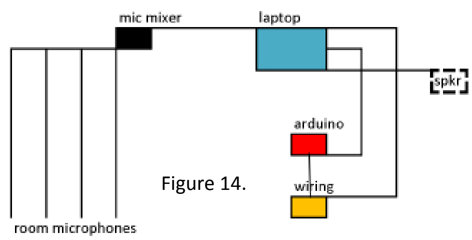


Figure 14.

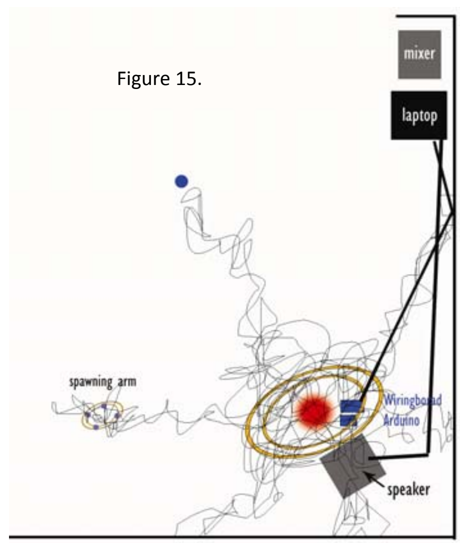


Figure 15.

Code example

Programming code was created in collaboration with, EVL Phd candidate, Ratko Jagodic.

Arduino code

```
// nucleus pins
int nucleus1 = 9;
int nucleus2 = 10;
int extra_nucleus = 11;

// for running the nucleus
boolean volatile stopNucleus = false;
unsigned long lastActionTime = 0;
int minBrightness = 0; //35
int maxBrightness = 255;
int ledBrightness = minBrightness;
int dir = 1;
int nucleusTimeout = 5000;  //wait 5 secs of inactivity before running the nucleus

void setup()
{
 attachInterrupt(0, handleInterrupt, RISING);
}
void handleInterrupt()
{
 stopNucleus = true;
}
void runNucleus()
{
 // reverse the direction if we got to the end
 if(ledBrightness >= maxBrightness)
   dir = -1;
 else if(ledBrightness <= minBrightness)
   dir = 1;

 // light both halves of the nucleus equally
 ledBrightness += int(dir*3);
 if(ledBrightness > maxBrightness)
   ledBrightness = maxBrightness;
 if(ledBrightness < minBrightness)
   ledBrightness = minBrightness;

 analogWrite(nucleus1, ledBrightness);
 analogWrite(nucleus2, ledBrightness);
 analogWrite(extra_nucleus, ledBrightness);
}

void loop()
{
  // stopNucleus is set to true by the wiring board (mic)
 if (stopNucleus)
 {
   lastActionTime = millis();
   ledBrightness = maxBrightness;
   stopNucleus = false;
 }
   if ((millis() - lastActionTime) > nucleusTimeout)
 {
   runNucleus();
   delay(5);
 }
 else
```

```
 {
   analogWrite(nucleus1, maxBrightness);
   analogWrite(nucleus2, maxBrightness);
   analogWrite(extra_nucleus, maxBrightness);
 }
}
```

The Arduino board is connected to the Wiring board because when the contact microphones are activated, the cores become static at full luminosity.

