

Introduction to Programming II Course Notes

Felipe Balbi

October 24, 2019

Week 1

Learning Objectives:

- Reinforce the constructor functions learned in the 'Introduction to Programming I' module
- Understand how objects are used in larger programs
- Apply object orientation in practice

1.101 Welcome to Introduction to Programming II

We're going to rely more on object orientation, build larger projects. Won't present a lot of syntax.

3 case studies:

- Data visualizer
- Drawing app
- Music visualizer

Assignments will center around one of these case studies and letting us extend it.

1.201 Object concepts revisited

We're going to be making extensive use of objects. A quick recap of the previous module:

We started with *hardcoded* numbers in order to draw on the screen. Like in the example below:

```
function setup()
{
  createCanvas(800, 600);
}

function draw()
{
  background(255);
```

```

    rect(30, 20, 55, 55);
}

```

As the programs we wrote started to grow, we converted those *hardcoded* numbers into **variables**. That allowed us to change sizes, colors, etc, much more easily. See below:

```

let backgroundColor = 255;

let rectX = 30;
let rectY = 20;
let rectWidth = 55;
let rectHeight = 55;

function setup()
{
    createCanvas(800, 600);
}

function draw()
{
    background(255);
    rect(rectX, rectY, rectWidth, rectHeight);
}

```

As time went by, and objects being drawn became more complex, we started grouping related variables into **objects**. The original variables then became *properties* on our objects and we referred to them using the keyword *this*, like so:

```

let backgroundColor = 255;

let myRect;

function setup()
{
    createCanvas(800, 600);
    myRect = {
        x: 30,
        y: 20,
        width: 55;
        height: 55;
        draw: function ()
        {
            rect(this.x, this.y, this.width, this.height);
        }
    };
}

function draw()
{
    background(255);
}

```

```
    rect(myRect.x, myRect.y, myRect.width, myRect.height);
}
```

When we decided we wanted to build multiple copies of the same **object**, we augmented our objects with **Constructor Functions**. That allowed us to quickly spawn different instances of our objects using the keyword *new*, like below:

```
let backgroundColor = 255;

let myRect;

function Rectangle(x, y, width, height)
{
    this.x = x;
    this.y = y;
    this.width = width;
    this.height = height;

    this.draw = function ()
    {
        rect(this.x, this.y, this.width, this.height);
    }
}

function setup()
{
    createCanvas(800, 600);
    myRect = new Rectangle(30, 20, 55, 55);
}

function draw()
{
    background(255);
    myRect.draw();
}
```

1.202 Objects in practice, part 1

Working through a practical example, we build it up until we get to constructor functions. During the example, which contains a flying saucer, we start with hardcoded numbers and convert those to variables. Afterwards we create a *flyingSaucer* object and move variables to become properties within our object. After doing that, we added some extra properties and animation to our flying saucer.

1.203 Objects in practice, part 2

We start by extending our flying saucer object with methods. Starting by adding a method called *hover* which computes the hovering animation of our flying saucer. After adding the method, we call it from the `draw()` function.

The second extension is a new method to add a *Tractor Beam* to the flying saucer. Again we add a new method to our object, implement it and call it from `draw()` function.

After adding a beam, we created the ability of turning the beam on and off by adding a `beam_on` property to the object and adding support to keypresses by implementing `keyPressed()` and `keyReleased()` functions. Those functions were used to modify `beam_on` property directly.

The next step here was to create multiply flying saucers. In order to do that, we added a `FlyingSaucer()` constructor function. After converting the currently flying saucer object to a constructor function, we augmented it with a `draw()` function of itself and moved the drawing code from P5JS's `draw()` to the construction function's `draw()` method. Then we called it from P5JS's `draw()` function.

When this was all working fine, we added position arguments to the constructor function so that we could create a new flying saucer at whatever position we wanted. The next step was to create an array called `flyingSaucers` and populating it with a `for` loop.

