High-Precision Positioning Unit 2.1 Student Exercise: Creating Topographic Surfaces in ArcPro

Ian Lauer & Ben Crosby (Idaho State University), Updated by Isabella Metts (EarthScope Student Career Intern)

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 ArcPro or similar software to compare various sampling design and interpolation techniques for creating topographic surfaces from geospatial positions.

Note: Remember to save often when working in mapping programs; errors do occur.

Exercise Part 1: Creating the sample datasets to work with

1. Open ArcPro and the SalmonFallsAssignment.mxd file.
2. Note the various layers that are present in the map and what data they represent.
3. The digital elevation map, DEM, represents geospatial data that was collected using airborne LiDAR and will be used to extract geospatial data, emulating what would be measured if you surveyed the area with a GNSS device.
4. Under the **Analysis** drop-down menu you will find '**Tools**'. Use the **Sampling Toolbox** under **Data Management Tools** to extract geospatial positions from the DEM for various sample designs, starting with (1) a gridded and (2) an informed sample. For all samples, use the "Boundary" layer as a bounding box for the samples.
    a. Use the **Create Fishnet** tool to create a grid of points. The total number of samples should be evenly divisible by the number of rows and columns in a grid, making sure there at least 20 samples. Again, make sure to bound the sample using the Boundary layer. Name and save the output sample layer appropriately.
        i. When creating the fishnet there will be an option to set the 'Template Extent'. If you set the template extent to the Boundary layer, all other input values (other than naming the output layer) will be automatically filled and you can proceed to running the command.
    b. Use the provided "Informed Design" layer (recommended; skip to step c) or create an informed sample of your own design (below).
        i. Click the **Edit** drop-down menu and select **Create**.
        ii. Select the "Informed Sample Points" layer from the Create Features tab.
        iii. The option to create a point feature should be automatically selected, adjust this by choosing "Elevation Point from DEM" from beneath "Informed Sample Points" in the Create Features tab. This will allow you to automatically save elevation data from a specified DEM to the point feature.
            1. When using "Elevation Point from DEM" you will be prompted to choose an elevation layer and elevation attribute. The elevation

layer will be set to your DEM (SalFalls_2010_dem) and the attribute will be set to a column in the attribute table of your feature. To create a new column in the attribute table you need to right click on your feature in the contents pane, select open attribute table, then add field. Name this field appropriately, then select this field for the elevation attribute. After selecting the elevation layer and attribute you may continue to selecting your points.

iv. Begin selecting points on the map where you would ideally want to survey with a GNSS device to capture the prominent features of the landslide. Make at least 20 points.

v. When done, click **Editor** > **Save Edits** and then **Stop Editing**.

vi. Use the **Sample** tool to collect geospatial data, such as elevation, for the Gridded Sample positions. **ArcToolbox** > **Spatial Analyst** > **Extraction** > **Sample.** Input Raster = SalFalls_2010_dem, Input Points = Gridded Sample Points, Use Nearest Sampling. *Ensure that no points are currently selected (Map > Selection > Clear) before running.*

vii. The sample tool should have produced a table with elevation data for each point. Use the **Add Join** tool to add this data to your original point feature. The input table will be your original point feature, both join fields should be set to the object ID, and the join table should be the output from the Sample tool. Run this and ensure that the original point feature now contains elevation data.

c. Save your map.

Exercise Part 2: Interpolating surfaces from extracted points

You should now have two point shapefiles, one informed design and one gridded. Use these to interpolate a topographic surface using two methods. If you have trouble locating any of these tools, try the Search function.

1. Using the search tab on the right side of the screen (accessible by going to **Analysis** > **Tools**), search for the **Create TIN** tool. *If you do not ensure that both point features contain elevation data creating a TIN will not work.*
2. Using the default parameters, your gridded sample, and the bounding box of the study area, create a TIN surface map. The input feature class will be your point feature and the height field will be set to the name of the field containing elevation data in your attribute table. The bounding box of the study can be set under "Environments" by changing the extent to the Boundary polygon. Repeat this for your informed sample.
3. Convert each TIN to a raster. **Toolbox** > **3d Analyst** > **Conversion** > **From TIN** > **Tin to Raster.** You can adjust the symbology to better interpret the interpolated surface by right clicking the raster in the contents pane, selecting symbology, and changing the color scheme.
4. Now, search for and use the **IDW** tool to create surface maps using the two samples.
5. Now you should have four interpolated surfaces, two TINs and two IDWs.
6. Create a difference map for each interpolation and sample combination using the **Raster Calculator. Toolbox** > **Spatial Analyst Tools** > **Map Algebra** > **Raster Calculator**

