Ph3 LaTeX Week 2: Creating and editing vector graphics

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1 Introduction

Most scientific documents include figures, and one of latex's main strengths is including figures of many types. Before we go over how to include a figure in a latex document I want to show you how to create and edit vector-graphics drawings suitable for publication. We will use an open-source program called Inkscape. Inskscape has enough capabilities to meet most scientists' needs, but if for some reason you need to use a different program, Adobe Illustrator for example, the techniques and principles you will learn in this class and use in Inkscape will transfer over to most other vector-graphics editors.

In this class we will concentrate exclusively on importing external graphics files. While it is possible to draw figures using commands in latex, I don't know anybody who does it. It is just simpler, easier, and faster to generate your figures using a separate program than to do it in latex. You are learning how to generate plots in Mathematica, and later in the term you will learn how to export those plots as standalone graphics files. You also need to know how to draw figures, and I am going to teach you that in this week's latex lesson. First, however, I want to go over the basics of computer graphics. You may have seen some of this material before, or you may not. If not, there is no shame in it. I once had a ph3 student who was a Math-option Senior but had been so focused on proving theorems that she had never done any computer programming of any sort. I got to teach her what an iteration variable was, and she got into Harvard for graduate school. So, let's start from the beginning.

2 Graphics types

2.1 Bitmap

The two most common types of computer graphics are *vector* and *bitmapped.* A bitmapped image, also sometimes called a *raster* image, is simply an array of *pixels*, individual boxes, each of which has a specific color, and the image is stored as a series of numbers that *maps* the color of each pixel, hence the name.

Figure 1 shows an example of this, a sixteen-by-sixteen pixel image where each pixel can have one of several possible colors, in this case black, white, red, or brown.

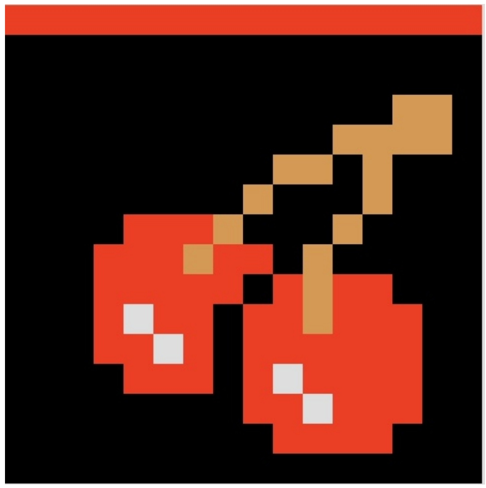


Figure 1: A 16x16 pixel raster image.

In this image there aren't very many pixels, and each one is quite large, visible as obvious squares in the image. If you want a more realistic-looking picture, you use more pixels and make each one smaller, and for the best images the pixels are so small the human eye can't resolve them. The number of pixels per square inch is called the *resolution*, and the number of possible colors each pixel can take is called the *depth*. Depth is usually measured in *bits*, so an 8-bit color depth would correspond to 2^8 possible values, or 256 possible colors.

The image in Figure 1 could be encoded in a sixteen-by-sixteen matrix, with each entry being a number that corresponds to the color of its corresponding pixel. For a simple image like the one above this would be just fine, but larger images usually use a compression scheme of some sort to reduce the size of the matrix and thus the amount of memory it takes up. For example, in Figure 1 the entire top row is red, and instead of specifying sixteen values of "red" the compressed matrix could specify that the first pixel is red and then that the same color should be repeated for the next fifteen pixels. Common file formats for compressed bitmapped graphics are JPEG (for Joint Photographic Experts Group), GIF (Graphics Interchange Format), TIFF (Tagged Image File Format), or PNG (Portable Network Graphics). JPEG is pronounced "jay-peg." GIF is pronounced "jif," like the peanut butter [1], and PNG is pronounced "ping," like what a submarine does to locate its target.

It is beyond the scope of this class to go into details of how these files are compressed, and it's not necessary. Latex can handle any of these formats transparently. You just ask it to include a graphics file of any of these types, and it does what is necessary to import your image and then display it in the correct way in the output.

