INFRA

Laurent

Trucheteries : pour faire des trucheteries au plotter ou à la brodeuse, il faut joindre des chemins disjoints avec vpype :

```
vpype read truchet_094.svg linemerge linesimplify -t 0.05 write truchet_94_merge.svg
```

Infrabuble

https://dev.laurent-malys.fr/bacasable/infra/

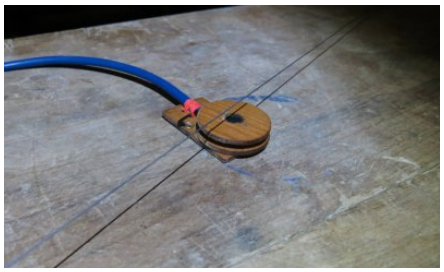
Multitude

https://multitude.labomedia.org/
https://multitude.exsitu.xyz/v/map/19255da86d5b11f61

Dessins génératifs

Broderie + upcycling : https://www.instagram.com/p/C58HraKiuYE/?img_index=1
Trucs à broder: https://dev.laurent-malys.fr/harmono-bro/

Infra PickUp



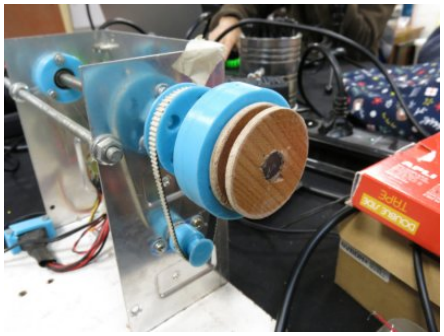
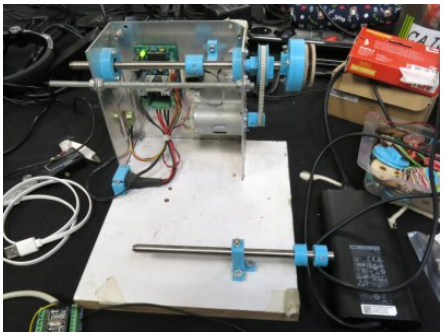
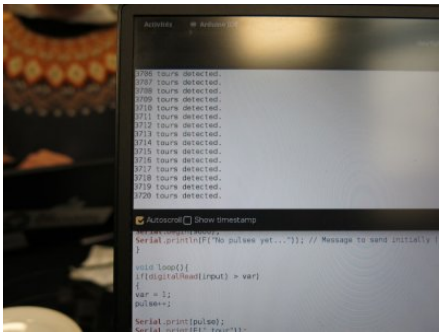
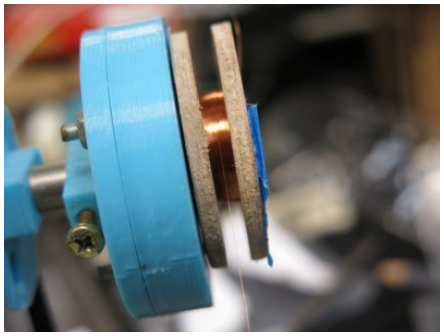
Profiter de ces beaux jours d'automne pour se chauffer au néons et ressortir la petite bobineuse pour créer un mirco

la base infrastructurelle

- Deux disques de cp plaqué de 3 mm découper à la scie cloche
- Un aimant Alnico de 10mm de diamètre
- Du fil enamel de 0,063mm de diamètre
- Une plaque rectangulaire pour insérer les œillets et fixer le câbles audio

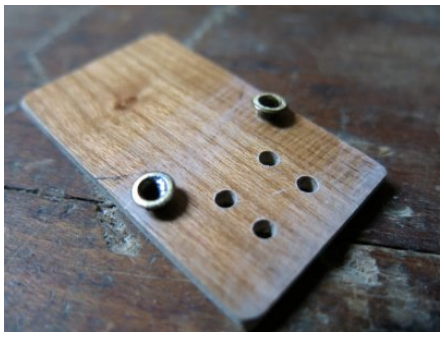
le bobinage

- Un petit programme arduino pour compter les tour de bobines (grâce à un aimant placer sur l'axe de rotation et interrupteur reed)
    - récupérer ici : https://forum.arduino.cc/t/simple-pulse-counter/519930
- Environs 3500 tours

