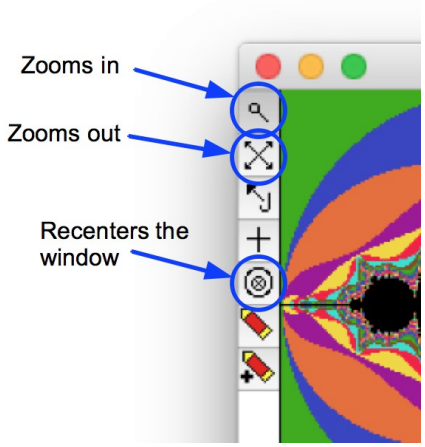
# Lab 1: The Mandelbrot Set and Julia Sets

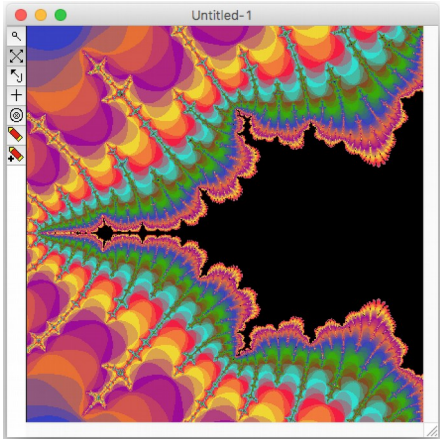
1. In this lab, you will generate your own images of the Mandelbrot set and Julia sets. To get started, open the program FractalDomains, which is available on the Dock or in the Applications folder. This will pop up a small window showing the region of the complex number plane containing the Mandelbrot set. The real axis runs from -2.0 to +2.0, and the imaginary axis runs from -2*i* to +2*i*. As you move the mouse around in the window, the corresponding complex number coordinates appear in the information bar at the top of the screen (where **r:** indicates the real part and **i:** the imaginary part of the number). Try locating the following numbers in the window: 0, 1, 2, –1, *i*

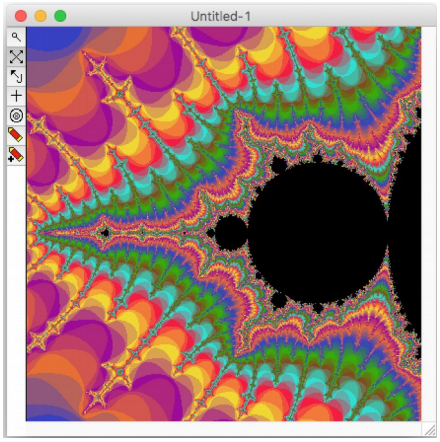
2. Next, open the Fractal Parameters control panel by choosing the menu option *Fractal* → *Parameters*, and change the width and height of the window to a larger value (600 works well), then click Apply. The Resolution parameter controls the zoom magnification. Experiment with different resolution values to see the effect on the image (smaller values give larger magnification).

3. You can also zoom in and out by using the controls on the left side of the fractal window:




4. As you zoom further and further into the Mandelbrot set, you may notice that the boundary between the black regions and the colored regions becomes smoother, like in the left image below. This is an artifact of the program's Dwell Limit parameter, which controls the number of steps it uses to decide whether a pixel should be colored black. Larger dwell limits take longer to compute, but give more accurate images. Open the Fractal Parameters control panel and click on the Dwells tab. Then try changing the Dwell Limit to different values to see the effect on the fractal window. For example, the image below was generated with a dwell limit of 100 (left) and 1000 (right).



5. The button in the fractal window with a capital J and an arrow generates the Julia set associated with a complex number *c*. Try clicking in different regions of the complex plane, both inside and outside the Mandelbrot set, to see what the associated Julia sets look like. Each Julia set pops up in a new window, which you may need to move out of the way of underlying windows. You can find out the exact value of *c* that generated a particular Julia set image by selecting the Julia set window, then opening the Fractal Parameters control panel and clicking on the Julia tab.

6. The colors of an image are controlled by the *Palette* menu. In general, the color of a point indicates how fast the associated complex number *c* diverges to infinity when the equation $z \rightarrow z^2 + c$ is iterated (starting from 0). Several pre-defined palettes are available, or you can have the program pick a random palette by choosing Randomize from the menu, or just pressing Command-R (⌘R). Experiment with different color palettes in different regions of the complex plane.

7. To save an image, choose Fractal → Render Image from the menu, click the Anti-Alias checkbox (this will produce nicer images), and then click on *Create Image in Memory*. This may take some time to render the image. Once it's done, take a screenshot of the rendered image by pressing the Shift-Command-4 key combination and then selecting the region you want to save by clicking and dragging the mouse. This will create a new PNG file. You should then rename this file as ***yourname*-mandel.png** or ***yourname*-julia.png**.

8. Now use the program to create your best Mandelbrot and Julia set images (rendered as 1000 × 1000 PNG files), and then send me a single email (to jmarshall@sarahlawrence.edu) with the following information in the message body:

   (a) Your name (and your lab partner's name if you worked together).

   (b) The parameter information for your Mandelbrot set and Julia set images, obtained from the Fractal Parameters menu:

   <u>For your Mandelbrot set image:</u>
   - Area tab: Real value
   - Area tab: Imaginary value
   - Area tab: Resolution
   - Dwells tab: Dwell Limit

   <u>For your Julia set image:</u>
   - Area tab: Real value
   - Area tab: Imaginary value
   - Area tab: Resolution
   - Dwells tab: Dwell Limit
   - Julia tab: the real and imaginary parts of C

   (c) Your Mandelbrot image PNG file as an attachment.

   (d) Your Julia set image PNG file as an attachment.

9. You can easily generate many more exotic types of fractal images with the Fractal Domains program, including those based on Newton's method (discussed in Steven Strogatz's article *Finding Your Roots*). A detailed tutorial is available online at **fractaldomains.com/tutorial**. Also, check out some of the amazing images in the Gallery section of the website.