Exploring Interpolation with the Spatial Analyst Extension in ArcGIS Pro

Peggy Wong

February 6, 2022

GEOM 105 | Fleming College

ArcGIS Pro 2.8.0

Table of Contents

1.0 Introduction

Spatial interpolation is a statistical technique of estimating unknown values using known values, based on the Tobler's Law of Geography that closer features are more alike. It is widely used in the GIS field where users can convert discrete samples into continuous surfaces. For example, users can use spatial interpolation methods to generate precipitation maps based on the data collected in different weather stations.

The following spatial interpolation methods that are available in ArcGIS Pro were explored, with the main goal to compare and analysis their results:

- Inverse Distance Weighting (IDW)
- Spline
- Topo to Raster
- Natural Neighbor

2.0 Methodology

2.1 Batch Project Data

To explore the topography of the Peterborough area in Ontario, the National Topographic System (NTS) 31D8 dataset were used (Appendix Table 1).

Since the projected coordinate system of the NTS dataset is *NAD83 UTM, Zone 17 North, Meter*, the data were reprojected to a more common coordinate system in Southern Ontario, *NAD 1983 UTM Zone 17N*, using the Batch Project tool (Figure 1), as the first step of the exploration.

2.2 Simplify Contour Lines

After reprojecting the data, the contour lines were simplified using the Simplify Line tool (Figure 2). By simplifying the contour lines, the number of the converted contour points in the next step can be reduced significantly, which is necessary in order to perform the Spline interpolation.

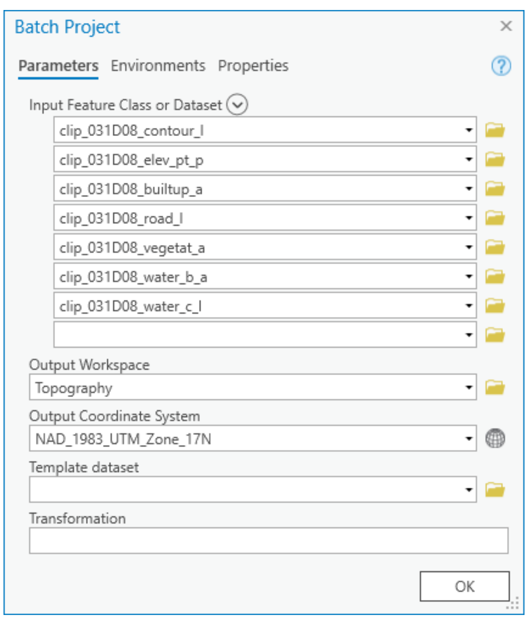

Figure 1. The parameters of the Batch Project tool

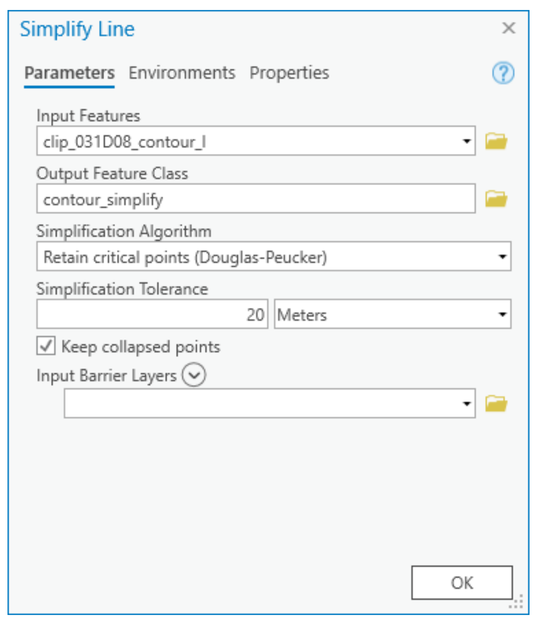

Figure 2. The parameters of the Simplify Line tool

2.3 Convert Contour Lines to Contour Points

Since most interpolation methods do not use lines as input features, the original contour lines and the simplified contour lines must be converted to contour points first using the Feature Vertices To Points tool (Figure 3), before running the interpolation tools.

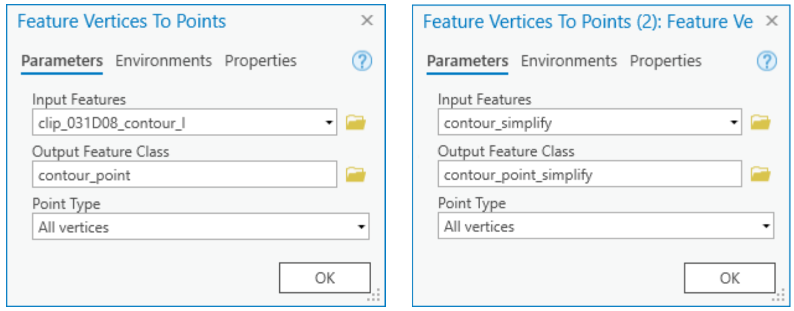

Figure 3. The parameters of the Feature Vertices To Points tool, using the original contour lines (left) and the simplified contour lines (right) as input features

2.4 Interpolation: Inverse Distance Weighting (IDW)

Inverse Distance Weighting (IDW) interpolation is an exact method that enforces the conditions that the estimated value of a point is influenced more by nearby known points than by those farther away (Chang, 2019). The unknown values were weighted inversely by distance.

Since IDW is the default interpolation method in many GIS software, the IDW tool was run as the first interpolation method to be explored (Figure 4).

