Interpolating Raster Surfaces

You can use interpolation to model the surface of a feature or a phenomenon—all you need are sample points, an interpolation method, and an understanding of the feature or the phenomenon being modeled.

The idea behind interpolation is simple: estimating unknown values using a sample of known values. Although certain methods of interpolation, such as Inverse Distance Weighted (IDW) and Spline, solve this problem differently, they each work with the same underlying principle, called spatial autocorrelation.

Introduction to Interpolation

Whether you are concerned with the amount of rainfall, concentrations of pollution, or the differences in elevation, it is impossible to measure these phenomena at every point within a geographic area. You can, however, obtain a sample of measurements from various locations within the study area, then, using those samples, make inferences about the entire geographic area.

Interpolation is the process that enables you to make such an inference. The primary assumption of spatial interpolation is that points near each other are more alike than those farther away; therefore, any location's values should be estimated based on the values of points nearby.

With spatial interpolation, your goal is to create a surface that models the sampled phenomenon in the best possible way. To do this, you start with a set of known measurements and, using an interpolation method, estimate the unknown values for the area. You then make adjustments to the surface by limiting the size of the sample and controlling the influence the sample points have on the estimated values.
What is interpolation?

Interpolation is the process of estimating unknown values that fall between known values.

Spatial interpolation calculates an unknown value from a set of sample points with known values that are distributed across an area. The distance from the cell with unknown value to the sample cells contributes to its final value estimation.

You can use spatial interpolation to create an entire surface from just a small number of sample points; however, more sample points are better if you want a detailed surface.

In general, sample points should be well-distributed throughout the study area. Some areas, however, may require a cluster of sample points because the phenomenon is transitioning or concentrating in that location. For example, trying to determine the size and shape of a hill might require a cluster of samples, whereas the relatively flat surface of the surrounding plain might require only a few.
Spatial Autocorrelation

The principle underlying spatial interpolation is the First Law of Geography. Formulated by Waldo Tobler, this law states that everything is related to everything else, but near things are more related than distant things.

The formal property that measures the degree to which near and distant things are related is spatial autocorrelation. According to this, if it is raining where you are, it is probably raining 10 feet away from you, is less likely to be raining on the other side of town, and might even be clear and sunny 20 miles away. Most interpolation methods apply spatial autocorrelation by giving near sample points more importance than those farther away.

Sample size

Most interpolation methods allow you to control the number of sample points used to estimate cell values. For example, if you limit your sample to five points, the interpolator will use the five nearest points to estimate cell values. The distance to each sample point will vary depending on the distribution of the points. If you have a lot of sample points, reducing the size of the sample you use will speed up the interpolation process because a smaller set of numbers will be used to estimate each cell value.
You can also control your sample size by defining a search radius. The number of sample points found within a search radius can vary depending on how the points are distributed. You can choose to use some or all of the samples that fall within this radius to calculate the cell value. A variable search radius will continue to expand until the specified sample size is found. A fixed search radius will use only the samples contained within it, regardless of how many or how few that might be.

Interpolation barriers

The physical, geographic barriers that exist in the landscape, like cliffs or rivers, present a particular challenge when trying to model a surface using interpolation. The values on either side of a barrier that represents a sudden interruption in the landscape are drastically different.
Most interpolators attempt to smooth over these differences by incorporating and averaging values on both sides of the barrier. The Inverse Distance Weighted method allows you to include barriers in the analysis. The barrier prevents the interpolator from using sample points on one side of it.
Interpolation methods

Three of the most common interpolation methods are Inverse Distance Weighted (IDW), Spline, and Kriging.

- IDW takes the concept of spatial autocorrelation literally. It assumes that the nearer a sample point is to the cell whose value is to be estimated, the more closely the cell’s value will resemble the sample point’s value.
- Spline virtually guarantees you a smooth-looking surface. Imagine stretching a rubber sheet so that it passes through all of your sample points.
- Kriging is one of the most complex and powerful interpolators. It applies sophisticated statistical methods that consider the unique characteristics of your dataset. In order to use Kriging interpolation properly, you should have a solid understanding of geostatistical concepts and methods.

Regardless of the method you use, you should thoroughly understand your data and the phenomenon you’re trying to model before interpolating.

Inverse Distance Weighted

The Inverse Distance Weighted method is the practical, easy-to-understand interpolator. When you use IDW, you are applying a "one size fits all" assumption to your sample points.

IDW works best for dense, evenly-spaced sample point sets. It does not consider any trends in the data, so, for example, if actual surface values change more in the north-south direction than they do in the east-west direction (because of slope, wind, or some other factor), the interpolated surface will average out this bias rather than preserve it.

IDW interpolation considers the values of the sample points and the distance separating them from the estimated cell. Sample points closer to the cell have a greater influence on the cell's estimated value than sample points that are further away.
Inverse Distance Weighting cannot make estimates above the maximum or below the minimum sample values. For an elevation surface, this has the effect of flattening peaks and valleys (unless their high and low points are part of the sample). Because the estimated values are averages, the resulting surface will not pass through the sample points.

You can adjust the relative influence of sample points. In other words, you can increase how much power the values of sample points have over the interpolation process. Increased power means that the output cell values become more localized and less averaged. Their influence, however, drops off rapidly with distance.

Lowering the power that sample point values have provides a more averaged output because sample points farther away become more and more influential until all of the sample points have the same influence.
**Spline**

Instead of averaging values, like IDW does, the Spline interpolation method fits a flexible surface, as if it were stretching a rubber sheet across all the known point values.

This stretching effect is useful if you want estimated values that are below the minimum or above the maximum values found in the sample data. This makes the Spline interpolation method good for estimating lows and highs where they are not included in the sample data.

However, when the sample points are close together and have extreme differences in value, Spline interpolation doesn't work as well. This is because Spline uses slope calculations (change over distance) to figure out the shape of the flexible rubber sheet.

Phenomena that cause surface values to change suddenly, such as a cliff face or a fault line, are not represented well by a smooth-curving surface. In such cases, you might prefer to use IDW interpolation, where barriers can be used to deal with these types of abrupt changes in local values.
There are two types of Spline: Regularized and Tension. A Tension Spline is flatter than a Regularized Spline of the same sample points, forcing the estimates to stay closer to the sample data. You might say that the Tension Spline method produces a surface more rigid in character, while the Regularized Spline method creates one that’s more elastic.

Kriging

Getting to know the Kriging method involves delving into the mysterious world of probability and prediction, which, depending on your understanding of statistics, could lead either to years of therapy, or to your Ph.D.

Like IDW, Kriging is a weighted average technique, except that the weighting formula in Kriging uses much more sophisticated math. Kriging measures distances between all possible pairs of sample points (that’s right, all of them) and uses this information to model the spatial autocorrelation for the particular surface you’re interpolating.

In other words, Kriging tailors its calculations to your data by analyzing all the data points to find out how much autocorrelation they exhibit and then factors that information into the weighted average estimation.

Kriging aficionados consider the initial kriged surface a first draft—a test surface against which they compare future iterations as they search for the perfect surface. Directional influences, such as prevailing winds and random error, can be accounted for using Kriging, but you will need a statistical tool such as ArcGIS™ Geostatistical Analyst to visualize these trends.
Two general and widely used Kriging methods are Ordinary and Universal Kriging. *Universal* Kriging assumes that there is an overriding trend in the data. For example, you may know that there is a prevailing wind or a gently sloping hillside across your study area. *Ordinary* Kriging assumes there is no trend in the data, which should be your standard operating assumption.