From `draw()` function we converted all flying saucer code to operate on the new `flyingSaucers` array instead.

1.205 Object orientation

Object Orientation is a programming paradigm that was created to reduce the *clutter* of multiple function calls operating on different variables. Code like this is usually referred to as *spaghetti code*.

Object Orientation deals with this problem through two principles

1. Encapsulation

Through encapsulation, related functionality (functions and variables) are grouped together into entities called *objects*. Variables inside objects are called *properties* and functions inside objects are called *methods*.

An object is referred to as *well-encapsulated* when it modifies strictly its own properties. A corollary of this is that other entities don't modify an object's internal state (i.e. their properties) directly; only through method calls.

This means that *the outside world*, anything outside of the object itself, treats the object as a black box that provides functionality. We could even replace the internal implementation completely without having to modify anything outside the object, provided the **behavior** of a particular object doesn't change.

2. Abstraction

This teaches us that only the bare minimum details about the inner workings of an object should be revealed. If a user of an object doesn't know how the object works, we allow ourselves to modify our object without affecting the rest of our code.

Choosing a good abstraction, however, takes practice.

1.206 Object orientation in practice, part 1

Continuing with the flying saucer, we put in practice the principles of encapsulation and abstraction. When we want to hide properties of an object, we turn those properties into local variables of the constructor function using one of `var`, `let` or `const` keywords.

When converting methods to be internal to the object, we start similarly by removing `this.` and turning it into `var`, `let` or `const`. However, this results in `this` inside the method no longer referring to the object itself. A simple trick for this is to create a local variable to hold a reference to `this`, like so:

```
let self = this;
```

Then, in our method, we replace all references to `this` with `self`.

We can see that in our code, the flying saucer knows nothing about cows and cows know nothing about flying saucer. When we decide we want flying saucer to be able to beam up cows, we're faced with a problem that we want to maintain encapsulation.

In order to avoid breaking encapsulation, we create a new object *CowManager* that handles the communication between cows and flying saucers.

1.207 Object orientation in practice, part 2

Implementing the beaming of cows. This brings a new set of issues which try to break our encapsulation and abstraction. We have added a `levitateCows()` method to the *CowManager*.

With all this code properly abstracted and encapsulated, it becomes easy to add more flying saucers to the scenery and everything will still behave correctly.

Week 2

Learning Objectives:

- Reinforce constructor functions learned in the 'Introduction to Programming I' module
- Understand how objects are used in larger programs
- Apply object orientation in practice

1.301 Splitting across multiple files

Splitting code up into among files makes the codebase a lot more organized and easier to follow.

A good rule of thumb is to put each constructor function into its own file.

We want to keep our *sketch.js* as small as possible. Most of the implementation details should be left on separate files on their own constructor functions.

sketch.js will simply combine those with a little business logic to implement our application.

We must remember to modify `index.html` in order to include our new javascript files. Ordering is important; we must make sure to import our constructor function files before `sketch.js` but after `p5.min.js`.

1.401 Case studies overview

Our focus is on understanding larger applications. Dividing the code up into multiple files will help us get organized and navigate through the codebase.

Moreover, we should be more comfortable reading and understanding code written by others. During this module we will write a project based on one of three different case studies.

The first of these applications will be a simple Drawing App. The second application is a Music Visualization App. The third app will be a Data Visualization App.

After completing these three case studies, we must choose one to be extended.

Week 3

Learning Objectives:

- Practice object orientation design and technique
- Interpret a larger code base
- Use the `p5.dom` library to create and interact with `p5.dom` elements
- Use function callbacks

2.102 Introduction to case study, part 1: drawing app

Investigation of the current features of the drawing app and an overview of the structure of the code in terms of object orientation.

The drawing app can be downloaded from 2.104 Case study 1: drawing app.

as we run the app, we will notice that some features don't work well; that's because fixing them is part of future lectures.