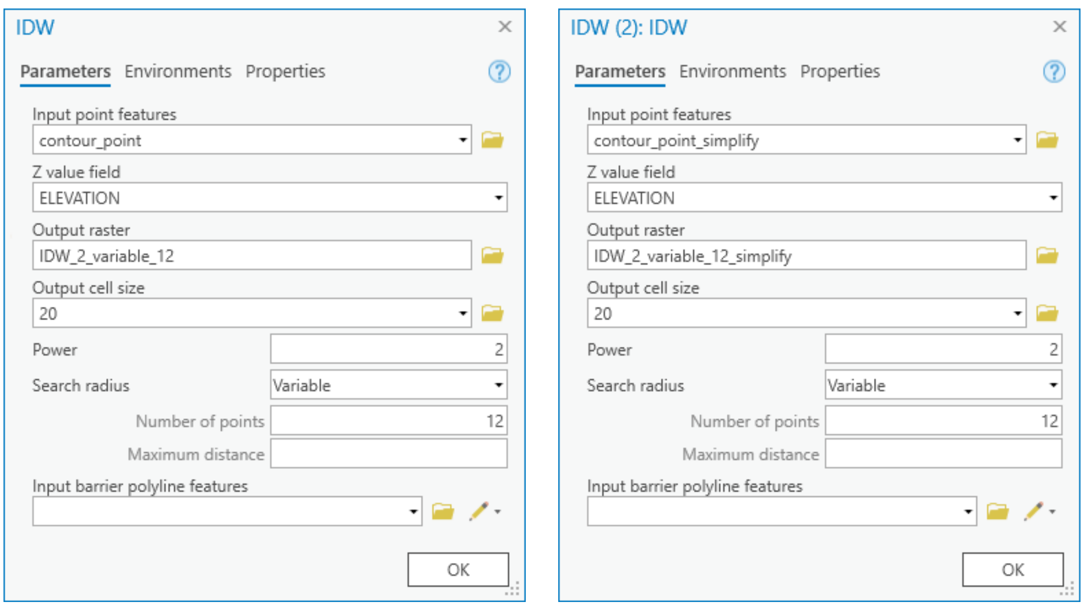

Figure 4. The parameters of the IDW tool, using the converted contour points generated by the original contour lines (left) and the simplified contour lines (right).

2.5 Interpolation: Spline

According to the ArcGIS Pro documentation, the spline tool uses an interpolation method that estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points. It is not widely used in GIS but more in CAD.

As the Spline tool does not work with a large number of input point features, converted contour points generated by the simplified contour lines were used. The Tension option, where the resulted surfaces closely conform to the control points, was explored primarily as it is better suited for interpolation. However the Regularized option that produces smoother surfaces was also explored briefly (Figure 5).

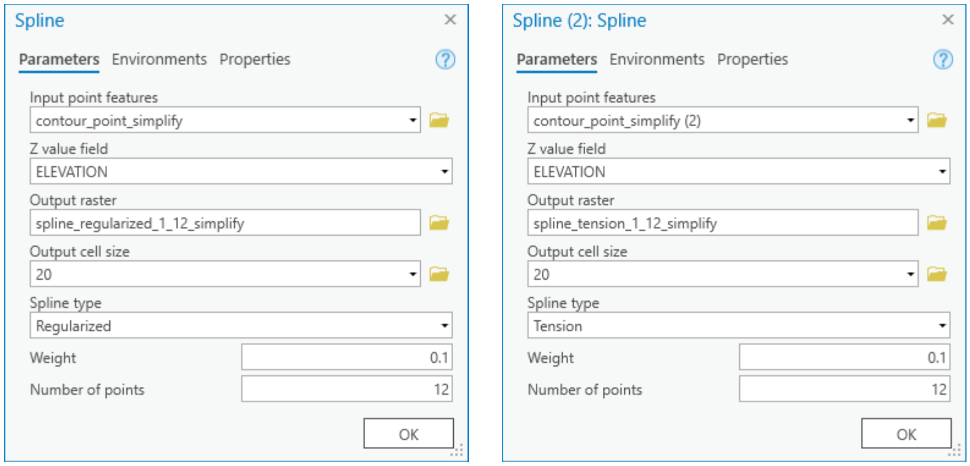

Figure 5. The parameters of the Spline tool with the Regularized option (left) and the Tension option (right). Note that only converted contour points generated by the simplified contour lines were used.

2.6 Interpolation: Topo to Raster

According to the ArcGIS Pro documentation, the Topo to Raster tool is an interpolation method specifically designed for the creation of hydrologically correct digital elevation models.

Unlike other interpolation methods, the Topo to Raster tool accepts contour lines as input features. Therefore both contour points and contour lines were used for exploration purposes (Figure 6).