2.2 Vector

The downside of a bitmap is that it does not *scale, i.e.* if you try and enlarge the image you wind up just enlarging the pixels as well. Your resolution is fixed, and if you try and zoom in on one particular feature, you will begin to see the individual pixels.

Figure 2: This bitmapped (or raster) image looks good at its full resolution. Zoom in on the logo, however, and you will begin to see pixels.

In contrast to the map of pixel colors that defines a bitmapped image, a *vector* graphics object uses a mathematical description of points, lines, and curves, along with colors, to define an image. When it comes time to display this image on a screen or print it on paper, the computer *resolves* the image at the appropriate resolution so that no pixels will be visible. This allows you to magnify the image as much as you want, without any degradation in resolution.

Photographs are generally created and stored as bitmapped images, whereas the vector format is more suitable for drawings, especially experimental diagrams. Making such drawings suitable for publication is something every scientist needs to know, so now I am going to teach it to you.

2.3 Programs for creating and editing vector graphics files

The gold standard for creating and editing vector graphics has traditionally been Adobe Illustrator. This is proprietary software, and Caltech does not currently maintain a site license for it. An open-source alternative that has been in development for quite some time and was just recently released in Version 1.0 is Inkscape (`https://inkscape.org/`). Inkscape works on MacOS, linux, and Windows, and it shares much of its interface with Illustrator. If you learn the basic ideas of pen and selection tools, bezier curves, shapes, text boxes, etc. in one piece of software, most of that knowledge will carry over into any vector-editing program.

So let's get started.

3 The tutorial

3.1 Getting started: Sheet size, pen, pencil, and selection tools

Exercise 1: If you don't already have a vector-editing program such as Adobe Illustrator, download and install Inkscape onto your computer from the url listed above.

Open Inkscape, and you will see a window that looks something like this.

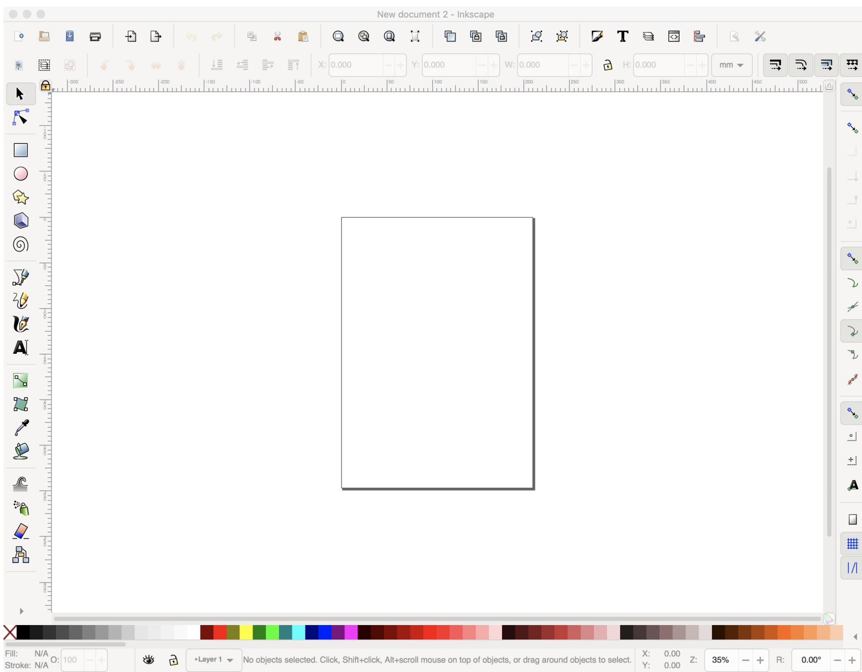


Figure 3: Inkscape window with blank sheet.

In the center of the window is a blank rectangle that looks like a sheet of paper, and that's basically what it is, a sheet of virtual "paper" that you are going to draw on. It looks like a sheet of paper because its dimensions have been specified to be 8.5 by 11 inches in portrait mode. We are going to make smaller drawings that will be added to a larger piece of paper in our latex document, so it will be useful to know how to change the size of the paper we are drawing on.

