Functionally Enabling *n*, *S*, *P*, and *J*

As you get more comfortable with the basic model you may start to search for similar images using functional relationships rather than educated guesses. More accurately, your educated guesses will turn into functional models.

A simple example. Suppose you want to find images based on a vertex frame that is a sharpest star. You need to have an ***n*** that produces a star, ***n*** = 5 or ***n*** > 6, but once you have ***n***, you need to adjust ***J*** to be just less than half the size of ***n***. It would be nice to be able to automatically change ***J*** as you change ***n***. An equation that works is:

J = INT((***n***-1)/2).

Consider how this function for ***J*** works:

If ***n*** is odd, ***n*** = 2***k***+1 and ***n***-1 = 2***k***, so (***n***-1)/2 = ***k***, the largest whole number less than ***n***/2 = ***k***+1/2.

If ***n*** is even, ***n*** = 2***k*** and ***n***-1 = 2***k***-1 is odd, and therefore INT((***n***-1)/2) = INT((2***k***-1)/2) = INT(***k***-1/2) = ***k***-1.

One could use this equation to change both ***n*** **and** ***J*** by simply changing ***n*** if you were able to control ***J*** via an equation instead of being forced to adjust ***J*** using the ⬍ arrows (or typing in numbers).

Recognize that this does not ensure that an ***n***,***k***-1-star as your VF because VCF > 1 may occur (as ***n*** = 10 = 2***k***, ***k*** = 5 so ***J*** = 4 shows us, the resulting VF is a pentagram since VCF = GCD(10, 4) = 2 here). [**MA.** This will hold whenever 2 = ***n*** MOD 4.]

Including functional relations is only available in the *Excel* version of the String Art model. The String Art *Excel* file forces users to click the large ⬍ arrow keys in order to control bounds on each parameter. Additionally, the cells showing numbers for ***n***, ***S***, ***P***, and ***J*** are protected against typing numbers into each cell. Modified versions of the file presented in this chapter allow users to create functional relationships between the four parameters and are provided along with suggested uses of those files. These files provide powerful tools for exploration because they streamline the exploration process especially when parameters (especially ***P***) are sometimes reasonably large.

By contrast, the web version allows users to adjust each parameter in 4 ways: 1) by typing in a number, 2) by clicking the ⬍ arrow to the right of the number, 3) by using the scroll slider to the left of the number, and 4) by clicking on the box with a number in it (to make it active) and then using the ↑ or ↓ arrows on your keyboard. *These four methods provide great flexibility, but that flexibility does not extend to providing functional relations between the parameters.*

The modified files allow multiple methods of entering parameter values. By unlocking the cell controlling a parameter, the user is able to type in a value manually or use the large ⬍ arrow keys as before. But the user is also able to enter an equation in the cell that relates to one or more of the other parameters (just like ***J*** referenced ***n*** in the above example).

It is worth noting that the ⬍ arrow key overrides an equation controlling that cell so that care must be taken to avoid using the ⬍ arrow key of a parameter unless you want to revert to manual operation. Absent that, you must reenter the equation you are testing for further analysis. (The ***S*** *and* ***P*** *as linear functions* file removes the ***S*** and ***P*** ⬍ arrow keys.)

A simple example of this multiple entry option is the treatment of the **First *k* lines** feature in the (*for teachers*) version of the file that superimposes the first ***k*** lines in **red** on the image. The **First *k* lines** toggle is in cell B10 and ***k*** is shown in C11. ***k*** is controlled by the ⬍ arrow key in C10:C12 or by typing a number or an equation in C11. When the file is initially opened, C11 looks like it contains the number 2, but it actually contains the equation =C1 (because ***S*** (in C1) is the number of lines in the first cycle, ***S***/GCD(***S***,***P***), unless GCD(***S***,***P***) > 1).

If using division, make sure the equation creates a whole number in the end. Each of the four parameters in the String Art model is a positive whole number. If your equation uses division, you may end up with a fraction rather than a whole number. Two options are available in *Excel* to deal with this.

The integer function, INT(#), produces the integer portion of a number so that 11 = INT(11) = INT(11.3) = INT(11.5).

The round function, ROUND(#,##), produces the closest number and has two arguments: the number, and how many decimal places to round that number to (use 0 for whole numbers). Therefore, 11 = ROUND(11,0) = ROUND(11.3,0) but ROUND(11.5,0) = 12 since, by convention, 0.5 rounds up.