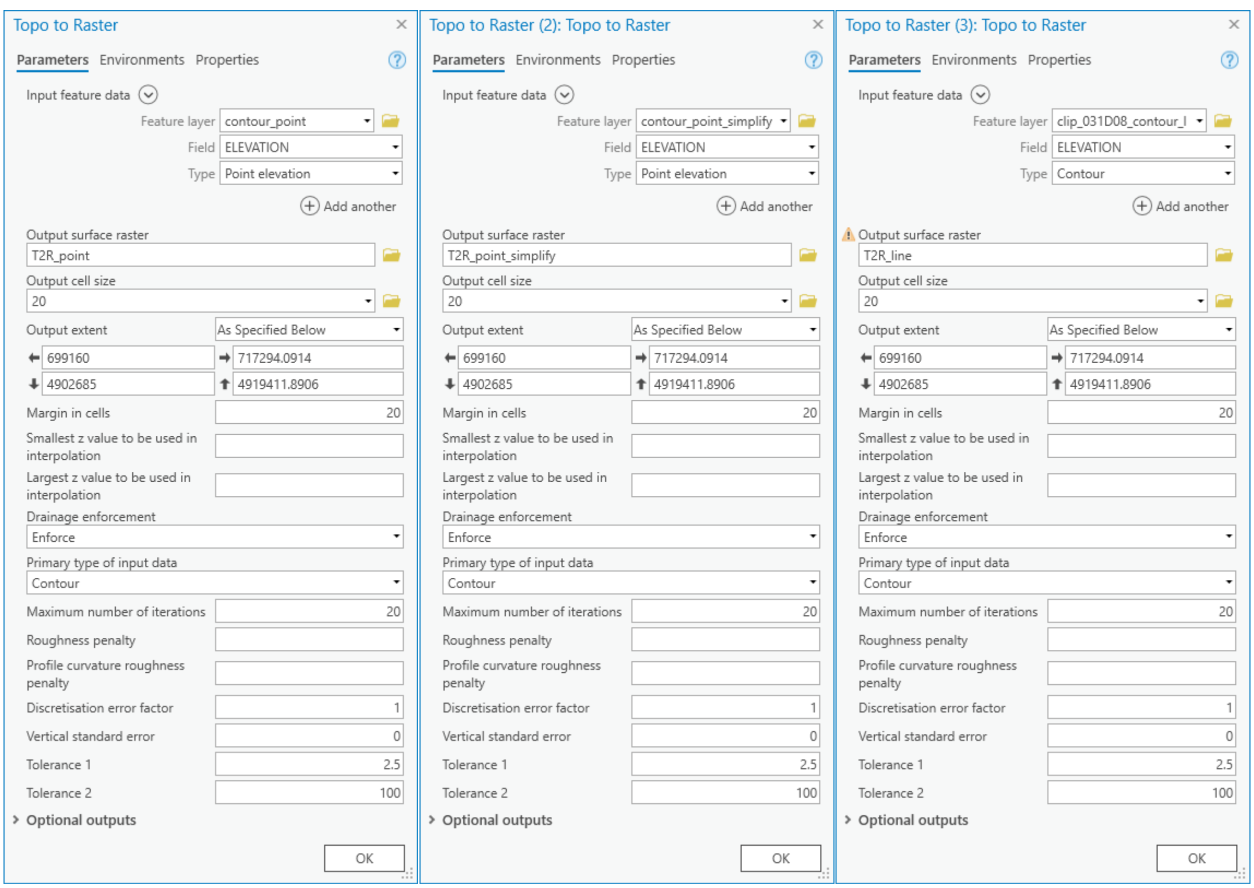

Figure 6. The parameters of the Topo to Raster tool, using the converted contour points generated by the original contour lines (left), the converted contour points generated by the simplified contour lines (middle), and the original contour lines (right).

2.7 Interpolation: Natural Neighbor

According to the ArcGIS Pro documentation, the Natural Neighbor tool finds the closest subset of input samples to a query point and applies weights to them based on proportionate areas to interpolate a value.

Since the Natural Neighbor interpolation is easy to use and can be used in a wide range of circumstances, it was chosen to be the last interpolation method to be explored (Figure 7).

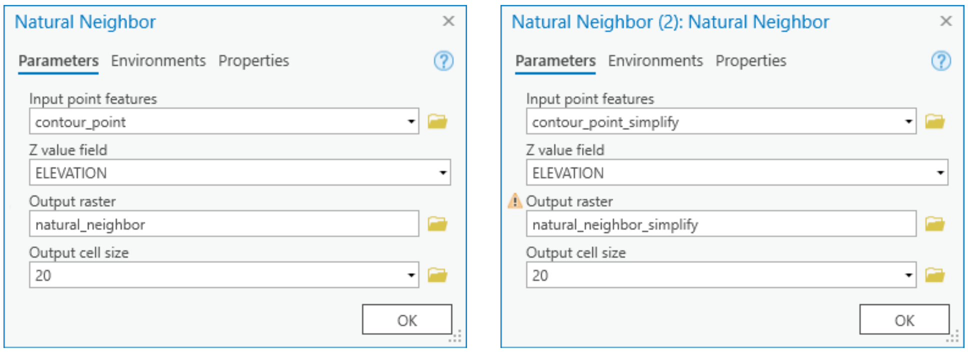

Figure 7. The parameters of the Natural Neighbor tool, using the converted contour points generated by the original contour lines (left) and the simplified contour lines (right).

3.0 Results

3.1 Topography

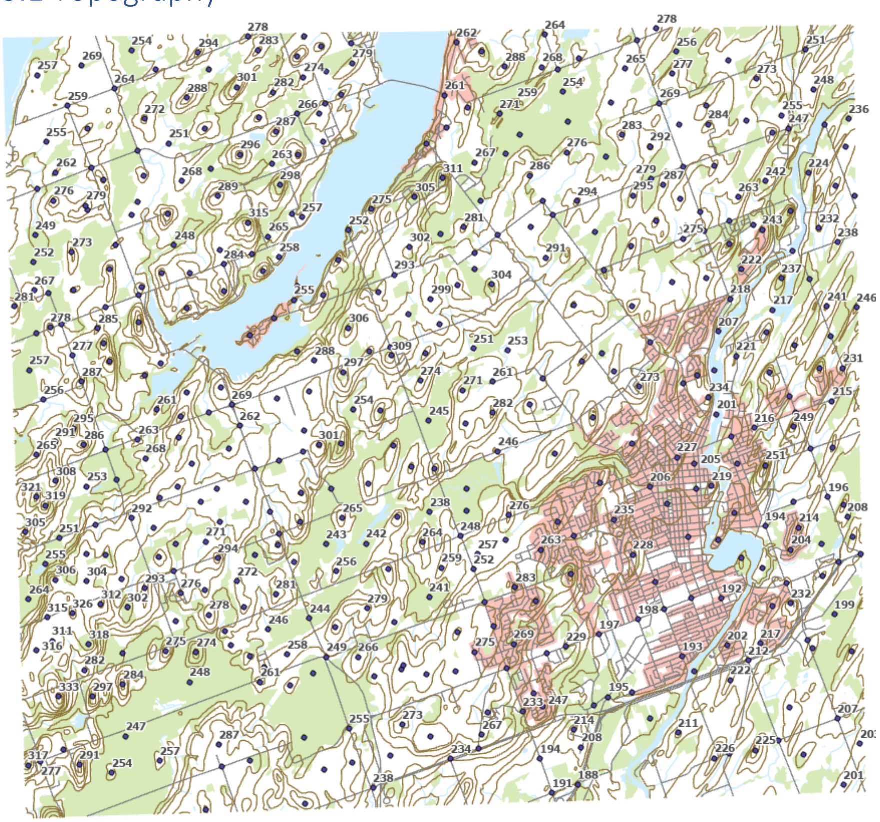

Figure 8. The topographic map of the Peterborough area, at a scale of 1:80,000. Note that the City of Peterborough (pink area) has a lower elevation compared to the other portions of the map.