assemblage

- La bobine et la base sont collés à l'epoxy



trempage

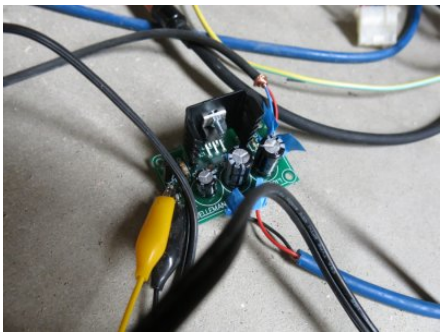
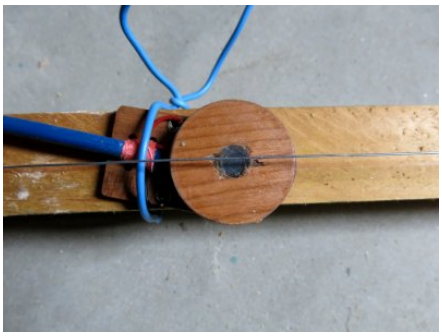
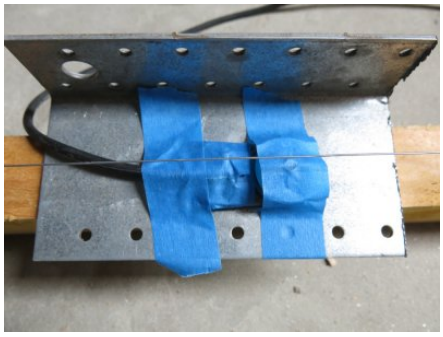
- Pour donner à l'ensemble un peu d'homogénéité et surtout protéger la bobine le tout est laisser trempé dans de la paraffine jusqu'à temps qu'il n'y ai plus de petites bulles




essai infrabassique avec retour d'informations



- Ça fonctionne plutôt bien au niveau des infras
- Ajout d'un second micro (caché sous le scotch bleu)
- Câblage du gros micro et du petit avec un ampli mono 7W pour créer un feedback de résonnances

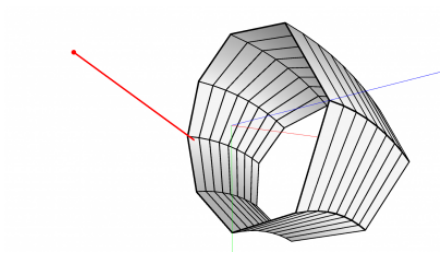
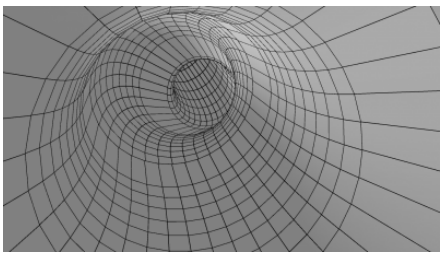
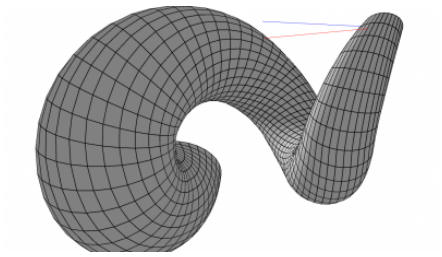





Infra graphique

Dérive dans les images semi-graphiques. Avant le graphisme «hi-res». Journal : infra-graphique

Quaternion

Exploration des quaternions et de la modélisation procedurale avec Processing



Les sketchs Processing ci-dessous dépendent de façon importante sur deux librairies non officielles:

- **QueasyCam** (modifié), pour la navigation dans l'espace en 3D → https://github.com/gweltou/queasycam/tree/master/distribution/queasycam-6/download/
- **LibAvatar**, pour l'intégration des classes de LibGDX dans Processing → https://github.com/gweltou/Processing-libAvatar/blob/2.0/distribution/libAvatar-3/download/libAvatar.zip

Vous pouvez naviguer dans l'espace 3D avec les touches ZQSDA et E. Affichage en mode filaire avec W.

