Math 168 Weekly assignment #7 Due Thursday, Nov 1, 10 AM

**About computer-controlled cutting**

*At this point in the class, I'd like to start to provide experience with computer-controlled fabrication techniques. The three most important of these techniques currently are two-dimensional cutting, 3D printing, and automated 3D milling. Unfortunately, the third one of these is beyond the scope of this course, but we will cover the other two briefly. This assignment is the first of a sequence of two assignments on computer-controlled cutting connected with our work on point groups. This one is related to two-dimensional point groups, and the subsequent assignment will be on three-dimensional point groups. The next assignment will be due Thursday, Nov 8, at 10 AM; note that is the day after your next significant assignment is due, but both this weekly assignment and the next are relatively lighter in workload to provide you ample time to work on Making Math.*

*There are many computer-controlled cutting techniques, including laser cutting and water-jet cutting. Unfortunately, there is not time remaining in this class for obtaining the training and authorization necessary for using established laser cutting facilities on campus, such as the Graduate School of Design's "Fabrication Lab." (Nor is it clear whether, as FAS/College students and faculty, we would be eligible to use such facilities. However, I will be investigating whether we can have access to the SEAS Active Learning Lab for use of 3D printers next month.) Therefore, to give you a chance to gain some experience with computer-controlled cutting, we will be using an off-the-shelf home/hobbyist computer-controlled blade-cutting machine, likely the Silhouette Cameo 3. This will be set up in my office next Thursday, Nov 1 at 10AM when your submissions for this assignment are due. From that time on, I will be cutting all of the submitted designs to bring them to class on Friday. I will post an announcement on the class website when the cutting session is complete. You are encouraged but not required to stop by my office some time during that cutting session to see the process in action. (I will cut the designs in the order that people arrive, with those that don't come cut last.)*

1. Download and install the free (and very basic) SymmetriSketch app from https://www.evilmadscientist.com/2009/symmetrisketch-a-simple-app-for-playing-with-symmetry
   on any computer you can use it on. [No response needed for this item.]
2. Use the app to design a shape that will be cut out from a sheet of 0.35 mm-thick plastic. Your considerations:
   (a) Choose which of the 2D point groups your shape will have. You can control the point group that SymmetriSketch uses with the controls in the bottom-left corner of the app. You many not use the trivial point group (no symmetries at all) for two reasons: (i) this assignment is about symmetry, and (ii) the app does not produce closed paths when the point group is trivial, and we want the machine to actually cut something out for us.
   (b) The machine we are using will not handle self-intersecting cut paths. So although SymmetriSketch can display many beautiful patterns with self-intersecting borders, we will not be able to cut them. So do not turn one in. This condition makes it somewhat difficult to change which point group you choose in midstream, as a pattern that works well for one point group often creates a self-intersecting path for a different point group (especially a larger one). If you do decide to change, you may have to start over from the beginning.
   (c) You control the border of your shape using the "control points" which are highlighted by circles when you move your mouse pointer over the border. When a control point is orange, you may move it by clicking and dragging. Note that only about half of the displayed

control points actually “exist” at a given time. “Extra” control points are displayed at the midpoint of every segment comprising the border, and these extra control points become actual control points when you move them (creating two additional extra control points at the two midpoints of the newly created segments). This is a clever technique on the part of the app designers to allow points to be moved *and* to be added with the same user interface, but beware – there is no way to remove control points. (At least not that I am aware of. If you find one, please post the method to the course website; I will allow comments on this assignment.) That means once you have a lot of control points, you will have to drag many circles to make changes, and unfortunately there is no clear distinction between the “real” and “extra” control points, so you may find yourself inadvertently creating lots more control points as you make changes. For this reason, I recommend that you try your best to get your first several control points as close as you can to the places you will ultimately want them. Then fill in additional detail between these first rough control points.