3.2 Interpolation: Inverse Distance Weighting (IDW)

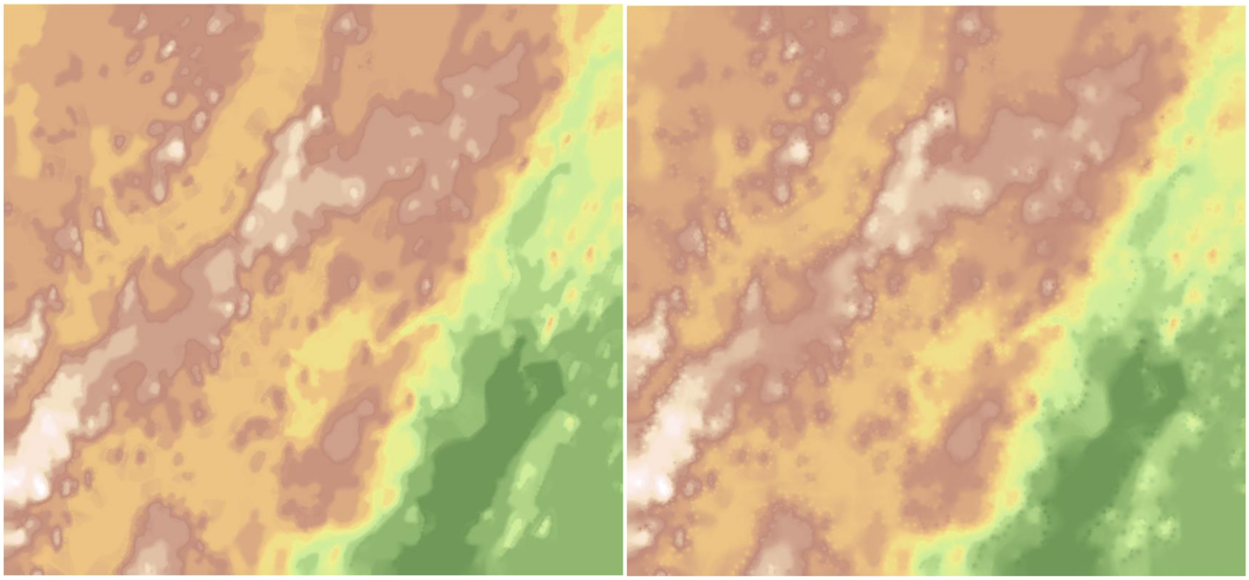

Figure 9. The DEMs generated by the IDW tool, using the converted contour points generated by the original contour lines (left) and the simplified contour lines (right). The symbology used is Stretch (Minimum Maximum).

3.3 Interpolation: Spline

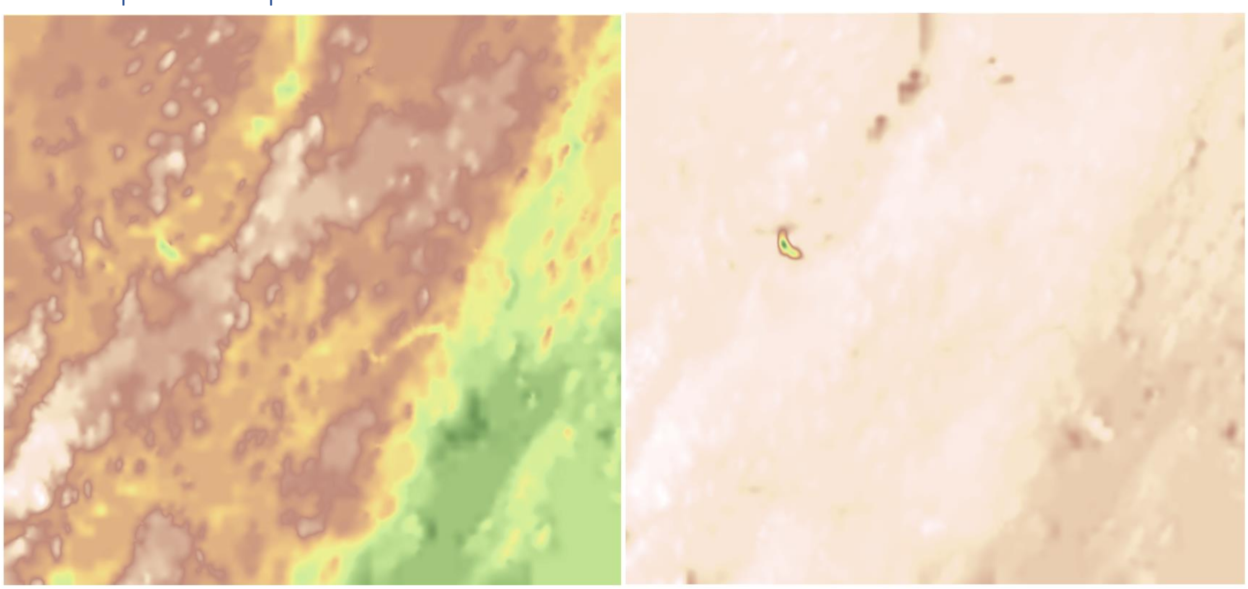

Figure 10. The DEMs generated by the Spline tool, with the Tension option (left) and the Regularized option (right). The symbology used is Stretch (Minimum Maximum).