iteration1.pde

```
import queasycam.*;
import com.badlogic.gdx.math.*;
import nervoussystem.obj.*;


QueasyCam cam;

static final Vector3 xAxis = new Vector3(1.0, 0.0, 0.0);
float rootSize = 8;
int numSeg = 128;

Segment root = new Segment(null, 10, new Quaternion());


public void setup() {
  fullScreen(P3D);

  cam = new QueasyCam(this, 1, 9999);
  cam.key_forward = 'o';
  cam.key_left = 'k';
  cam.key_backward = 'l';
  cam.key_right = 'm';
  cam.key_up = 'i';
  cam.key_down = 'p';

  sphereDetail(16);

  Segment c1 = root.branch(rootSize, new Quaternion().setEulerAngles(0, 0, -100));
  Segment c2 = root.branch(rootSize, new Quaternion().setEulerAngles(120, 0, -100));
  Segment c3 = root.branch(rootSize, new Quaternion().setEulerAngles(240, 0, -100));
  for (int i=0; i<numSeg; i++) {
    c1 = c1.branch(rootSize * pow(1.0-i/(20.0*numSeg), i), new Quaternion());
    c2 = c2.branch(rootSize * pow(1.0-i/(20.0*numSeg), i), new Quaternion());
    c3 = c3.branch(rootSize * pow(1.0-i/(20.0*numSeg), i), new Quaternion());
  }

  root.update();
}

public void draw() {
  checkKeys();

  background(255);
  lights();

  noStroke();
  translate(width/2, height/2);

  sphere(50);

  root.draw();
}


void checkKeys() {
  if (keyPressed == false)
    return;

  float step = 0.1;
  Quaternion rotation = new Quaternion();
  if (key == 'a') {
    rotation.setEulerAngles(-step, 0.0, 0.0);
  }
```

```
  if (key == 'z') {
    rotation.setEulerAngles(step, 0.0, 0.0);
  }
  if (key == 'q') {
    rotation.setEulerAngles(0.0, -step, 0.0);
  }
  if (key == 's') {
    rotation.setEulerAngles(0.0, step, 0.0);
  }
  if (key == 'w') {
    rotation.setEulerAngles(0.0, 0.0, -step);
  }
  if (key == 'x') {
    rotation.setEulerAngles(0.0, 0.0, step);
  }

  for (Segment seg : root.children) {
    while (seg.hasChildren()) {
      seg.localRot.mul(rotation).nor();
      seg = seg.children.get(0);
    }
    seg.localRot.mul(rotation).nor();
  }

  root.update();
}



/*****************************
**       class Segment      **
*****************************/

public class Segment {
  static final int faces = 32;
  static final float l2b = 10.0;  // Length to base ratio

  protected Segment parent = null;
  protected Vector3 head = new Vector3();
  protected Vector3 rootWorldPos = null;

  private Quaternion localRot = new Quaternion(); // Rotation from parent Segment
  private Quaternion globalRot = new Quaternion(); // Total rotation in world space
  private float len;
  private float baseRadius;
  private Vector3[] points = new Vector3[faces];
  private Vector3 tmpVec = new Vector3();

  private ArrayList<Segment> children = new ArrayList();

  public Segment(Segment parent, float len, Quaternion rot) {
    this.parent = parent;
    if (parent == null) {
      rootWorldPos = new Vector3();
      globalRot = rot.cpy();
    } else {
      rootWorldPos = parent.rootWorldPos;
    }
    this.localRot = rot.cpy();
    this.len = len;
    baseRadius = len * l2b * 0.5;
  }

  public Segment branch(float len, Quaternion rot) {
    Segment child = new Segment(this, len, rot);
    children.add(child);
    return child;
  }

  public boolean hasChildren() {
    return !children.isEmpty();
  }

  public void draw() {
    // Draw head line
    stroke(0);
    Vector3 up = new Vector3(0, len*0.4, 0);
    globalRot.transform(up);
    if (parent != null)
      line(parent.head.x, parent.head.y, parent.head.z, head.x, head.y, head.z);
    else
      line(0.0, 0.0, 0.0, head.x, head.y, head.z);

    // Draw UP line
    stroke(255, 0, 0);
    line(head.x, head.y, head.z, head.x + up.x, head.y + up.y, head.z + up.z);

    noStroke();
    if (hasChildren())
      drawSegment();
    else
      drawTip();

    for (Segment child : children)
```

```
      child.draw();
  }

  private void drawSegment() {
    beginShape(QUAD_STRIP);
    for (int i=0; i<faces+1; i++) {
      if (parent == null) {
        Quaternion rot = new Quaternion();
        rot.setFromAxisRad(xAxis, i * TWO_PI / faces);
        rot.mulLeft(globalRot);
        rot.transform(tmpVec);
        tmpVec.set(len, baseRadius, 0.0);
      } else {
        tmpVec.set(parent.points[i%faces]);
      }
      vertex(tmpVec.x, tmpVec.y, tmpVec.z);
      tmpVec.set(points[i%faces]);
      vertex(tmpVec.x, tmpVec.y, tmpVec.z);
    }
    endShape();
  }

  private void drawTip() {
    // Draw a capped tip if this segment has no children
    beginShape(TRIANGLE_FAN);
    vertex(head.x, head.y, head.z);
    for (int i=0; i<faces+1; i++) {
      if (parent == null) {
        Quaternion rot = new Quaternion();
        rot.setFromAxisRad(xAxis, i * TWO_PI / faces);
        rot.mulLeft(globalRot);
        rot.transform(tmpVec);
        tmpVec.set(len, baseRadius, 0.0);
      } else {
        tmpVec.set(parent.points[i%faces]);
      }
    }
    endShape();
  }

  public void update() {
    Vector3 pos = rootWorldPos.cpy();
    globalRot.set(localRot);
    if (parent != null) {
      pos.add(parent.head);
      globalRot.mulLeft(parent.globalRot).nor();
    }
    head.set(len, 0.0, 0.0); // Going right by default
    globalRot.transform(head);
    head.add(pos);

    float angle = 0.0;
    Quaternion rot = new Quaternion();
    for (int i=0; i<faces; i++) {
      rot.setFromAxisRad(xAxis, angle);
      rot.mulLeft(globalRot);
      tmpVec.set(len, baseRadius, 0.0);
      rot.transform(tmpVec);
      points[i] = tmpVec.cpy().add(pos);
      angle += TWO_PI / faces;
    }

    for (Segment child : children)
      child.update();
  }
}
```