(d) The program has no mechanism for specifying curved borders. Therefore, approximate any curves you would like in your shape with a number of short, straight sections (calculus basically consists of the observation that we can approximate in this way as closely as we would like.) As mentioned in the first point, get a few control points located roughly along the curve you want, then fill in detail by moving the “extra” control points, creating even more, and so on.

(e) There is no way to resize the app window or “zoom” the design. (Again, as far as I can tell. If you can find a way to obtain more working area, please post to the course website.) So you will just have to work within the detail level you can achieve given the resolution provided.

(f) Note that all of your corners will automatically be slightly rounded off by the cutting software, so designs with many extremely sharp points (or cutouts with very sharp angles, for that matter) will not necessarily be reproduced exactly as you imagine by the cutting process. That doesn’t mean you can’t submit them, just be prepared for your sharp points to be blunted.

(g) When you are happy with your design, hit the “Save” button in the lower-right corner. (Be careful not to hit the “Clear” button accidentally, which will immediately erase everything you’ve done, without asking you if you’re sure.) This will (also without any feedback) save a file called “SymmetriSketch-NNNNN.pdf” somewhere to your disk drive, where “NNNNN” is some sequence of digits. Find and submit this file.

3. What is the 2D point group of your shape?
4. I have 305mm x 457mm white material and 279mm x 432mm material in yellow, green, and blue. (The colors are all quite saturated and “classic rainbow” hues.) Which color would you like your pattern to be cut from?
5. Note that unless otherwise specified, your shape will be scaled to roughly the largest size that will fit on the material of the color you chose, with a 12 mm border of uncut material around the edges of the sheet. If you would like your cutout to be *smaller* than this, specify two points on your design and let me know how far apart they should be when cut. However, note that if different sections of your border come closer to each other than 2 mm, the cutting process may fail. Hence, take care in designing and scaling your shape to avoid extremely narrow gaps between portions of your shape. All that said, do you want the maximum-size cutout? If not, indicate two points and specify how far apart they should be.

6. Submit a two-to-four-paragraph essay describing how you chose your point group, describing how you chose your color, and describing the remaining design characteristics of your shape. What aesthetic or principles guided your choice of border contour within the structure of the chosen point group? Is your design representational in any way, or is it abstract? Does it have any mathematical significance beyond the point group itself? (It's not necessary for your shape to have any further mathematical significance, but if it does, be sure to describe it.)
7. Come to class on Friday, Nov 2, prepared to examine the shapes that other students have designed, identify the point groups of three of them, and discuss the other designs you observe. [Nothing to submit for this item, but your IDs of point groups will be collected and included for credit with this assignment.]

**Challenge problems**

1. **Improve our software tools**. The web page linked above also details how to get the code that implements the SymmetriSketch app. For challenge problem credit, implement any one or more of the following features and submit the modified source code; we'll try to get it re-posted at the original site. The features are listed in increasing order of the amount of credit they would generate:
   (a) Add a confirmation dialog before clearing out the design.
   (b) Add a dialog for saving the design as a PDF that allows you to specify the file name (and directory) of the save file.
   (c) Allow the app to be resized.
   (d) Allow the design to be zoomed in or out.
   (e) Visually indicate the difference between the "actual" and "extra" control points in a clear, simple way.
   (f) Allow control points to be removed as well as added. A simple gesture would be ideal for this, in keeping with the simplicity of the existing design. For example, when you drag an "actual" control point to be within some small radius of the midpoint of the segment between its two neighboring control points, it could turn red, indicating that if you release the drag there, the control point will be eliminated (and hence "replaced" with an "extra") control point. There are other reasonable mechanisms for removing control points that you might implement, such as dragging one control point on top of another. (Then the dragged one would be eliminated.)
   (g) Implement a mechanism for specifying actual curves. For example, by some command, button, or gesture, a given control point or set of control points could become Bezier curve control points, or control points for some other sort of curved spline. Obviously, make sure to use curves that can be portions of a path in a PDF, since the output format for SymmetriSketch is PDF.