Lab Assignment 3 – Line Analysis

Due Date: 09/30/2020

Overview

This assignment is designed to help you practice various analytical methods regarding data of linear feature type. The topics covered in the Week 4 Lecture (hence, this lab assignment) include: calculating line length, line density, circular/spherical variance (measures how scatted lines are), linear directional mean, and linear orientational mean as well as the comparisons.

Objectives

The objectives of this lab assignment are to help you:

- Refresh the skills about creating and manipulating line features using both ArcMap and ArcGIS Pro.
- Know how to use various measurements and analysis tools for linear features.
- More importantly, through comparing manual calculations with using software, gain an in-depth understanding about linear directional mean and linear orientational mean.

Data

- Prince George County Boundaries
- Caribou Migration Tracks that you'll download later in the lab assignment online
- The rest of the data you will create as you go through the lab.

Part I – About Line Features

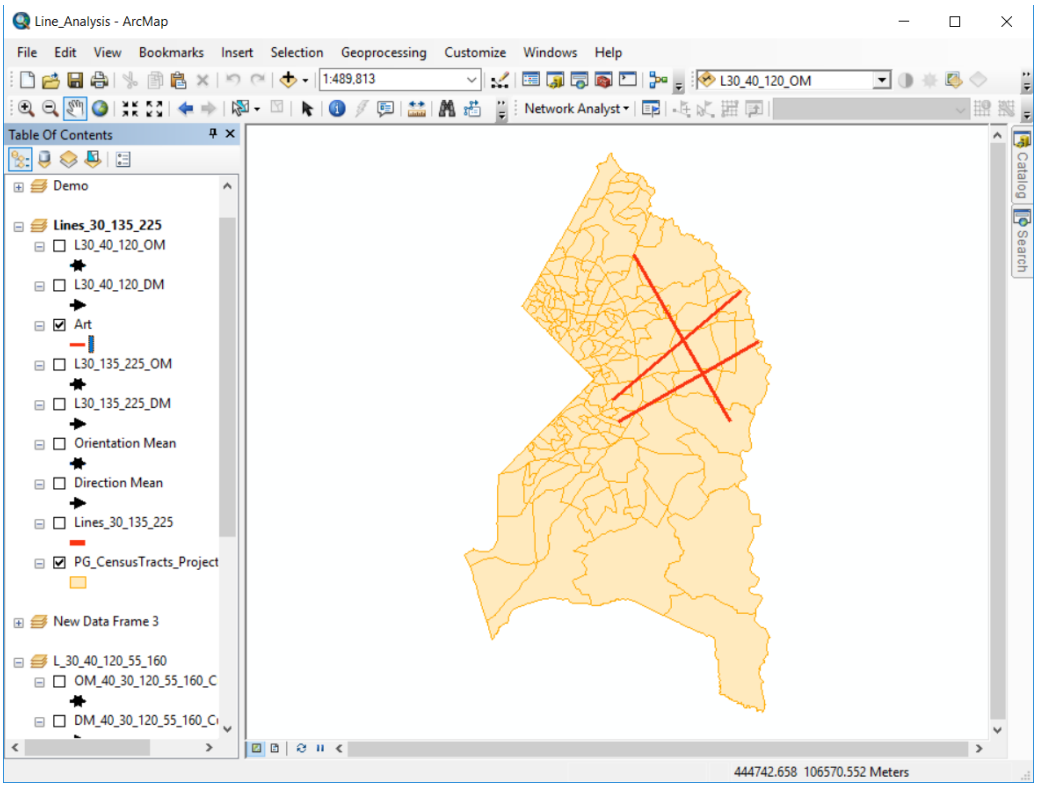
1. Creating Lines

In this first exercise, you are required to create a new dataset which is a line feature type.

First, you are required to use ArcMap to create a set of five lines with directions: 30^o, 40^o, 60^o, 125^o, and 230^o respectively.

- If you are not familiar with how to create a new shapefile, you can refer to this link - http://desktop.arcgis.com/en/arcmap/latest/manage-data/shapefiles/creating-a-new-shapefile.htm
- After you create the data, make sure you define the coordinate system as the same as that of PG County Census Tracts data.
- If you don't know how to create the lines with precise angles (direction), you can refer to the demos video archive during the lab session this week.
- When you create the lines, you can use various lengths. (The length is less important than the direction in this specific exercise.)

After you create the five lines, make a screen shot similar to the one below. On your map, you would have five lines.



Use a different color scheme and apply appropriate labels as necessary.

[1] Include a screenshot of your data in the lab report.