7. A difference map is created by subtracting the “actual” elevations of the LiDAR from the interpolated surface elevation maps you just created. For each map use the **Raster Calculator** and click in the blank box to enter an equation similar to below:

   [“Informed Sample Map” – “Salmon Falls LiDAR”]

8. Colorize the four difference maps so they are more visually appealing. Right click the layer under the **Contents** pane. Navigate to **Symbology**. Stretch symbology displays the values along a color scheme of your choice. Classify symbology allows you to create groups based on value and color code them appropriately. Either display is beneficial when analyzing your maps. Select a basic color ramp, such as Green to Red.

You have now created maps that show how close your interpolated maps fit the actual elevations. Neutral colors are where the maps fit best, and darker colors, either Green or Red, show where the greatest mismatch occurs.

9. You can compare the accuracy statistically by looking at the Mean value of the difference map. Right click on the Difference Map layer in the table of contents and select **Properties** > **Source** and scroll down to **Statistics**. The mean and standard deviation explain how accurate the interpolated surface is relative to the originally sampled LiDAR. A mean close to 0 would indicate that the average elevation values of the interpolated surface map you created are near the actual values represented in the LiDAR.
10. Discuss with a small group. Think about whether the gridded or random point sample produces the most accurate map. Why is this?
11. Again, with the group, discuss which interpolation technique provided the most accurate model?
12. Create a map with title, legend, north arrow, scale bar, interpolation, and sample points for your four differences.
13. Export the maps as image files. **Share > Export Map**

Discussion (300–500 words)

1. Discuss the two sampling techniques: gridded and informed sampling.
   a. What are the benefits and concerns with each?
   b. Which do you prefer and why?
   c. How important is point density in getting a good surface?
2. Discuss the two interpolation techniques: TIN and IDW
   a. What are the benefits and concerns with each?
   b. Which do you prefer and why?
3. Which combination of sampling technique and interpolation was most accurate?
   a. How did you quantify this accuracy and what was the actual value for this and other techniques?
   b. Consider that a mean value only represents the average of all differences between the maps, so an equal number of high and low values could produce a mean of 0.

What are some potential problems with this, and how could you visually check the map to see if this is occurring?

4. How well did interpolation techniques do at reproducing complex topography of the landslide area?
    a. If you were to do a sample again, would you increase or decrease the number of samples you took?
    b. It is easy to sample a lot of points digitally, but is your suggested number of sample realistic for a GNSS survey? How would you balance the ideal number of points with the amount of field time it takes to complete a survey?
    c. How is a kinematic survey the ideal GNSS technique for producing topography?

Deliverables

1. Four maps, one for each of the interpolation techniques and sampling techniques used
2. Answers to the discussion questions above.

Component	Exemplary	Basic	Nonperformance
General Considerations	Exemplary work will not just answer all components of the given question but also answer correctly, completely, and thoughtfully. Attention to detail—as well as answers that are logical and make sense—is an important piece of this.	Basic work may answer all components of the given question, but some answers are incorrect, ill-considered, or difficult to interpret given the context of the question. Basic work may also be missing components of a given question.	Nonperformance occurs when students are missing large portions of the assignment, or when the answers simply do not make sense and are incorrect.
10 pts **Two Maps**	**9–10** points: The student used the interpolation techniques correctly and produced two clean, well-designed maps. Maps should include: Title, legend, scale, the interpolated surface.	**5–8** points: The student used the interpolation techniques correctly and produced two maps. Maps should include: Title, legend, scale, the interpolated surface, but may be missing 1–2 elements.	**0–5** points: The student wasn't able to make progress on the maps. and/or Maps are missing a significant number of elements.
10 pts **Discussion Questions**	**9–10** points: The discussion is well written and includes all of the following components: • Justification of preferred technique • Cost/benefit analysis of the two techniques • Discussion of how interpolation would work with two research problems Should additionally identify that measurement errors directly translate to and decrease accuracy of interpolated surfaces.	**5–8** points: The discussion is moderately well written and includes all of the components. or The discussion is well written but missing 1–2 components or fails to answer some of the questions.	**0–4** points: The discussion is poorly written and is missing several components. and/or The discussion fails to address more than 2 critical components or fails to answer questions.