2.103 Introduction to case study, part 2: drawing app

Capturing Drawing App's features:

1. Pen Tool
2. Line Tool
3. Spray Can
4. Symmetry Tool
 - (a) Vertical

- (b) Horizontal
- 5. Save Image
- 6. Clear Image
- 7. Colours

2.201 Drawing application, part 1 - under the hood

The first we notice when looking at the code for this application, is that it contains quite a few files and a considerable amount of code.

We start by opening sketch.js where we're faced with the following content:

```
//global variables that will store the toolbox colour palette
//amnd the helper functions
var toolbox = null;
var colourP = null;
var helpers = null;

//spray can object literal
sprayCan = {
  name: "sprayCanTool",
  icon: "assets/sprayCan.jpg",
  points: 13,
  spread: 10,
  draw: function(){
    //if the mouse is pressed paint on the canvas
    //spread describes how far to spread the paint from the mouse pointer
    //points holds how many pixels of paint for each mouse press.
    if(mouseIsPressed){
      for(var i = 0; i < this.points; i++){
        point(random(mouseX-this.spread, mouseX + this.spread),
              random(mouseY-this.spread, mouseY+this.spread));
      }
    }
  }
};

function setup() {

  //create a canvas to fill the content div from index.html
  canvasContainer = select('#content');
  var c = createCanvas(canvasContainer.size().width,
    canvasContainer.size().height);
  c.parent("content");

  //create helper functions and the colour palette
  helpers = new HelperFunctions();
  colourP = new ColourPalette();
```

```

//create a toolbox for storing the tools
toolbox = new Toolbox();

//add the tools to the toolbox.
toolbox.addTool(new FreehandTool());
toolbox.addTool(new LineToTool());
toolbox.addTool(sprayCan);
toolbox.addTool(new mirrorDrawTool());
background(255);

}

function draw() {
  //call the draw function from the selected tool.
  //hasOwnProperty is a javascript function that tests
  //if an object contains a particular method or property
  //if there isn't a draw method the app will alert the user
  if (toolbox.selectedTool.hasOwnProperty("draw")) {
    toolbox.selectedTool.draw();
  } else {
    alert("it doesn't look like your tool has a draw method!");
  }
}

```

We can see that the canvas is created in a slightly different manner in setup:

```

canvasContainer = select('#content');
var c = createCanvas(canvasContainer.size().width,
  canvasContainer.size().height);

```

This `select()` method, is a P5.js DOM library method which allows us to find elements of the DOM using the elements ID, class or tag.

Continue with the code walkthrough, the next thing that happens is:

```
helpers = new HelperFunctions();
```

We create a new object *HelperFunctions* to hold all our helpers that don't seem to be related to any particular object. Currently, here, we register a handler for the *Clear Image* button and another for the *Save Image* button.

Right after, we create a *Colour Palette* with the following line of code:

```
colourP = new ColourPalette();
```

The *colourP* object handles our colour picker area. This class provides a list colours to be shown on the HTML page. It, also, tracks the currently-selected colour so it can be styled differently.

Its method *loadColours()* will iterate over the array of colors, create a new html `<div>` for each of them and colour them with the correct colour.

It also registers a click event handler for each of the new `<div>` elements so the user can change the selected colour.

Moving on, we find our toolbox:

```
//create a toolbox for storing the tools
toolbox = new Toolbox();
```

The toolbox contains an empty list of our drawing tools. It provides a click event for the toolbar so the user can change the tool.

This class also provides a method for adding new tools to the toolbox. This method is called *addTool()*. Paired with this, the class provides a method for changing tools, assuming that we will have more than one tool to use.

On the few following lines, we actually add tools to the toolbox:

```
//add the tools to the toolbox.
toolbox.addTool(new FreehandTool());
toolbox.addTool(new LineToTool());
toolbox.addTool(sprayCan);
toolbox.addTool(new mirrorDrawTool());
```

Each and every tool are expected to follow a contract. What we mean by this is that when *Toolbox* was created, a contract was created along with it as to how tools are supposed to behave. As long as tools follow this contract, they can be added to the toolbox.