iteration2.pde

```
import queasycam.*;
import com.badlogic.gdx.math.*;
import nervoussystem.obj.*;
import processing.pdf.*;

static final Vector3 xAxis = new Vector3(1.0, 0.0, 0.0);
static final Vector3 yAxis = new Vector3(0.0, 1.0, 0.0);
static final Vector3 zAxis = new Vector3(0.0, 0.0, 1.0);


QueasyCam cam;

boolean wireframe = false;
boolean record = false;

ArrayList<Drawable> objects = new ArrayList();


public void setup() {
  fullScreen(P3D);
  //size(800, 600, P3D);
```

```
  cam = new QueasyCam(this, 1, 9999);
  cam.key_forward = 'z';
  cam.key_left = 'q';
  cam.key_backward = 's';
  cam.key_right = 'd';
  cam.key_up = 'e';
  cam.key_down = 'a';

  Pipe pipe = new Pipe(
    new Vector3(0, 0, 0), new Quaternion().setEulerAngles(10, 0, 40),
    10, 32);
  objects.add(pipe);
  float size = 20;
  for (int i=0; i<8; i++) {
    pipe.changeSize(size);
    size += 10;
    pipe.addBend(90, 0.0, 45.0);
  }
}

public void draw() {
  background(255);
  lights();

  strokeWeight(1);
  stroke(255, 0, 0);
  line(0, 0, 0, 100, 0, 0);
  stroke(0, 255, 0);
  line(0, 0, 0, 0, 100, 0);
  stroke(0, 0, 255);
  line(0, 0, 0, 0, 0, 100);

  if (wireframe)
    stroke(0);
  else
    noStroke();
  strokeWeight(2);

  if (record) {
    beginRaw(PDF, "output.pdf");
    noFill();
  }

  for (Drawable o : objects)
    o.draw();

  if (record) {
    record = false;
    endRaw();
  }
}


void keyPressed() {
  if (key == 'w')
    wireframe = !wireframe;

  if (key == 'p')
    record = true;
}



public interface Drawable {
  public void draw();
  public void update();
}

public interface Chainable extends Drawable {
  public Vector3 getOutPos();
  public Quaternion getOutOrientation();
}


/*****************************
**        class Pipe        **
*****************************/

public class Pipe implements Drawable {
  private Vector3 pos;
  private Quaternion orientation;
  private float radius;
  private float nextRadius;
  private int faces;
  private ArrayList<Chainable> objects = new ArrayList();
  private Vector3 currentPos;
  private Quaternion currentOrientation;

  public Pipe(Vector3 pos, Quaternion orientation, float radius, int faces) {
    this.pos = pos;
    this.orientation = orientation;
    this.radius = radius;
    this.nextRadius = radius;
    this.faces = faces;
```

```
    currentPos = this.pos.cpy();
    currentOrientation = orientation.cpy();
  }

  public void changeSize(float next) {
    this.nextRadius = next;
  }

  private void add(Chainable object) {
    objects.add(object);
    currentPos = object.getOutPos();
    currentOrientation = object.getOutOrientation();
    radius = nextRadius;
  }

  public void addTube(float len) {
    addTube(len, 0.0);
  }

  public void addTube(float len, float twist) {
    Tube tube = new Tube(
      currentPos, currentOrientation,
      len, radius, nextRadius, twist, 1, faces
      );
    add(tube);
  }

  public void addBend(float angleBendDeg) {
    addBend(angleBendDeg, 0.0, 0.0);
  }

  public void addBend(float angleBendDeg, float angleRotDeg) {
    addBend(angleBendDeg, angleRotDeg, 0.0);
  }

  public void addBend(float angleBendDeg, float angleRotDeg, float twist) {
    int rings = 8;
    float radInt = 50;
    currentOrientation.mul(new Quaternion().setEulerAngles(0, angleRotDeg, 0));
    Bend bend = new Bend(
      currentPos, currentOrientation,
      radius, nextRadius,
      radians(angleBendDeg), radInt, twist,
      rings, faces
      );
    add(bend);
  }

  public void update() {
    for (Chainable o : objects)
      o.update();
  }

  public void draw() {
    for (Chainable o : objects) {
      o.draw();
    }

    Vector3 head = currentOrientation.transform(new Vector3(32, 0, 0));
    head.add(currentPos);
    line(currentPos.x, currentPos.y, currentPos.z, head.x, head.y, head.z);
  }
}


/*****************************
**        class Tube        **
*****************************/

public class Tube implements Drawable, Chainable {
  private Vector3 pos;
  private Quaternion orientation;
  private float len;
  private float radiusIn;
  private float radiusOut;
  private float twist;
  private int rings;
  private int faces;
  private Vector3[] points;
  private Vector3 tmpVec = new Vector3();
  private Vector3 outPos = new Vector3();
  private Quaternion outOrientation = new Quaternion();

  public Tube(
    Vector3 pos,
    Quaternion orientation,
    float len,
    float radiusIn,
    float radiusOut,
    float twist,  // In degrees
