



## High-Precision Positioning Unit 2.1 Student Reading: Creating Topographic Surfaces from Measured Points

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*A common use of GNSS data is the creation of topographic surfaces such as in digital elevation models (DEM). Topographic models are created from the interpolation of a surface between multiple point data measurements, such as GNSS positions acquired in a kinematic survey. Kinematic surveys are ideal for this project as they allow rapid acquisition of many points across a spatially large area and the potential for repeat surveys and change detection, which is covered in Unit 2.2. Various methods for sampling design and interpolation exist and carry varying merits, dependent on the expected output. These factors strongly influence the output model and should determine survey design. This unit uses ArcMap or similar software to compare various sampling design and interpolation techniques for creating topographic surfaces from geospatial positions.*

### Introduction

In this unit you will apply knowledge of survey design from Unit 2 along with new concepts on interpolating topography. You will be challenged to think about how survey design, including sampling and interpolation techniques, affects your final product. Once this exercise is complete, you should have a basic understanding of the concepts and a confidence in designing your own survey.

### Getting the Point

Point data is the basis of all GNSS surveys. Points are collected one at a time and measure a position, typically in Cartesian ( $x, y, z$ ) or geographic (Latitude, Longitude, and height) system. These points represent a small area, the area just under the antenna. So, how do we take point data and use it to produce maps that represent large, continuous areas?

By collecting multiple points at appropriate sample locations we can use various interpolation techniques to fill in the values between the sampled points. Depending on the type of technique used, this may be as simple as looking at the value and distance between various points or it may involve complex statistics on how the elevations of points vary with respect to each other. In all cases, we are using math to estimate all of the potential unknowns between our known points we have sampled. This is interpolation.

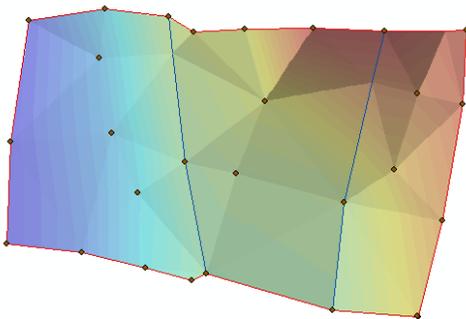


Figure 1. An example of an interpolation to give continuous elevations between a set of surveyed points. This interpolation uses the Triangulated Irregular Network (TIN) technique. Red is high elevation.

## Sampling Design

Significant thought should be contributed to sampling design in any survey. Often, a random sampling method is desired to eliminate human bias from an experimental design. Other times a structured or gridded sample is used. When creating a topographic model, we want to accurately represent some specific feature. We then design an informed sampling plan that accomplishes this goal. It is important to consider both how well the points we measure represent the topography *and* how the interpolation technique will transform the points into a surface.

We always want to collect topographic points at the highest possible density. Survey time or budget constraints often prevent this. Instead we collect points in densities that are required to accurately represent the topography present. If you have an expansive flat surface like a parking lot, you don't need to collect points every square meter. Instead focus on the areas where there are changes in elevation or slope breaks that need to be represented in the final surface.

For example, consider a linear object like a step, a cliff, or a canyon rim with an abrupt edge. If you take measurements along the upper and lower surface, but away from the edge, the interpolation may not correctly represent the abrupt change in elevation (Figure 2).

It is important to remember that interpolation techniques such as this will work best with surfaces that maintain relatively continuous horizontal extent. Areas such as overhanging cliffs cannot be well represented by the data, although it is unlikely you would use a GNSS device to measure these. A better option in that case would be a remote sensing measurement such as structure for motion or LiDAR scans such as in the High-Resolution Topography GETSI module.