Click on the File menu, and choose Document Properties. A window should pop up that looks like this.

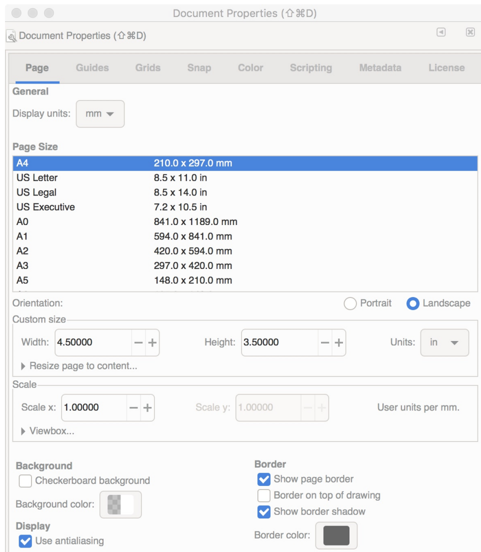


Figure 4: The Document Properties window, where you can change the size and orientation of your sheet. Set yours to a width of 4.5 inches and a height of 3.5 inches. This size will fit nicely into a latex document.

Change your paper size to 4.5x3.5" and your orientation to Landscape, as shown in Figure 4, then hit your $\stackrel{+}{=}$ key to zoom in so that your sheet fills most of your window.

Around the edges of this window are an array of icons, most of which represent various drawing tools. If you *mouse over*, or place your cursor over most of these tools but don't click, you will get a little pop-up window that tells you the name of the tool, and a shortcut command in parentheses.

These tools are not unique to Inkspace. Most vector drawing programs have them, and they usually go by the same names and have similar icons. The first and most obvious one we are going to cover is the *Pencil tool*, and it looks like this.

Figure 5: The Pencil Tool is for freehand drawing. It is flexible but not very precise.

Select it, then move your cursor over your paper and use it to draw a smiley

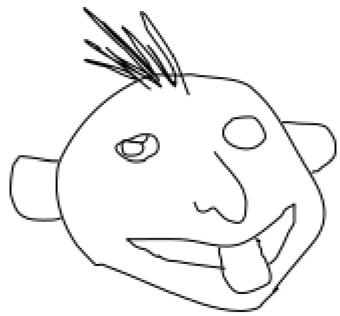


Figure 6: Draw with the Pencil tool by just clicking and dragging. Don't put a lot of work into this one. The Pencil tool can be useful for art drawings, but the Bezier tool is better suited for scientific diagrams.

face. Click and hold the button down to draw as you move your cursor around. Even if you are very good at drawing with pencil and paper (or stylus and tablet) you are not likely to be very satisfied with this result. Fortunately, there is a better way to do things, and it starts with the *Pen* or *Bezier tool.*

Figure 7: The Bezier tool.

This allows you to specify lines and curves by their *endpoints* or *nodes*. There are two ways to use it. First, you can just click where you want your lines to begin and end, and Inkscape will connect the dots and produce a polygon for you. Try this now. Make a triangle by clicking on three places on your sheet, then bring your cursor back to your starting point. When you get close to it, you will notice that your line will *snap to* the beginning point, and that the beginning point will turn red. *Snapping to* a point or grid is standard behavior in most drawing programs, in various contexts, and you can customize this behavior in the preferences. Click on your starting point once more, and you should get a triangle.

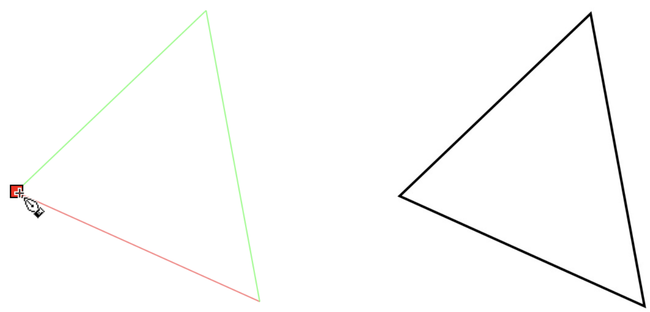


Figure 8: You can use the Bezier tool to make a polygon by clicking where you want its corners to be. When you move your cursor back to where you started, the starting point will turn red, indicating the line will *snap to* that point. Complete the polygon by clicking on the highlighted (red) point.