Wiring code

```
// LED pins
int leds[3][5];
int extraLegLeds[4] = {20,21,22,23};

// nucleus is on the arduino board
int arduinoPin = 19;

// mics and their pins
int mic1 = 0;
int mic2 = 1;
int mic3 = 2;

// ring LEDs
int ringLeds [13] = {
 0,1,2,3,4,5,29,30,31,35,36,37,38};
float currentRingLed = 0;  // this is an index into the above array
unsigned long lastRingTime = 0;
int ringDir = 1;

// for checking mic pins and firing leds
unsigned long checkPins[] = {
 0,0,0,0,0,0};
int sensitivity[5];
int dlay = 100;
unsigned long checkDelay = dlay*10;  //in ms

// for running sequences of LEDs without delay()
struct sequence {
 int current;
 int ledDelay;
 int ledPins[10];
 int used;
 int numPins;
 int doLoop;
 unsigned long prevTime;
};
sequence sequences[5];

char val;

void setup() {
 // set sensitvity for each micPin... lower = less sensitive
 sensitivity[mic1] = 400;
 sensitivity[mic2] = 400;
 sensitivity[mic3] = 400;

 pinMode(arduinoPin, OUTPUT);

 // declare LEDs hooked up to the mic as OUTPUT
 // for each mic list LED pins that are activated by it
 leds[mic1][0] = 14;
 leds[mic1][1] = 15;
```

```
  leds[mic1][2] = 16;
  leds[mic1][3] = 17;
  leds[mic1][4] = 18;

  leds[mic2][0] = 4;
  leds[mic2][1] = 5;
  leds[mic2][2] = 6;
  leds[mic2][3] = 7;
  leds[mic2][4] = 8;

  leds[mic3][0] = 9;
  leds[mic3][1] = 10;
  leds[mic3][2] = 11;
  leds[mic3][3] = 12;
  leds[mic3][4] = 13;

  int i;
  for (i=0; i < 3; i++)
  {
    pinMode(leds[i][0], OUTPUT);
    pinMode(leds[i][1], OUTPUT);
    pinMode(leds[i][2], OUTPUT);
    pinMode(leds[i][3], OUTPUT);
    pinMode(leds[i][4], OUTPUT);
  }
    for (i=0; i<4; i++)
  {
    pinMode(extraLegLeds[i], OUTPUT);
    //digitalWrite(extraLegLeds[i], HIGH);
  }

  pinMode(arduinoPin, OUTPUT);

  // intialize sequences
  for(i=0; i<5; i++)
    sequences[i].used = 0;

  // start the extra mini legs
  startLedSequence(extraLegLeds, 500, 4, 1);

  Serial.begin(9600);
}
void runLedRing()
{
  currentRingLed += ringDir/8.0;   // next time make the next LED the brightest one

  // light all the ringLeds but at lower brightness
  // as we get away from the currentRingLed
  //int currLed = currentRingLed;
  int led = 0;
  for(led=0; led < 6; led++)
  {
    analogWrite( ringLeds[led], int(100/(max(1,abs(currentRingLed-led))*2)) );
    analogWrite( ringLeds[led+6], int(100/(max(1,abs(currentRingLed-led))*2)) );
  }
  // advance the currentRingLed
  if (currentRingLed >= 6)
    ringDir = -1;
  else if(currentRingLed <= -1)
    ringDir = 1;
}

void startLedSequence(int pinSequence[], int ledDelay, int numPins, int doLoop)
{
  //add the pins to the array of leds to be lit
  int i=0, j=0;
```

```
  for(i; i<5; i++) {
    if (!sequences[i].used) {
      for(j; j<numPins; j++) {
        sequences[i].ledPins[j] = pinSequence[j];
        sequences[i].ledPins[j+numPins] = pinSequence[j];
      }
      sequences[i].ledDelay = ledDelay;
      sequences[i].current = 0;
      sequences[i].used = 1;
      sequences[i].prevTime = 0;
      sequences[i].numPins = numPins;
      sequences[i].doLoop = doLoop;
      break;
    }
  }
}

void runSequences()
{
  int i=0;
  for(i; i<5; i++) {
    if (sequences[i].used == 1){
      if ( millis()-sequences[i].prevTime > sequences[i].ledDelay) {
        sequences[i].prevTime = millis();

        if (sequences[i].current == sequences[i].numPins*2-1) {  // done with the sequence... reset it
          digitalWrite(sequences[i].ledPins[sequences[i].current], LOW);
          if (sequences[i].doLoop == 0)
            sequences[i].used = 0;
          else
            sequences[i].current = -1;  //we are looping so restart
        }
        else if(sequences[i].current > sequences[i].numPins-1)
          digitalWrite(sequences[i].ledPins[sequences[i].current], LOW);
        else
          digitalWrite(sequences[i].ledPins[sequences[i].current], HIGH);

        sequences[i].current += 1;
      }
    }
  }
}

void checkMic(int micPin)
{
  int micValue = analogRead(micPin);

  if (micValue <= sensitivity[micPin])
  {
    if ((millis() - checkPins[micPin]) > checkDelay){
      Serial.println(micPin);  // play sound
      startLedSequence(leds[micPin], dlay, 5, 0);
      checkPins[micPin] = millis();

      // notify the arduino board that a mic fired
      digitalWrite(arduinoPin, HIGH);
      delay(5);
      digitalWrite(arduinoPin, LOW);
    }
  }
}

void loop()
{
  runSequences();
  checkMic(mic2);
```

```
  checkMic(mic3);
  checkMic(mic1);
  // update the ring of LEDs 12 times a second
  if ( (millis() - lastRingTime) > 1000/60)
  {
    runLedRing();
    lastRingTime = millis();
  }

  // read the room mic volume and adjust the speed of the extraLegs
  if( Serial.available() )  {
    val = Serial.read();
    int d;
    if (val == '1')
      d=500;
    else if(val == '2')
      d=400;
    else if(val == '3')
      d=300;
    else if(val == '4')
      d=200;
    else if(val == '5')
      d=100;
    else
      d=500;
    sequences[0].ledDelay = d;//int((1.0/val) * 500.0);
  }
}
```

Thesis Show

My thesis show opened Thursday, May 22, 2008 at five in the evening. Replication of System, Bendybots and video documentation of Infinity Gliders were installed in a student gallery space. I decided to utilize the north gallery space in the Art and Design Hall, CUPPA, building. The large size of the north gallery ensured my audience had enough room to maneuver through and around my artworks. My primary concern was for my thesis project, Replication of System, as it had almost invisible sensor extensions attached to the floor. Those extensions could be a tripping hazard for participants or could be broken and cause damage to the project. Therefore, securing an extra amount of viewing space was important to me and the north gallery provided that. I designed the exhibition to be easy to flow in and out of. My thesis occupied the south east corner of the room. Bendybots were hung on a wall in the south west region of the gallery. A small niche, on the northwest side, was the perfect spot for Infinity Glider (Figure 14). I had excellent attendance which was difficult to obtain as the show was scheduled after the academic year ended. I received a lot of positive feedback from the audience and plenty of suggestions. I believe it was a great experience and showed my dedication to quality within my projects.