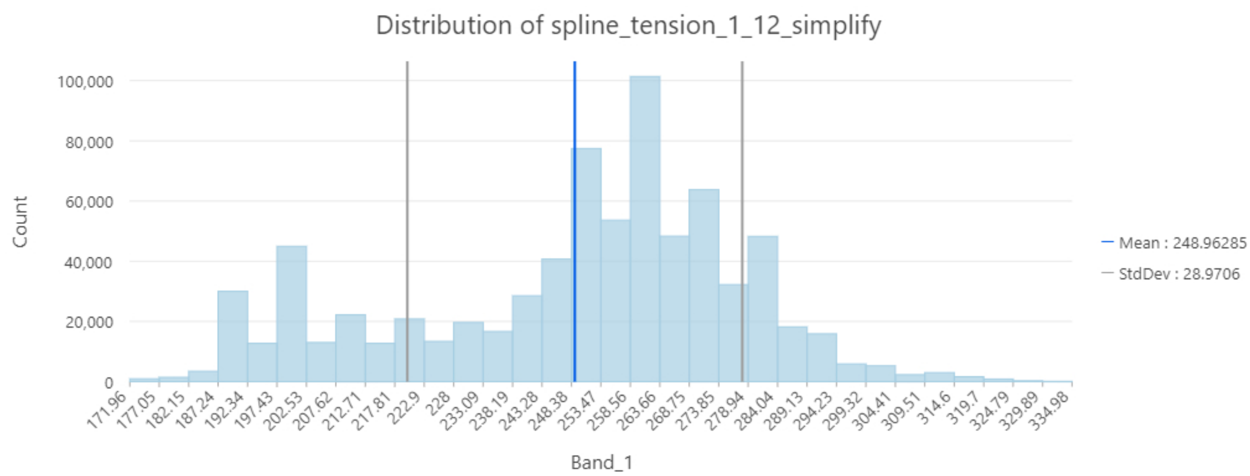

Figure 11. The histogram of the DEM generated by the Spline tool, with the Tension option.

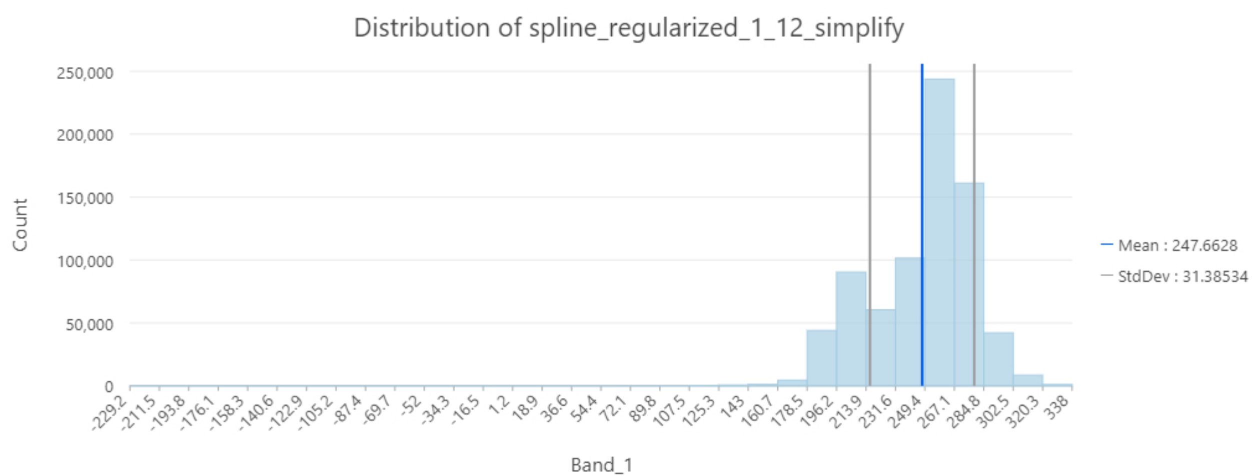

Figure 12. The histogram of the DEM generated by the Spline tool, with the Regularized option.

3.4 Interpolation: Topo to Raster

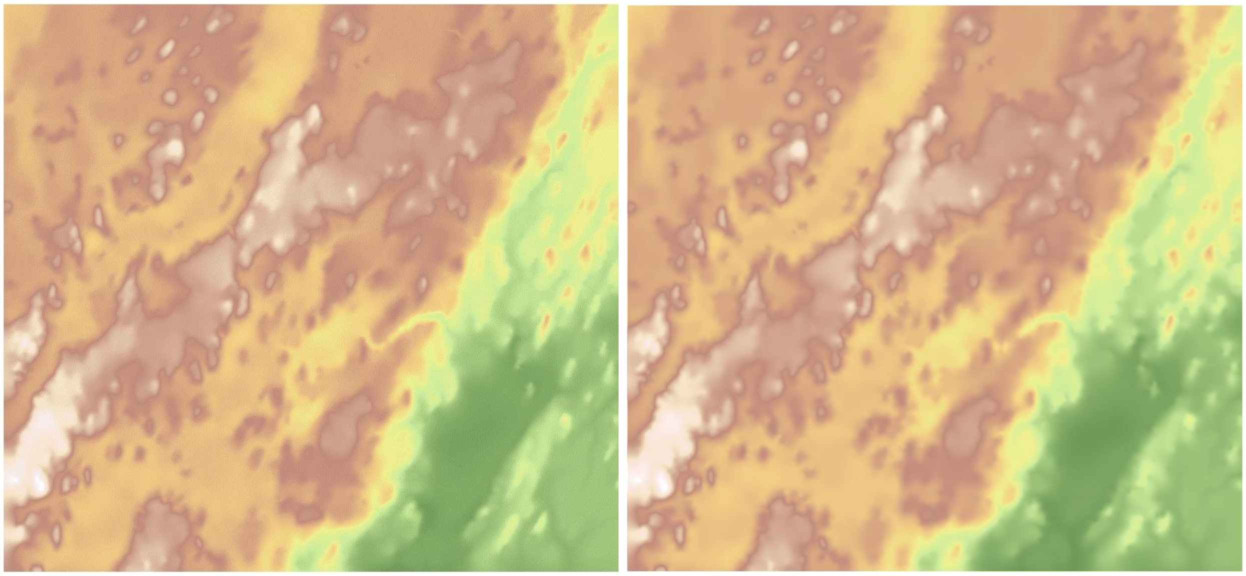

Figure 13. The DEMs generated by the Topo to Raster tool, using the converted contour points generated by the original contour lines (left), and the converted contour points generated by the simplified contour lines (right). The symbology used is Stretch (Minimum Maximum).