You are also required to practice how to create lines in ArcGIS Pro.

Now you need to add five more lines with these angles: 15°, 20°, 43°, 65°, and 330° respectively. You can either edit the lines previously created and then add the new ones. Or, you can create these 10 lines from scratch in ArcGIS Pro.

You may refer to the demo during the lecture this week and also these links on how to do it.

- Create a file geodatabase
  - https://pro.arcgis.com/en/pro-app/help/data/geodatabases/overview/create-a-file-geodatabase.htm
- Create a feature class
  - https://pro.arcgis.com/en/pro-app/help/data/feature-classes/create-a-feature-class.htm
- Direction formats for editing
  - http://pro.arcgis.com/en/pro-app/help/editing/direction-formats-for-editing.htm

After you have added the five new lines, make a screen shot of all 10 line features.

[2] Include a screenshot in the lab report.

Note:

- There is a reason why we need more lines. Without enough lines, when you use the software later to calculate the Linear Directional Mean, you will get a warning message because there is a requirement on the minimum number of lines.
- https://pro.arcgis.com/en/pro-app/tool-reference/tool-errors-and-warnings/110001-120000/tool-errors-and-warnings-110051-110075-110068.htm

2. Calculating Line Length

You have just created a line feature class. However, the lengths of those ten lines are unknown. So, your next task is to calculate the line length.

You will need to create a new field (define the data type as Double) and then calculate the geometry - Length. Make sure to select appropriate units and include them in the report!

After you finished, make a screenshot of the attribute table showing the line lengths.

[3] Include a screenshot of your table in the lab report.

3. Calculating Great Circle Distance

Caribou migrate long distances in Arctic region. There are data that you can download from this web site - http://www.learner.org/jnorth/gis/shapefile.html#Caribou. (**Note:** The link seems to be down right now. However, I had downloaded it before. I have included this data into the Lab 3 dataset on ELMS.) Based on the data in Spring, 2002, the migration roughly falls within this range:

	Latitude	**Longitude**
Top-left corner	65.037	-138.701
Bottom-right corner	68.707	-148.578

Now, your task is to calculate the great circle distance between these two points and find out the approximate range of Caribou's migration. Assume the radius of the Earth is 6371 km.

Refer to the formula in the lecture slides. Make sure you convert the angles into radians before plug into the formula.

You can use Excel to do the calculations. Take a screenshot of your work and include the final result (total migration distance). Include units!

[4] Include the screenshot of your work and final result in the report.

Use ArcGlobe to create those two points and measure the distance on the surface. The result should be very close to your calculated one. Use the "Go to XY" tool to create markers for the two locations and then use the measure tool to calculate the "Length on Ground."

[5] Include a screenshot of the two points in ArcGlobe and include the measured distance.

Part II – Linear Directional Mean and Linear Orientational Mean

1. Linear Directional Mean

You displayed the direction of the lines earlier. However, it only shows the direction of how the line starts and/or ends. A much more interesting question is to find out the trend of a set of lines. This is particularly useful because it allows us to compare the trend in a set of lines to other features to look for possible relationships.

First, you need to manually calculate the Linear Directional Mean of these ten lines. Then, you will use ArcGIS tool to get the result. Finally, you will compare the two results to see if they match.

Doing so, you will have a thorough understanding about exactly how this tool works and also the concept of Linear Directional Mean. In addition, you will better understand the subtle differences between Linear Directional Mean and Linear Orientational Mean.

Now, you will calculate the Linear Directional Mean of those ten lines: 30º, 40º, 60º, 125º, 230º, 15º, 20º, 43º, 65º, and 330º.

Here below is the formula to calculate the Linear Directional Mean:

$$\theta_R' = \arctan \frac{\sum_{i=1}^{n} \sin \theta_i}{\sum_{i=1}^{n} \cos \theta_i}$$

Where:

θ_i: the direction of line i
n: the total number of lines

Here are some tips and hints:

- You may want to use Excel to help do the calculations.
- For those of you who are rusty with trigonometry, the conversion between radian and degree is: Radian = (Degree * π / 180).
- To determine the actual linear directional mean, you may need to compensate the result depending on the scenarios in the table below.
- If you are not sure how to do the calculations, you can refer to the demos video archive during the lab session this week.

Note: To get the final angle for linear directional mean, you will need to refer to the table below as there are different scenarios where you may need to compensate the number from the calculations.