Straight lines are nice, but the real power in the Bezier tool lies in making curved lines. You do this by specifying end points, as you did before, but this time you can control the *slope* of the line, *i.e.* the direction it comes out of the end point, by extending a *handle*. Go to a clear area in your window, and then click and drag out from this new starting point, as shown in Figure 9.

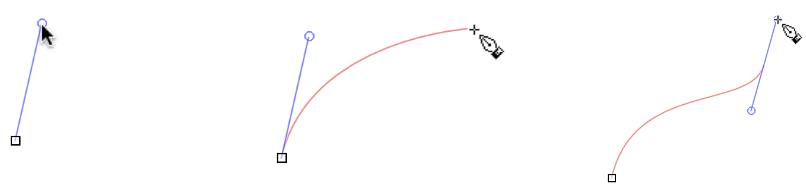


Figure 9: Click on a point, and then while holding the mouse button down *drag* a *handle* out that will define the slope of the curve at that point. Once you release the button you will get a red path whose endpoint moves with your cursor, and you will see how the slope of the line is pinned by the handle on the starting point. Click and drag a second time to define another point on the curve and its associated handles.

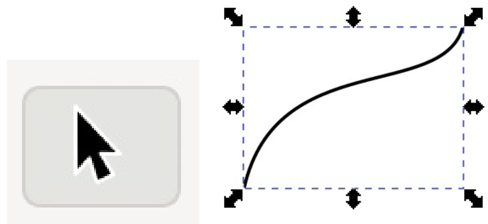


Figure 10: Once you have defined your handle, move your cursor over to the row of tools on the left side of your window and click the *Select tool* to finish and select your curve. You can now click and drag on the curve to move it around or resize it using the stretch arrows on the border of the selection box.

A handle is a line segment that is tangent to your curve, but there is more to it than first appears. The handle has a length as well as a slope, and its length lets you effectively control the radius of curvature of your curve at that point. You can also specify intermediate points, called *anchors* or *nodes*, and pull handles out from them as well, to specify the slope and radius anywhere along the curve.

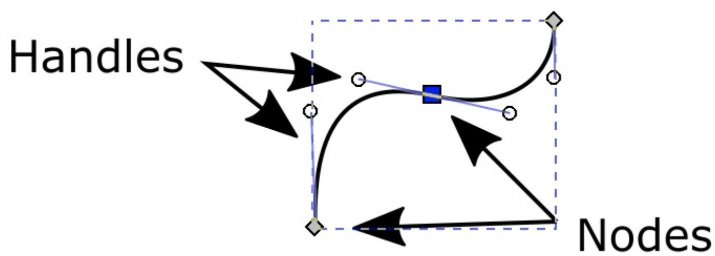


Figure 11: An *anchor* or *node* allows you to specify the slope and radius of your curve at any point.

The select tool allows you to select an entire object. Just under it is the *node tool* which, as you might have guessed, allows you to select and edit individual nodes or handles in an object.

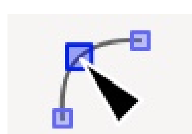
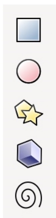


Figure 12: The *node tool* allows you to select and edit individual nodes or handles.

3.2 Shape tools



While you can make your own polygons as I described above, there are tools that make this process much easier. In the upper left of your Inkscape window are five icons for various shapes. Most people will use the first and second of these, squares and rectangles, and circles, elipses, and arcs the most. The basic way these work is, you click and drag to create a shape. Where you first click defines one corner of a rectangle that encloses your shape, and where you let up on the mouse button defines the opposite corner. Make a few shapes now, and you'll see what I mean.

I'm going to let you learn how to make shapes mostly by experimenting on your own, but there are two tricks to using these shape tools I want you to be aware of.