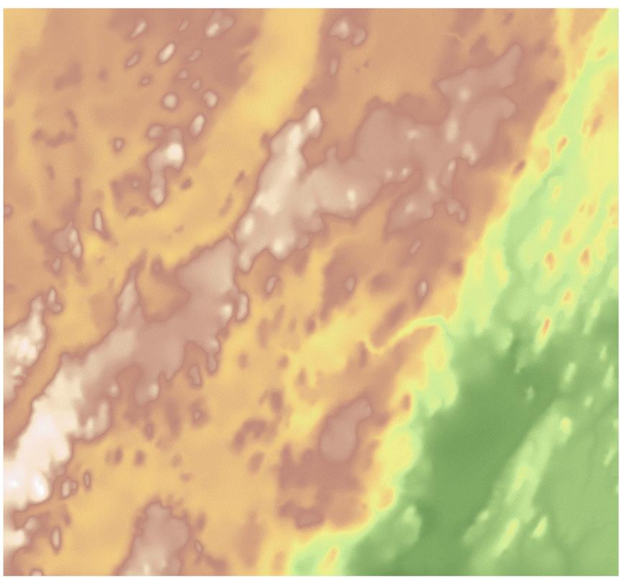

Figure 14. The DEM generated by the Topo to Raster tool, using the original contour lines (right). The symbology used is Stretch (Minimum Maximum).

3.5 Interpolation: Natural Neighbor

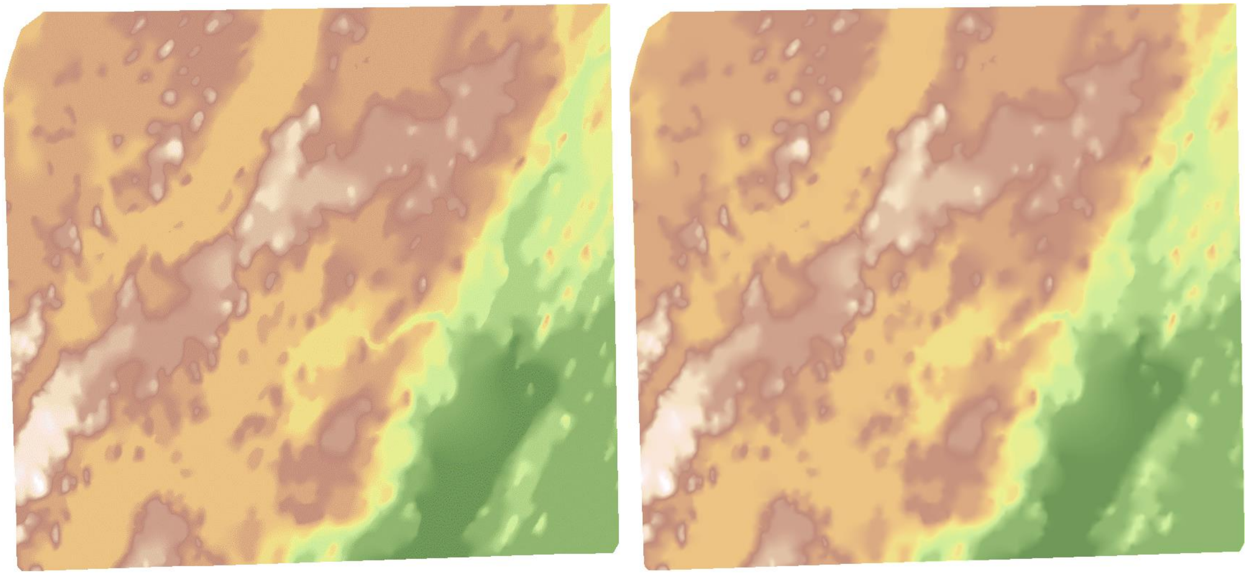

Figure 15. The DEMs generated by the Natural Neighbor tool, using the converted contour points generated by the original contour lines (left) and the simplified contour lines (right). The symbology used is Stretch (Minimum Maximum).

3.6 Interpolation Methods Comparison

FID	Spot Height	IDW Points Generated by Original Contour Lines	IDW Points Generated by Simplified Contour Lines	Spline Tension	Topo to Raster Points Generated by Original Contour Lines	Topo to Raster Points Generated by Simplified Contour Lines	Topo to Raster Original Contour Lines	Natural Neighbor Points Generated by Original Contour Lines	Natural Neighbor Points Generated by Simplified Contour Lines
25	208m	**199m**	200m	204m	204m	202m	**205m**	201m	201m
50	284m	278m	**276m**	282m	282m	281m	**283m**	278m	277m
75	275m	269m	**267m**	278m	**274m**	273m	**274m**	270m	270m
100	326m	**320m**	320m	**321m**	**321m**	**321m**	**321m**	320m	320m
125	286m	**282m**	283m	283m	283m	**282m**	**284m**	**284m**	**284m**
150	243m	250m	**251m**	**244m**	246m	246m	246m	250m	250m
175	208m	**201m**	**203m**	202m	**203m**	**203m**	**203m**	202m	**203m**
200	269m	258m	**257m**	261m	**262m**	260m	**262m**	260m	258m
225	242m	248m	**251m**	**241m**	242m	**241m**	**243m**	246m	246m
250	215m	**212m**	**215m**	**212m**	**212m**	**212m**	213m	213m	213m
275	295m	290m	**285m**	**293m**	**293m**	291m	**293m**	290m	289m
300	265m	**260m**	**261m**	**261m**	**261m**	**261m**	**261m**	**261m**	**261m**
325	304m	300m	**298m**	**302m**	**302m**	**302m**	**302m**	300m	300m
350	248m	**250m**	251m	251m	**250m**	**250m**	**250m**	**250m**	**252m**
375	273m	**270m**	**270m**	**270m**	**270m**	**271m**	**271m**	**270m**	**270m**
400	264m	**260m**	**260m**	**260m**	**260m**	**260m**	**260m**	**260m**	**260m**
425	287m	**280m**	**280m**	**283m**	**283m**	282m	**283m**	**280m**	**280m**
450	264m	**259m**	260m	**261m**	**261m**	**261m**	**261m**	260m	260m

Table 1. The actual values (spot height) vs. the estimated values of different interpolation methods (rounded to the nearest integer). The closest interpolated values to the original spot height values are indicated in red, and the most different values are indicated in blue.