    int rings, int faces
    ) {
    this.pos = pos.cpy();
    this.orientation = orientation.cpy();
```

```
    this.len = len;
    this.radiusIn = radiusIn;
    this.radiusOut = radiusOut;
    this.twist = radians(twist);
    this.rings = rings;
    this.faces = faces;
    points = new Vector3[faces * (rings+1)];
    update();
  }

  Vector3 getOutPos() {
    return outPos.cpy();
  }

  Quaternion getOutOrientation() {
    return outOrientation.cpy();
  }

  public void update() {
    Quaternion rot = new Quaternion();
    int pointIdx = 0;
    for (int s=0; s<rings+1; s++) {
      float angle = s * twist/rings;
      for (int i=0; i<faces; i++) {
        tmpVec.set(s * len/rings, map(s, 0, rings, radiusIn, radiusOut), 0.0);
        rot.setFromAxisRad(xAxis, angle).mulLeft(orientation);
        rot.transform(tmpVec);
        points[pointIdx++] = tmpVec.cpy().add(pos);
        angle += TWO_PI / faces;
      }
    }
    outOrientation.set(orientation);
    outOrientation.mul(new Quaternion().setFromAxisRad(xAxis, twist));
    outPos.set(len, 0.0, 0.0);
    outOrientation.transform(outPos);
    outPos.add(pos);

  }

  public void draw() {
    for (int s=0; s<rings; s++) {
      beginShape(QUAD_STRIP);
      for (int i=0; i<faces+1; i++) {
        tmpVec.set(points[s * faces + i%faces]);
        vertex(tmpVec.x, tmpVec.y, tmpVec.z);
        tmpVec.set(points[(s+1) * faces + i%faces]);
        vertex(tmpVec.x, tmpVec.y, tmpVec.z);
      }
      endShape();
    }
  }
}


/*****************************
**        class Bend        **
*****************************/

public class Bend implements Drawable, Chainable {
  private Vector3 pos;
  private Quaternion orientation;
  private float radiusIn;
  private float radiusOut;
  private float bendAngle;
  private float radInt;
  private float twist;
  private int rings;
  private int faces;
  private Vector3[] points;
  private Vector3 tmpVec = new Vector3();
  private Vector3 outPos = new Vector3();
  private Quaternion outOrientation = new Quaternion();

  public Bend(
      Vector3 pos,
      Quaternion orientation,
      float radiusIn,
      float radiusOut,
      float bendAngle, // In radians
      float radInt, // Internal radius
      float twist,
      int rings,
      int faces
    ) {
    this.pos = pos.cpy();
    this.orientation = orientation.cpy();
    this.radiusIn = radiusIn;
    this.radiusOut = radiusOut;
    this.bendAngle = bendAngle;
    this.radInt = radInt;
    this.twist = radians(twist);
    this.rings = rings;
    this.faces = faces;
    points = new Vector3[faces * (rings+1)];
```

```
    update();
  }

  Vector3 getOutPos() {
    return outPos.cpy();
  }

  Quaternion getOutOrientation() {
    return outOrientation.cpy();
  }

  public void update() {
    int pointIdx = 0;
    Quaternion segRot = new Quaternion();
    Quaternion rot = new Quaternion();
    Vector3 bendOffset = new Vector3(0.0, radInt + radiusIn, 0.0);
    orientation.transform(bendOffset);
    float angleSeg = 0.0;
    for (int s=0; s<rings+1; s++) {
      segRot.setFromAxisRad(zAxis, angleSeg);
      segRot.mulLeft(orientation);
      float tubeRadius = map(s, 0, rings, radiusIn, radiusOut);
      Vector3 segOffset = new Vector3(0.0, radInt + tubeRadius, 0.0);
      segRot.transform(segOffset);
      angleSeg += bendAngle / rings;
      float angle = s * twist/rings;
      for (int i=0; i<faces; i++) {
        tmpVec.set(0.0, tubeRadius, 0.0);
        rot.setFromAxisRad(xAxis, angle);
        rot.mulLeft(segRot);
        rot.transform(tmpVec);
        points[pointIdx++] = tmpVec.cpy().sub(segOffset).add(bendOffset).add(pos);
        angle += TWO_PI / faces;
      }
    }

    outPos.set(0, -radiusOut - radInt, 0);
    outOrientation.set(orientation);
    outOrientation.mul(new Quaternion().setFromAxisRad(zAxis, bendAngle));
    outOrientation.transform(outPos);
    outOrientation.mul(new Quaternion().setFromAxisRad(xAxis, twist));
    tmpVec.set(0.0, radInt + radiusIn, 0.0);
    orientation.transform(tmpVec);
    outPos.add(tmpVec).add(pos);
  }

  public void draw() {
    for (Vector3 p : points) {
      point(p.x, p.y, p.z);
    }

    for (int s=0; s<rings; s++) {
      beginShape(QUAD_STRIP);
      for (int i=0; i<faces+1; i++) {
        tmpVec.set(points[s * faces + i%faces]);
        vertex(tmpVec.x, tmpVec.y, tmpVec.z);
        tmpVec.set(points[(s+1) * faces + i%faces]);
        vertex(tmpVec.x, tmpVec.y, tmpVec.z);
      }
      endShape();
    }
  }
}
```