The contract states that a tool must provide:

- Tool name
- Tool icon
- *draw()* method

These contracts are commonly referred to as *Injected Dependencies*. This is commonly used by languages which are loosely typed.

And finally, we create our white background:

```
background(255);
```

2.202 drawing application, part 2 - under the hood

the line tool is peculiar because it doesn't actually "draw" until we let go of the mouse button.

the way this is implemented is by means of *loadpixels()* and *updatepixels()*. these two functions work together to create the illusion that the line tool only "draws" after the mouse button is released. *loadpixels()* will copy the current state of our canvas to a global pixels array, while *updatepixels()* will reset the screen to the values that were last stored in the pixels array.

in practice, it's almost like having a constant *undo* tool happening every time we move the mouse with the button still depressed.

2.204 introduction to p5.dom

The DOM library allows us to access other parts of the webpage outside of the P5 canvas.

The DOM (Document Object Model) is a tree representation of the components of a webpage, such as headings, paragraphs, buttons, etc.

To select a specific element from the html page, we use the DOM library's *select()* method and pass it the *id*, *class* or *tag* name as a string argument. The *select()* method will either return the element it found or *null*.

Note that when passed a *class* name argument, *select()* will return the first occurrence. If we want **every** element belonging to a class, we should use the *selectAll()* method, which will return an array with all occurrences.

2.206 P5.dom: handling events 1

In order to add a button to the webpage, we can use the *createButton()* function. This function takes a label string argument and an optional value string for the button

A slider can be created with the *createSlider()* function. The arguments to this function are the minimum value, the maximum value, an optional default value and an optional step size.

To create an area where we can input text, we can use the *createInput()* function. This function only takes two **optional** arguments: a default value and the type (text, password, etc).

The function *createSelect()* allows us to create a drop-down selectable list of options. This has one optional argument *multiple* which tells the selection box if multiple options can be selected at the same time or not. In order to add options to this selection box, we must call the *.option()* method of the object created by *createSelect()*. The argument passed to *.option()* is the option to be added.

As a sidenote, we could have used the *createColorPicker()* function instead. It takes no arguments and allows us to choose **any** color from a color wheel.

When we want to create elements inside another element, we can change its parent by calling the *.parent()* method on created elements and passing the new parent element.

2.207 P5.dom: handling events 2

During this video, the lecturer cleans up the code a bit before adding support for the button.

The button is peculiar since we need to figure out the button state at the moment the user clicks it.

For the button, we call the *.mousePressed()* method, which allows us to pass another function as an argument to it which will be the event handler for the *Mouse Pressed* event of the button.

2.208 Drawing application 2

During the video, the lecturer explains the purpose of the *populateOptions()* method, which is to add extra options as HTML elements to our own tools from the toolbox.

On the other hand, *unselectTool()* will call *updatePixels()* to reload the image of the canvas without any modifications that may have been done by the previously selected tool. For example, the mirror tool adds a red line through the middle of the canvas and when we move to another tool, we want to remove that red line.

Apart from that, *unselectTool()* will also empty the HTML element with the class *options*.

Week 4

Learning Objectives:

- Practice object orientation design and technique
- Interpret a larger code base
- Use the p5.dom library to create and interact with p5.dom elements
- Use function callbacks

This week is all about a peer graded assignment. The only video is an interview with a student.

Week 5

3.102 Introduction to case study 2: music visualiser

The Music Visualizer App is an implementation of an old idea that was created as a way of enhancing the listening experience of music.

During this case study, we build upon a basic music visualization program to create interesting visualizations that reflect the tone, energy and time signature of music.

The model app is a little more responsive than the drawing app. We can make it go full screen by tapping on the screen. With a second tap we can bring it back to window mode.