	Spot Height	IDW Contour Points Generated by Original Contour Lines	IDW Contour Points Generated by Simplified Contour Lines	Spline Tension	Spline Regular	Topo to Raster Contour Points Generated by Original Contour Lines	Topo to Raster Contour Points Generated by Simplified Contour Lines	Topo to Raster Original Contour Lines	Natural Neighbor Contour Points Generated by Original Contour Lines	Natural Neighbor Contour Points Generated by Simplified Contour Lines
Minimum	188.00	190.00	190.00	171.96	-229.24	183.47	185.39	186.14	190.00	190.00
Maximum	333.00	330.00	329.98	334.98	337.98	332.57	332.34	332.58	330.00	330.00
Mean	260.00	250.45	251.28	248.96	247.66	249.30	249.53	249.30	250.56	250.72
Std. Dev.	30.20	28.17	27.93	28.97	31.39	28.77	28.72	28.69	27.81	27.71

Table 2. The statistics of different interpolation methods (rounded to 2 decimal places).

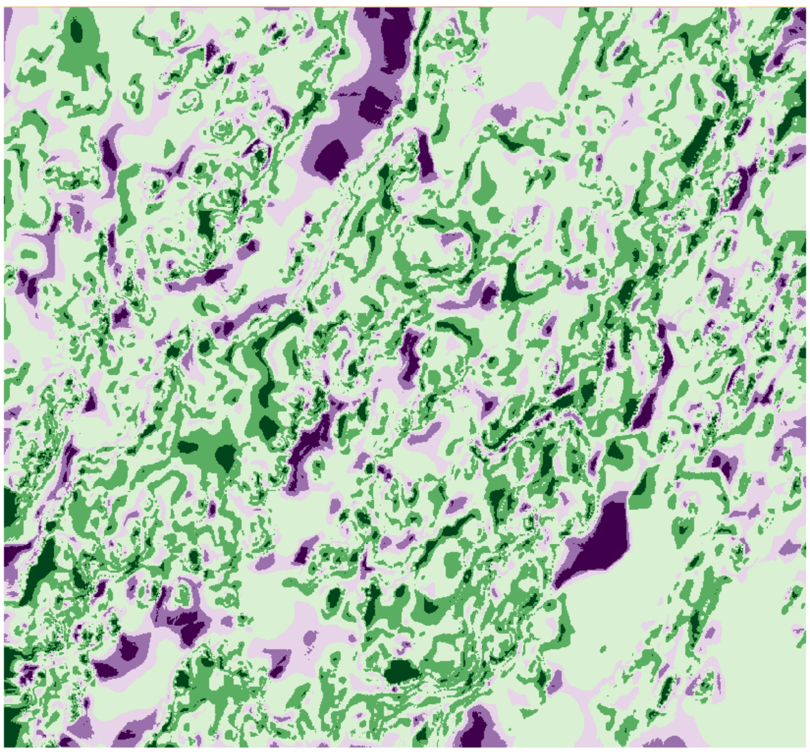

Figure 16. The DEM generated by the Raster Calculator tool, showing the differences between the DEMs generated by the IDW tool (contour points generated by the original contour lines as input features) and the Topo to Raster tool (original contour lines as input features). The range of the differences is between -19.45 and 17.07 (rounded to 2 decimal places). The symbology used is Classify (1 Standard Deviation).

4.0 Discussions

4.1 Interpolation: Inverse Distance Weighting (IDW)

Although Inverse Distance Weighting (IDW) interpolation is the default interpolation methods in many GIS software, it did not estimate the unknown values as good as the other interpolation methods based on the collected sample data (Table 1). However, it is important to be aware that the performance of the interpolation method was evaluated based on the sample values that were collected randomly, which may not be representative and may be limited to the context. There were no significant differences between the DEMs generated by the converted contour points using the original contour lines and the simplified contour lines (Figure 9).

4.2 Interpolation: Spline

Before discussing the results of the Spline interpolation, the importance of setting the Spline type parameter should be discussed. Unlike the histogram of the Tension option (Figure 11), the histogram of the Regularized option was extremely left skewed and it had negative elevation values (Figure 12). Since the Regularized option gradually changes surface values using values not necessarily true to the surface values, the parameter of the Spline tool should be set to Tension instead of Regularized.

The Tension option of the Spline interpolation uses values representative of the surface by controlling stiffness, producing a rough but accurate surface. As the result, the DEM generated by the Spline tool was rougher compared to the DEMs generated by other interpolation methods. For example, the Chemong Lake (top-left area) had a consistent elevation (i.e. flatter surface) in the DEMs generated by other interpolation methods, whereas it had a relative inconsistent elevation (i.e. rougher surface) in the DEM generated by the Spline tool (Figure 10). In terms of the accuracy, the Spline interpolation estimated the unknown values almost as good as the Topo to Raster interpolation, which will be discussed in the next section, based on the collected sample data (Table 1).

4.3 Interpolation: Topo to Raster

One of the main characteristics of the Topo to Raster interpolation is that it also accepts lines and polygons as input features. Therefore it should generate a more accurate result as the contour lines does not have to be converted to the contour points first before running the tool.