scene.pde

```
import queasycam.*;
import com.badlogic.gdx.math.*;


static final Vector3 xAxis = new Vector3(1.0, 0.0, 0.0);
static final Vector3 yAxis = new Vector3(0.0, 1.0, 0.0);
static final Vector3 zAxis = new Vector3(0.0, 0.0, 1.0);


QueasyCam cam;

boolean wireframe = false;

ArrayList<Drawable> objects = new ArrayList();


public void setup() {
  fullScreen(P3D);

  cam = new QueasyCam(this, PConstants.PI/2.5f, 0.01, 9999);
  cam.key_forward = 'z';
  cam.key_left = 'q';
  cam.key_backward = 's';
  cam.key_right = 'd';
  cam.key_up = 'e';
```

```
cam.key_down = 'a';

// Center tower
Pipe pipe = new Pipe(
  new Vector3(0.0, 800, 0.0),
  new Quaternion().setFromAxis(zAxis, -90),
  550, 64);
pipe.addTube(1000);
pipe.changeSize(800);
pipe.addTube(1000);
pipe.changeSize(820);
pipe.addTube(20);
pipe.changeSize(2600);
pipe.addTube(200);
pipe.addTube(-400);
objects.add(pipe);

// Surrounding circus
pipe = new Pipe(
  new Vector3(0.0, 800, 0.0),
  new Quaternion().setFromAxis(zAxis, -90),
  800, 64);
pipe.addTube(600);
pipe.changeSize(2000);
pipe.addTube(200);
pipe.changeSize(2040);
pipe.addTube(40);
pipe.addTube(1000);
objects.add(pipe);

for (int r=0; r<4; r++) {
  Quaternion rot = new Quaternion().setEulerAngles(r * 90, 0, 9);
  for (int i=0; i<6; i++) {
    Vector3 pos = new Vector3(-2100, 298, (i-3)*34 + 17);
    rot.transform(pos);
    pipe = new Pipe(pos, rot, 16, 16);
    pipe.addTube(1480 + 4 * abs(i-3));
    pipe.addBend(99, 180);
    pipe.addTube(300, (3-i) * 5);
    pipe.addBend(14);
    if (abs(i-2.5)<=1) {
      pipe.addTube(860);
      pipe.changeSize(24);
      pipe.addTube(18);
      pipe.changeSize(26);
      pipe.addTube(200);
    } else {
      pipe.addTube(1000);
      pipe.addBend(70);
      float l=0.0, ll=0.0;
      int state = 0; // -1: left; 0: center; 1: right
      while (l<1800) {
        int turn = floor(random(3.0)-1.0);
        if (state==0 && turn == -1) {
          pipe.addBend(45, 90);
          state = -1;
        } else if (state==0 && turn == 1) {
          pipe.addBend(45, -90);
          state = 1;
        } else if (state == -1 && turn == 1) {
          pipe.addBend(45, 180, -90);
          state = 0;
        } else if (state == 1 && turn == -1) {
          pipe.addBend(45, -180, 90);
          state = 0;
        } else if (state == 0) {
          pipe.addTube(ll);
          l += ll;
          ll = 0.0;
        }
        ll += 100;
      }
    }
   objects.add(pipe);
  }
  float deg = r * 90 + 45;
  rot.setFromAxis(zAxis, -90);
  rot.mul(new Quaternion().setFromAxis(xAxis, deg));
  Vector3 pos = new Vector3(590 * cos(radians(deg)), 800, 590 * sin(radians(deg)));
  pipe = new Pipe(pos, rot, 34, 16);
  pipe.addTube(980);
  pipe.addBend(14);
  pipe.addTube(950);
  pipe.addBend(70);
  pipe.addTube(1800);
  objects.add(pipe);

  deg = r * 90 + 45;
  rot.setFromAxis(zAxis, -90);
  rot.mul(new Quaternion().setFromAxis(xAxis, deg));
  pos = new Vector3(1700 * cos(radians(deg)), 50, 1700 * sin(radians(deg)));
  pipe = new Pipe(pos, rot, 140, 32);
  pipe.addBend(90, 0, 0, 300);
  objects.add(pipe);
```

```
  }
}


public void draw() {
  background(0);
  //lights();
  //ambientLight(12, 4, 1);
  //pointLight(100, 100, 110, 140, -2000, 144);
  directionalLight(204, 204, 204, .5, 0.6, 0.2);
  emissive(50, 46, 51);
  //specular(204, 102, 0);
  shininess(1.0);

  strokeWeight(1);
  stroke(255, 0, 0);
  line(0, 0, 0, 100, 0, 0);
  stroke(0, 255, 0);
  line(0, 0, 0, 0, 100, 0);
  stroke(0, 0, 255);
  line(0, 0, 0, 0, 0, 100);

  if (wireframe)
    stroke(0);
  else
    noStroke();
  strokeWeight(1);

  for (Drawable o : objects)
    o.draw();
}


void keyPressed() {
  if (key == 'w')
    wireframe = !wireframe;
}


public interface Drawable {
  public void draw();
  public void update();
}