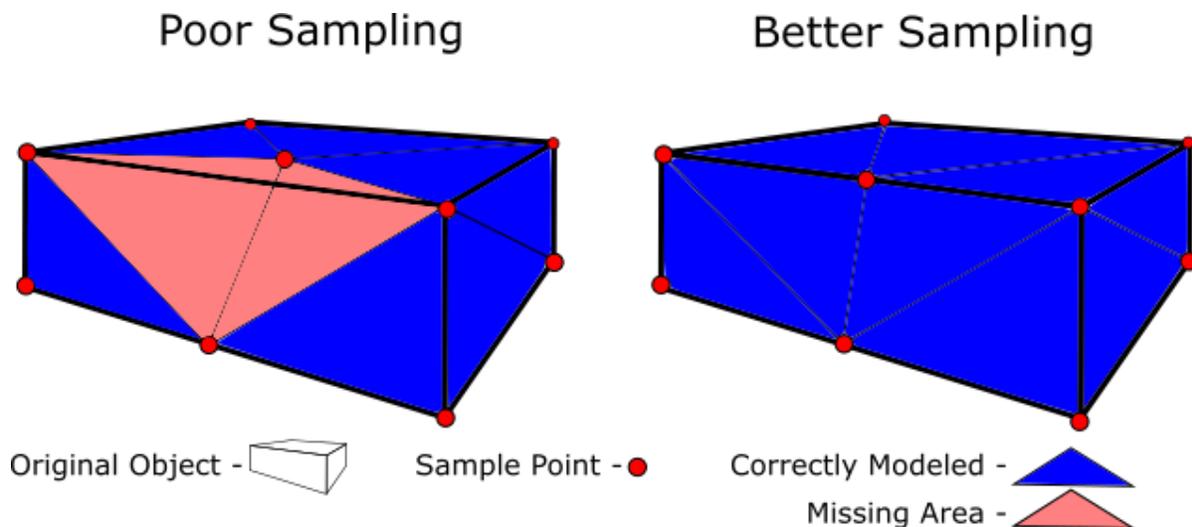


Figure 2: Careful placement of sampling positions is needed for interpolation techniques to accurately capture the surface of the object. For example, a TIN may inaccurately place triangles, which intersect the surface of an object, missing areas of the object you are trying to capture (in red above) when the sample point is taken away from the edge.

## Interpolation Techniques

Many interpolation techniques exist. These include but are not limited to TIN, IDW, and Kriging (Figure 3). The basis behind each of these models is a class within itself, but this unit will touch briefly on the general characteristics and merits of several popular techniques.

### Triangulation Irregular Network (TIN)

The TIN model connects the three closest neighbors in any given network of points to form triangular surfaces between each series of points or nodes. This produces triangular polygons with flat faces between connected nodes. The advantage of TIN is that it is quick and can accurately represent many geometric features, especially when edge detection techniques are used. The disadvantage is a lack of any weighting metric for values, which often creates unnaturally edgy, sharp, geometric surfaces.

### Inverse Distance Weighting (IDW)

The IDW model is one of the more basic models, which incorporates spatially variable data that is weighted. Unknown points are given a value that corresponds to their distance from other measured points and the known point's elevation. This can give a much more natural, smooth shape to the model. In most ways this is a step up from TIN mapping, but does require minimally more computing.

### Kriging

Kriging is a method that can produce data using several different models within the Kriging function that produce a best fit for the how data varies as a function of other points in the known samples. Kriging calculates a combination of points with varying separation distances from each other and measures how much these points vary as a function of this distance. Kriging then produces values for any unknown locations based on the distance from known sample points and the semivariogram model that was produced from the previous step. Kriging is known as the best linear unbiased estimate, or BLUE model, because it accounts for spatial variability within its model. The downside to Kriging is that it often produces overly smoothed estimates of a surface, which may or may not represent the topography.

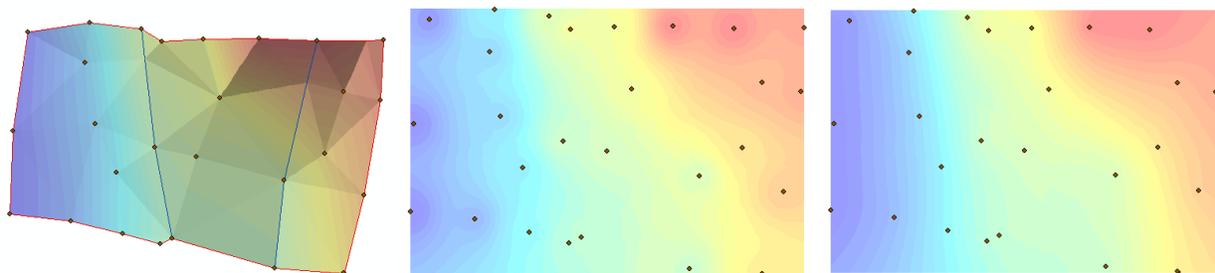


Figure 3: Comparison of three interpolated elevation surfaces using the same set of surveyed points. The techniques are, from left to right, TIN, IDW, and Kriging.

Once you have an interpolated surface, you can do all kinds of fun analysis, such as creating slope maps, contour lines, or differencing between two overlapping surfaces.