3.201 P5.js sound: loading and playing a sound

To load and play sounds, we're going to use P5js Sound library. We can find its reference [here](#).

3.202 P5.js sound: amplitude

The sound volume, or its amplitude, is what gives us a perception of how loud or quiet a sound sample is. The P5js Sound library provides an object for dealing

with an sound file's amplitude.

We can use the method *getLevel()* to get the amplitude of the sound. The output of *getLevel()* is a value between 0 and 1. We can use that value for different things, such as producing a line on the screen or controlling the size or position of a shape, etc.

3.203 P5.js sound: frequency, part 1

Apart from amplitude, sound also has a frequency, or pitch. Frequency is measured in hertz with a healthy, young human ear being able to hear the range between 20 Hz to 20 kHz.

Usually, sounds we hear are not composed of a single frequency. They contain other frequencies referred to as Harmonic Frequencies.

Because counting every frequency within the human hearing range is a bit overkill, we commonly group these frequencies into *frequency bands*.

3.203 P5.js sound: frequency, part 2

P5js provides us with a an implementation of the FFT algorithm wrapped in a p5.FFT object. Its documentation is hosted [here](#).

After creating the FFT object, we need to call the *analyze()* method while the audio sample is playing. According to documentation, *analyze()* returns an array of amplitude values between 0 and 255. Note that this is different from the previous p5.Amplitude object which returned amplitudes as a value between 0 and 1.

After calling *analyze()* we can rely on *getEnergy()* to get the amplitude of a specific band. There are predefined band strings corresponding to predefined frequency ranges ("bass", "lowMid", "mid", "highMid", "treble"). We can also pass a specific frequency if we want to. The value returned by *getEnergy()* is the amplitude value for the specified frequency band, between 0 and 255.

3.206 Music visualisation application: under the hood

Opening up *sketch.js*, we're greeted with:

```
// global for the controls and input
let controls = null;
// store visualisations in a container
let vis = null;
// variable for the p5 sound object
let sound = null;
// variable for p5 fast fourier transform
let fourier;

function preload() {
  sound = loadSound('assets/stomper_reggae_bit.mp3');
}
```

```

function setup() {
  createCanvas(windowWidth, windowHeight);
  background(0);
  controls = new ControlsAndInput();

  // instantiate the fft object
  fourier = new p5.FFT();

  // create a new visualisation container and add visualisations
  vis = new Visualisations();
  vis.add(new Spectrum());
  vis.add(new WavePattern());
  vis.add(new Needles());
}

function draw() {
  background(0);
  // draw the selected visualisation
  vis.selectedVisual.draw();
  // draw the controls on top.
  controls.draw();
}

function mouseClicked() {
  controls.mousePressed();
}

function keyPressed() {
  controls.keyPressed(keyCode);
}

// when the window has been resized. Resize canvas to fit
// if the visualisation needs to be resized call its onResize method
function windowResized() {
  resizeCanvas(windowWidth, windowHeight);
  if (vis.selectedVisual.hasOwnProperty('onResize')) {
    vis.selectedVisual.onResize();
  }
}

```

The first thing to notice here is the use of a *preload()* function:

```

function preload() {
  sound = loadSound('assets/stomper_reggae_bit.mp3');
}

```

The *preload()* function runs before the regular *setup()* function. We're using it to load our sound tracks into P5.js and saving a reference to our sound object into the *sound* variable.

During our *setup()* function, we create a black background:

```
createCanvas(windowWidth, windowHeight);
background(0);
```

And instantiate our *ControlsAndInput()* object:

```
controls = new ControlsAndInput();
```

We're also instantiating a FFT object from P5, which is used by our visualization objects. Moving on, we instantiate our visualizations:

```
vis = new Visualisations();
vis.add(new Spectrum());
vis.add(new WavePattern());
vis.add(new Needles());
```

Inside our *draw()* function, we draw the currently select visualization and our controls:

```
function draw() {
  background(0);
  // draw the selected visualisation
  vis.selectedVisual.draw();
  // draw the controls on top.
  controls.draw();
}
```

We're also using a *mouseClicked()* event handler (which currently is unimplemented) and a *keyPressed()* event handler (which allows us to show a list of visualizations and choose one from the list).