Although the Topo to Raster interpolation had the best performance in estimating unknown values based on the collected sample data, especially when the original contour lines were used as input features (Table 1), it has the most complicated parameter settings among the interpolation methods.

Although the DEM generated by the original contour lines were slightly more accurate compared to the converted contour points, the differences were not very significant (Figure 13 and Figure 14).

4.4 Interpolation: Natural Neighbor

Natural Neighbor interpolation is very easy to use in terms of the parameter settings. It has the fewest parameter settings among the interpolation methods, as it requires users to set the input point features, the Z value field, and the output cell size (optional) only. Based on the sample data collected (Table 1), the Natural Neighbor interpolation estimated unknown values better compared to the IDW method. There are no significant differences between the DEMs generated by the original contour lines and the simplified contour lines (Figure 15).

4.5 Comparing Interpolation Methods

The difference between Inverse Distance Weighting (IDW) and Topo to Raster was generated using the Raster Calculator tool. As mentioned above, the IDW tool did not estimate unknown values as good as other interpolation methods, and the Topo to Raster tool delivered the most accurate results among the interpolation methods, based on the sample values collected randomly (Table 1). Therefore, we can assume that the differences between these two interpolation methods were the largest compared to other interpolation methods. Based on the results, the differences between the two interpolation methods were approximately ± 20 metres (Figure 16). It showed that the interpolation methods that are available in ArcGIS Pro can generate similar results as their differences were not extremely significant.

5.0 Conclusions

In conclusion, the interpolation methods that are available in ArcGIS Pro can estimate the unknown values fairly accurate. Although there were no significant differences between the DEMs generated by the converted points using original contour lines and simplified contour lines, in terms of the processing time and the interpolated results, simplified contour lines may reduce the accuracy of the results and thus original contour lines should always be the first priority.

In terms of the interpolated results, the Topo to Raster interpolation had the best performance in estimating unknown values based on the collected sample data. However, it has the most complicated parameter settings and users should have a good understanding of the interpolation method first before using the tool. In terms of the ease of use, the Natural Neighbor interpolation is an efficient interpolation method for the users who do not have much knowledge about interpolation and want to generate interpolated surfaces quickly.

Although the Inverse Distance Weighting (IDW) interpolation method did not estimate unknown values as good as other interpolation methods in this specific exploration, it can still generate an interpolated surfaces fairly accurate. It is important to understand that there is no "best interpolation method" or "worth interpolation method" for all circumstances. Each interpolation method has their own advantages and disadvantages, and users should choose an interpolation method based on their research purposes and context.

6.0 References

Chalmers, K. (2022). *Environmental Modeling using GIS & Spatial Interpolation* [PowerPoint slides]. https://fleming.desire2learn.com/d2l/le/content/165957/viewContent/1921292/View

Chang, K. (2019). Chapter 15 Spatial Interpolation. *Introduction to Geographic Information Systems* (9th ed.). McGraw-Hill Education.

Esri. (n.d.). *How Spline works*. ArcGIS Pro Documentation. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-spline-works.htm

Esri. (n.d.). *How Topo to Raster works*. ArcGIS Pro Documentation. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-topo-to-raster-works.htm

Esri. (n.d.). *How Natural Neighbor works*. ArcGIS Pro Documentation. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-natural-neighbor-works.htm

Appendices

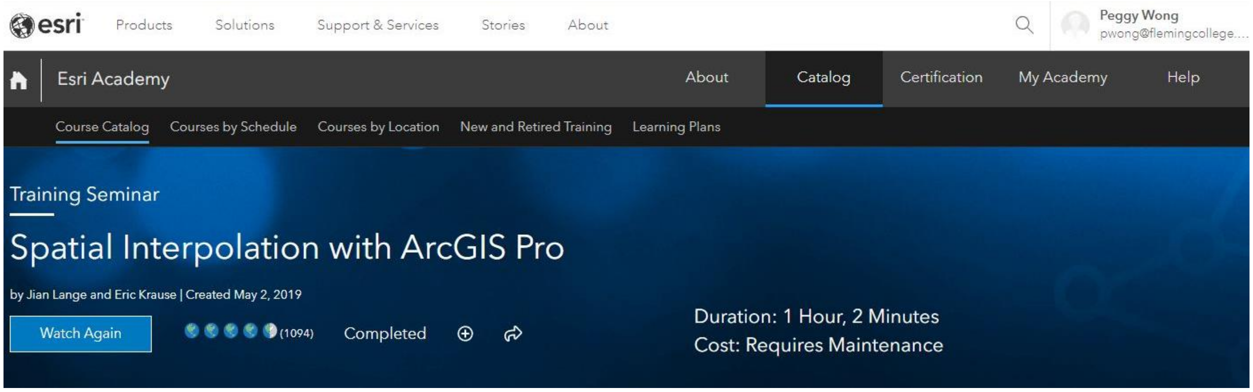

Figure 1. The completion of the Esri training seminar "Spatial Interpolation with ArcGIS Pro" by the author.

File Name	Classification / Category	Feature Type	Number of Records	Description
clip_031D08_contour_l.shp	Clipped contours	Line	533	Contour
clip_031D08_elev_pt_p.shp	Clipped spot heights	Point	486	Elevation point
clip_031D08_builtup_a.shp	Clipped built-up area	Polygon	15	Built-up area
clip_031D08_road_l.shp	Clipped roads	Line	3016	Road
clip_031D08_vegetat_a.shp	Clipped vegetation	Polygon	404	Vegetation
clip_031D08_water_b_a.shp	Clipped water	Polygon	107	Waterbody
clip_031D08_water_c_l.shp	Clipped water	Line	376	Watercourse

Table 1. The shapefiles in the National Topographic System (NTS) 31D8 dataset that were used to explore the topography of the Peterborough area in Ontario. Note that all shapefiles were re-projected from NAD83 UTM Zone 17 North Meter to NAD 1983 UTM Zone 17N.