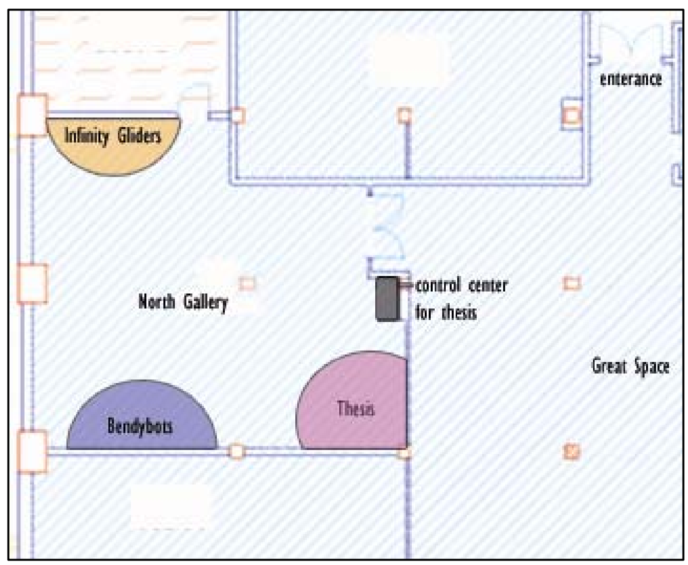


Figure 16. Diagram for gallery layout.

I chose to show these three projects together because they all have similar themes. They are linked by a theme which explores a technologically organic world. The theme links all my thesis show pieces together. Bendybots is the most infused with the technologically organic concept. Bendybots replicate an organically inspired movement using standard electronic technologies and materials. Bendybots imitate seaweed swaying in the ocean's bottom current. I wanted to take this organic movement and combine it with electronic elements to create an imaginative techno plant robot. There are glowing sea creatures, including plants, in the deepest parts of the ocean. The water pressure is so great that humans cannot dive that deep. Even with deep sea diving equipment, people still cannot freely wander around the ocean floor. Often, explorers damage the creatures with lights and other bacteria that are brought down with them. I feel these quiet simple robots can give the impression of getting up close to deep sea plant life, without actually going on an expensive deep sea dive.

Infinity Gliders are an imaginative daydream about what technologically organic creatures could be. Their wall-climbing abilities are adopted from lizards or spiders. Lizards and spiders can easily defy gravity and walk up walls. However, what if the spiders were in the endless void of space? Infinity Gliders are creatures which are capable of climbing the void of infinity without spending millions on NASA shuttles. It is the infinity of the mind which is on display; the endlessness of repeated thought. My thesis project again creates the imitation of such a creature. Replication of System is a semi-intelligent creature which reacts and communicates with the environment around it. Replication of System embodies the essence of a technologically organic living cell or creature.

Conclusion

My thesis has been an interesting endeavor from both an artistic and scientific perspective. Conceptually, all my projects have explored specific subject matters. These subject matters include creating artistic expression inspired by cellular communication systems and repetition of the designs found in nature. Another philosophical exploration is the concept of spatial infinity. My artwork takes these subject matters and creates a visual experience with the hope of inspiring thought and wonder in my audience. I want my audience to simply enjoy the visual eye candy that I delighted in making. My body of work has been inspired by many artists and many years of researching. I have only featured a few of my personal influences in this paper. Those artistic influences are: Ken Rinaldo, Karl Sims, Peter Vogel and M.C. Escher. Other visual inspirations are: space visualization, nature sciences and philosophical discussions of infinity. Infinity Gliders centered on the concept of visualizing spatial infinity and was created out of easily accessible materials. Similar materials and custom electronic mechanisms created Bendybots. Bendybots mimics oceanic plant-life and the unseen currents moving among them. My thesis project, Replication of System, was an interactive electronic sculpture. The project took inspiration from the communication systems in brain cells. Replication of System was a cumulative entity which embodied all three conceptual endeavors over my entire Master's of Fine Art degree experience. All three projects were included in my thesis show because they displayed a common thread of thought. That common thread provides a spring board for the audience to begin thinking about technological evolution and existence beyond tangible know spaces.

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LIST OF FIGURES

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