Finally, we have a *windowResized()* event handler which resizes the canvas and the visualization itself:

```
function windowResized() {
  resizeCanvas(windowWidth, windowHeight);
  if (vis.selectedVisual.hasOwnProperty('onResize')) {
    vis.selectedVisual.onResize();
  }
}
```

We can see that this app makes use of the P5js Sound library. Its documentation is hosted [here](#). For example the `p5.SoundFile` object is what allows us to load a sound file into the sketch and control play, pause, loop, stop and several other controls.

Week 6

Learning Objectives

- Practice object orientation design and technique
- Interpret a larger code base
- Use the p5 sound library to play and analyse sound files
- Understand basic properties of sound waves to visualise digital sound

There is no content on this week. Just peer-graded assignment of Music Visualizer App.

Week 7

4.102 Introduction to case study 3: data visualisation

Introduction to the application. No real content here.

4.201 Introducing P5 data

There are two types of data:

- Qualitative Data

Refers to forms such as text, audio, images and video where we can't distill their meaning into figures for performing mathematical operations.

- Quantitative Data

Data commonly stored as numbers, scales and categories.

The following table contains a simple table showing data regarding fruits on a supermarket:

ID	Fruit	Type	Calories	Price	Popularity
1	Apple	hard	43	80	4
2	Banana	soft	72	89	3
3	Grapes	soft	89	103	10
4	Pear	hard	91	107	9
5	Orange	citrus	92	93	6
6	Lemon	citrus	102	98	7
7	Lime	citrus	94	121	8
8	Strawberry	berry	122	143	1
9	Raspberry	berry	108	124	2
10	Blackberry	berry	118	154	5

This table shows different types of data. The column *Fruit* contains strings, the column *Type* contains a category, and the columns *Calories*, *Price*, and *Popularity* contain numbers.

Each row of the table represents a single data point and the columns are referred to as variables.

P5 provides us with the `Table()` object which gives us methods for manipulating tabular data.

Here's how we load data from a CSV file:

```
let data;  
  
preload() {  
  data = loadTable('myData.csv', 'csv', 'header');  
}
```

We must call `loadTable()` from `preload()` so the data is read when we need it. The *header* argument, tells P5 that the first line of our CSV file has the labels for each column.

The P5 table object gives us methods for accessing entire rows of data, adding rows, removing rows, accessing entire columns, adding columns and removing columns. All methods are properly documented in the P5 reference.

4.202 Accessing external data

When we want to load external data, we must do so in `preload()`. From inside `preload()` we call `loadTable()` with the path to the file that P5 should load. For the student data example, it should look like so:

```
let studentData;

preload() {
  studentData = loadTable('students.csv', 'csv', 'header');
}
```

After loading the data, we will be able to process it and plot it any way we like by drawing to the canvas with the regular `ellipse`, `rect()`, `vertex()` and similar methods.

4.204 Data visualisation application: under the hood

This tool is somewhat larger than the others, but this is mostly because the code is separated into different files, one for each constructor function.

The files themselves are quite small and self-contained.

This app, uses both P5 and P5 DOM libraries. We're using P5 DOM to find a `<div>` with the id `#app` on the page where we create our canvas.

We create a *Gallery* object which holds each of the *visuals*. *Gallery* has a property called *selectedVisual* which holds a reference to the currently selected visual. The *addVisual()* method registers a new visual to the Gallery.

Week 8

Learning Objectives

- Apply object orientation design and technique
- Interpret a larger code base
- Understand p5's data functions and use them to manipulate and visualise data

No content on this week, just completion of Data Visualization assignment.