public interface Chainable extends Drawable {
  public Vector3 getOutPos();
  public Quaternion getOutOrientation();
}


/*****************************
**        class Pipe        **
*****************************/

public class Pipe implements Drawable {
  private Vector3 pos;
  private Quaternion orientation;
  private float radius;
  private float nextRadius;
  private int faces;
  private ArrayList<Chainable> objects = new ArrayList();
  private Vector3 currentPos;
  private Quaternion currentOrientation;

  public Pipe(Vector3 pos, Quaternion orientation, float radius, int faces) {
    this.pos = pos;
    this.orientation = orientation;
    this.radius = radius;
    this.nextRadius = radius;
    this.faces = faces;
    currentPos = this.pos.cpy();
    currentOrientation = orientation.cpy();
  }

  public void changeSize(float next) {
    this.nextRadius = next;
  }

  private void add(Chainable object) {
    objects.add(object);
    currentPos = object.getOutPos();
    currentOrientation = object.getOutOrientation();
    radius = nextRadius;
  }

  public void addTube(float len) {
    addTube(len, 0.0);
  }

  public void addTube(float len, float twist) {
    Tube tube = new Tube(
      currentPos, currentOrientation,
      len, radius, nextRadius, twist, 1, faces
      );
```

```
    add(tube);
  }

  public void addBend(float angleBendDeg) {
    addBend(angleBendDeg, 0.0, 0.0);
  }

  public void addBend(float angleBendDeg, float angleRotDeg) {
    addBend(angleBendDeg, angleRotDeg, 0.0);
  }

  public void addBend(float angleBendDeg, float angleRotDeg, float twist) {
    float radInt = 50;
    addBend(angleBendDeg, angleRotDeg, twist, radInt);
  }

  public void addBend(float angleBendDeg, float angleRotDeg, float twist, float radInt) {
    int rings = ceil(angleBendDeg * 64.0 / 360.0);
    currentOrientation.mul(new Quaternion().setEulerAngles(0, angleRotDeg, 0));
    Bend bend = new Bend(
      currentPos, currentOrientation,
      radius, nextRadius,
      radians(angleBendDeg), radInt, twist,
      rings, faces
      );
    add(bend);
  }

  public void update() {
    for (Chainable o : objects)
      o.update();
  }

  public void draw() {
    for (Chainable o : objects) {
      o.draw();
    }

    Vector3 head = currentOrientation.transform(new Vector3(32, 0, 0));
    head.add(currentPos);
    line(currentPos.x, currentPos.y, currentPos.z, head.x, head.y, head.z);
  }
}


/*****************************
**        class Tube        **
*****************************/

public class Tube implements Drawable, Chainable {
  private Vector3 pos;
  private Quaternion orientation;
  private float len;
  private float radiusIn;
  private float radiusOut;
  private float twist;
  private int rings;
  private int faces;
  private Vector3[] points;
  private Vector3 tmpVec = new Vector3();
  private Vector3 outPos = new Vector3();
  private Quaternion outOrientation = new Quaternion();

  public Tube(
    Vector3 pos,
    Quaternion orientation,
    float len,
    float radiusIn,
    float radiusOut,
    float twist,  // In degrees
    int rings, int faces
    ) {
    this.pos = pos.cpy();
    this.orientation = orientation.cpy();
    this.len = len;
    this.radiusIn = radiusIn;
    this.radiusOut = radiusOut;
    this.twist = radians(twist);
    this.rings = rings;
    this.faces = faces;
    points = new Vector3[faces * (rings+1)];
    update();
  }

  Vector3 getOutPos() {
    return outPos.cpy();
  }

  Quaternion getOutOrientation() {
    return outOrientation.cpy();
  }

  public void update() {
    Quaternion rot = new Quaternion();
```

```
    int pointIdx = 0;
    for (int s=0; s<rings+1; s++) {
      float angle = s * twist/rings;
      for (int i=0; i<faces; i++) {
        tmpVec.set(s * len/rings, map(s, 0, rings, radiusIn, radiusOut), 0.0);