- **Shift:** Hold down the Shift key while dragging the cursor, and the point you first clicked on becomes the *center* of your shape, as opposed to one corner.
- **Control:** Hold down the Control key while you make a shape, and that will constrain the *aspect ratio* of the shape. If you are using the rectangle tool and drag the cursor anywhere close to diagonal, for example, the shape will be constrained to 1:1, and you will make a square.

These tricks can be combined. For example, to make a circle with its center at a specific point, hold down both the Shift and Control keys, and using the circle tool drag your circle out from that center point.

3.3 Editing shapes and lines

Shapes typically have two main attributes, *fill* and *stroke*. The *fill* is the color of the inside of the shape, and the *stroke* is the type of line around the edge. Click on the bottom left corner of your Inkscape window where it says Fill and Stroke, and that will pull up a window where you can change those properties.

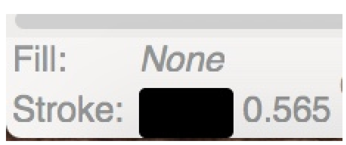
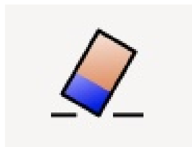


Figure 13: Click on the Fill or Stroke values (the words *None*, the black rectangle, or the number 0.565 in my window, meaning no fill and black stroke of that width) to pull up a dialog window to change these properties.

3.4 Erasing and undoing

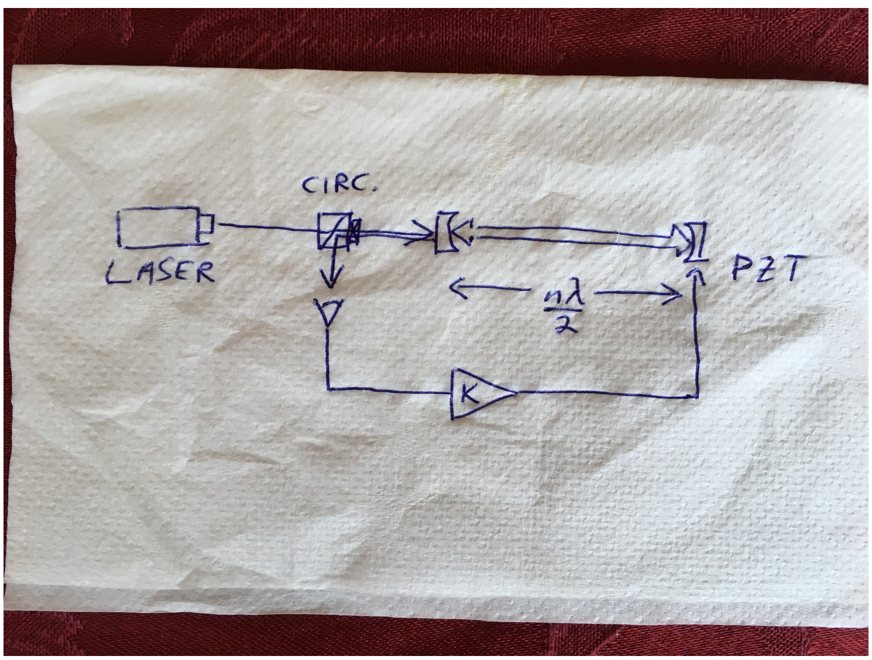
Once you have a shape or curve there are many ways to edit or modify it. To cover them all would be far beyond the scope of this course, and mastering even a few of them will start you down the path of becoming an actual artist. The two that I will show you are perhaps the most obvious, and they are the eraser tool



and *undo*. You may already be familiar with undo, Control-Z in Windows or Command-Z on a Mac, which just undoes your last action. The eraser tool should be self-explanatory, and I will let you play with it to get a feel for how it works.

4 The assignment

Exercise 2: Pretend you are at a conference, and at dinner a colleague sketches the following design on a napkin. Draw it in Inkscape on a 4.5x3.5" landscape canvas, and save your file. Submit your drawing in Canvas. Next week we will import it into your latex document.



References

[1] https://www.youtube.com/watch?v=CBtKxsuGvko

[2] https://en.wikipedia.org/wiki/Bezier_curve

[3] https://inkscape.org/learn/tutorials/