        rot.setFromAxisRad(xAxis, angle).mulLeft(orientation);
        rot.transform(tmpVec);
        points[pointIdx++] = tmpVec.cpy().add(pos);
        angle += TWO_PI / faces;
      }
    }
    outOrientation.set(orientation);
    outOrientation.mul(new Quaternion().setFromAxisRad(xAxis, twist));
    outPos.set(len, 0.0, 0.0);
    outOrientation.transform(outPos);
    outPos.add(pos);

  }

  public void draw() {
    for (int s=0; s<rings; s++) {
      beginShape(QUAD_STRIP);
      for (int i=0; i<faces+1; i++) {
        tmpVec.set(points[s * faces + i%faces]);
        vertex(tmpVec.x, tmpVec.y, tmpVec.z);
        tmpVec.set(points[(s+1) * faces + i%faces]);
        vertex(tmpVec.x, tmpVec.y, tmpVec.z);
      }
      endShape();
    }
  }
}


/*****************************
**        class Bend        **
*****************************/

public class Bend implements Drawable, Chainable {
  private Vector3 pos;
  private Quaternion orientation;
  private float radiusIn;
  private float radiusOut;
  private float bendAngle;
  private float radInt;
  private float twist;
  private int rings;
  private int faces;
  private Vector3[] points;
  private Vector3 tmpVec = new Vector3();
  private Vector3 outPos = new Vector3();
  private Quaternion outOrientation = new Quaternion();

  public Bend(
      Vector3 pos,
      Quaternion orientation,
      float radiusIn,
      float radiusOut,
      float bendAngle, // In radians
      float radInt, // Internal radius
      float twist,
      int rings,
      int faces
    ) {
    this.pos = pos.cpy();
    this.orientation = orientation.cpy();
    this.radiusIn = radiusIn;
    this.radiusOut = radiusOut;
    this.bendAngle = bendAngle;
    this.radInt = radInt;
    this.twist = radians(twist);
    this.rings = rings;
    this.faces = faces;
    points = new Vector3[faces * (rings+1)];
    update();
  }

  Vector3 getOutPos() {
    return outPos.cpy();
  }

  Quaternion getOutOrientation() {
    return outOrientation.cpy();
  }

  public void update() {
    int pointIdx = 0;
    Quaternion segRot = new Quaternion();
    Quaternion rot = new Quaternion();
    Vector3 bendOffset = new Vector3(0.0, radInt + radiusIn, 0.0);
    orientation.transform(bendOffset);
    float angleSeg = 0.0;
    for (int s=0; s<rings+1; s++) {
      segRot.setFromAxisRad(zAxis, angleSeg);
```

```
      segRot.mulLeft(orientation);
      float tubeRadius = map(s, 0, rings, radiusIn, radiusOut);
      Vector3 segOffset = new Vector3(0.0, radInt + tubeRadius, 0.0);
      segRot.transform(segOffset);
      angleSeg += bendAngle / rings;
      float angle = s * twist/rings;
      for (int i=0; i<faces; i++) {
        tmpVec.set(0.0, tubeRadius, 0.0);
        rot.setFromAxisRad(xAxis, angle);
        rot.mulLeft(segRot);
        rot.transform(tmpVec);
        points[pointIdx++] = tmpVec.cpy().sub(segOffset).add(bendOffset).add(pos);
        angle += TWO_PI / faces;
      }
    }

    outPos.set(0, -radiusOut - radInt, 0);
    outOrientation.set(orientation);
    outOrientation.mul(new Quaternion().setFromAxisRad(zAxis, bendAngle));
    outOrientation.transform(outPos);
    outOrientation.mul(new Quaternion().setFromAxisRad(xAxis, twist));
    tmpVec.set(0.0, radInt + radiusIn, 0.0);
    orientation.transform(tmpVec);
    outPos.add(tmpVec).add(pos);
  }

  public void draw() {
    for (Vector3 p : points) {
      point(p.x, p.y, p.z);
    }

    for (int s=0; s<rings; s++) {
      beginShape(QUAD_STRIP);
      for (int i=0; i<faces+1; i++) {
        tmpVec.set(points[s * faces + i%faces]);
        vertex(tmpVec.x, tmpVec.y, tmpVec.z);
        tmpVec.set(points[(s+1) * faces + i%faces]);
        vertex(tmpVec.x, tmpVec.y, tmpVec.z);
      }
      endShape();
    }
  }
}
```

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