	$\sum_{i=1}^{n} \sin\theta_i \geq 0$	$\sum_{i=1}^{n} \sin\theta_i < 0$
$\sum_{i=1}^{n} \cos\theta_i > 0$	$\theta_R = \theta_R'$	$\theta_R = 360\text{-}\theta_R'$
$\sum_{i=1}^{n} \cos\theta_i < 0$	$\theta_R = 180\text{-}\ \theta_R'$	$\theta_R = 180+\theta_R'$

Question:

- What is your calculated Linear Directional Mean?

Make a screenshot of the Excel sheet on which you did the calculations. The screenshot should show the calculations and also the final answer. If you used some other program for the calculations, make a screenshot show the similar information.

[6] Include the screenshot in the lab report.

Now, let the software work for you and switch to ArcGIS Pro.

Find the tool - Linear Directional Mean.

Note:

- Don't check the small box in front of “Orientation Only” yet.

Take a screenshot showing the result.

Open the attribute table of the output, you should be able to find the directional mean. Make a screenshot to show the result.

Does this number match your calculation earlier?

[7] Include the screenshot as well as the answer to the above question.

2. Linear Orientational Mean

Orientation is a similar but subtly different concept compared to direction.

A direction angle can be from 0 to 360 degrees. However, an orientation angle is between -90 and 90 degrees. You may refer to the demos I did during the lecture.

Similarly, you can calculate the Linear Orientational Mean:

$$\theta'_O = \arctan \frac{\sum_{i=1}^{n} \sin \theta_{Oi}}{\sum_{i=1}^{n} \cos \theta_{Oi}}$$

Where:

θ_i: the orientation of line i
n: the total number of lines
θ'_O: takes a value between -90 and +90 degrees

You can use Excel to do the calculations.

Question:

- What is your calculated Linear Orientational Mean?

Make a screenshot of the Excel sheet on which you did the calculations. The screenshot should show the calculations and also the final answer. If you used some other program for the calculations, make a screenshot show the similar information.

[8] Include the screenshot in the lab report.

Now, switch to ArcGIS Pro.

Find the tool - Linear Directional Mean.

Note:

- This time make sure you check the small box in front of "Orientation Only".

Take a screenshot showing the result.

Open the attribute table of the output, you should be able to find the orientational mean. Make a screenshot to show the result.

Question: Does this number match your calculation earlier?

[9] Include the screenshot as well as the answer to the above question.

Part III – Circular Variance

Given a set of lines, it is not enough to just look at the linear directional mean or orientational mean because they only indicate the trend of the lines but they do not tell the whole picture of how those lines are spatially distributed. This leads to a new analysis – Circular Variance, which measures the variability in direction of lines. In another words, it is a measure of how much line directions or orientations deviate from the directional mean.

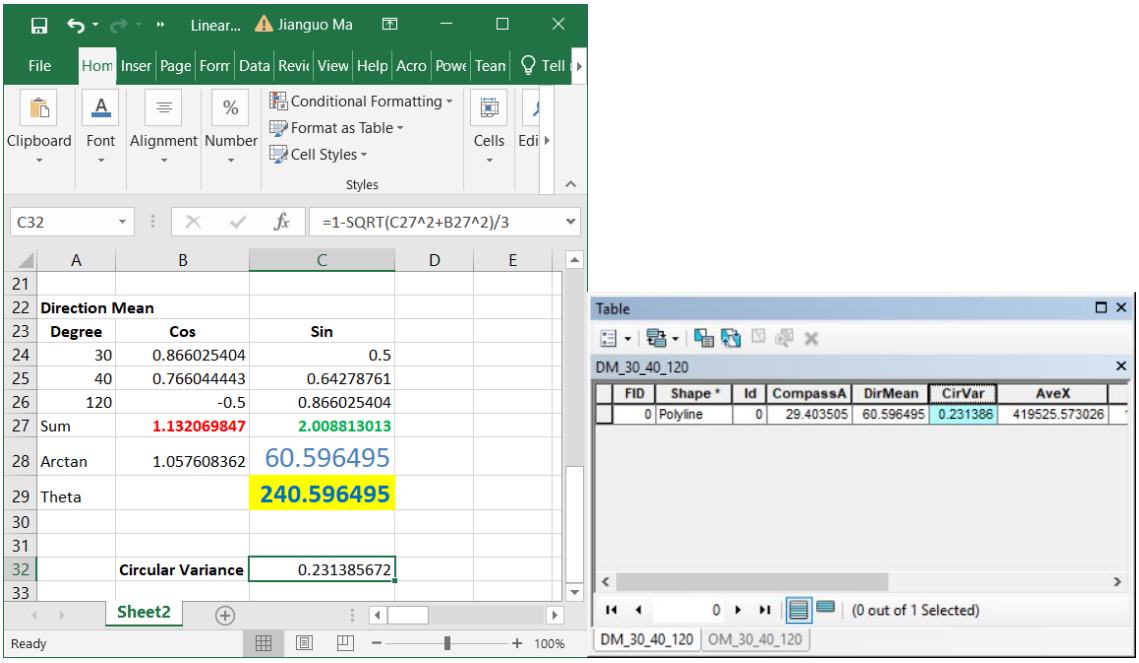
To calculate the Circular Variance, we use this formula:

$$S = 1 - \frac{\sqrt{(\sum_{i=1}^{n} \sin\theta_i)^2 + (\sum_{i=1}^{n} \cos\theta_i)^2}}{n}$$

θ_i: the direction of line i

n: the total number of lines

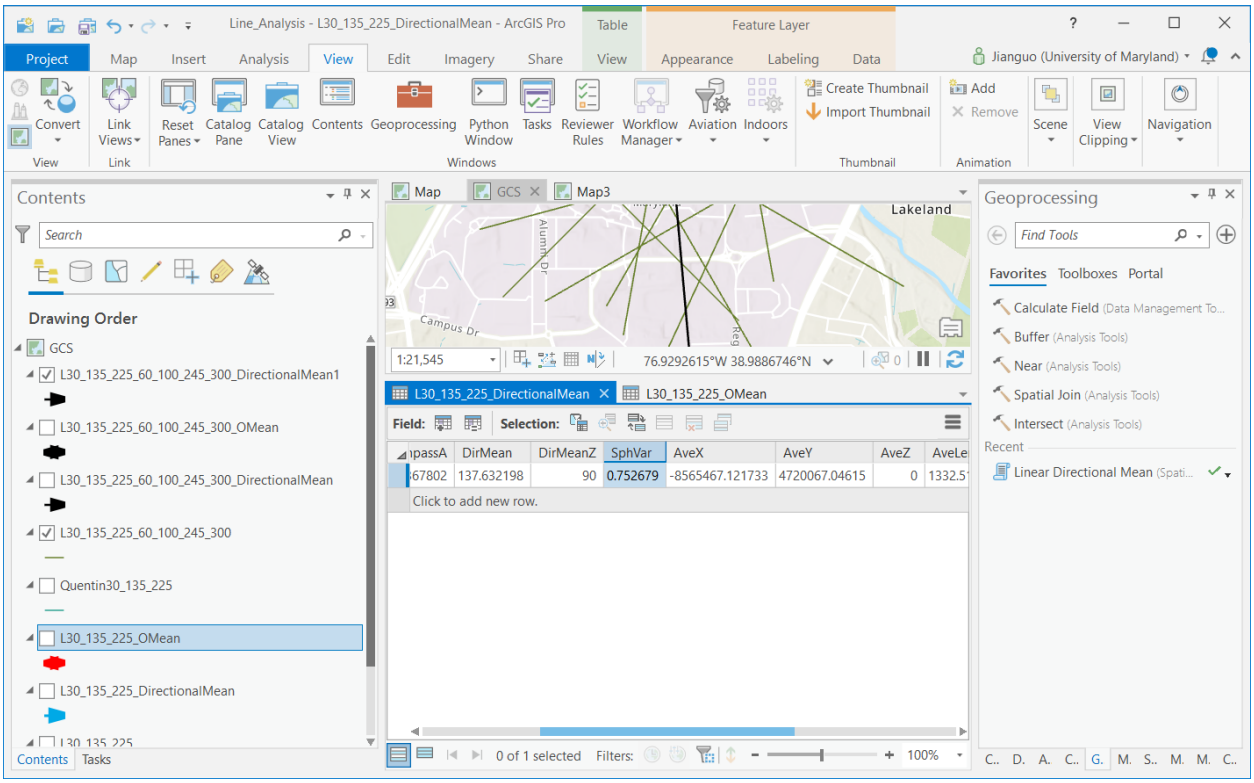
Here below is an example of how the circular variance of three lines was calculated. I also got the Circular Variance result by using the tool – Linear Directional Mean in ArcGIS. These two results match perfectly.



Note:

- This Circular Variance based on direction is different from that based on orientation.

While using ArcGIS Pro, the Circular Variance is equivalent to Spherical Variance. Here is a screenshot of what it looks like in Pro.



To learn more details about this topic, you can refer to this link – https://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/linear-directional-mean.htm

Earlier when you used the tool – Linear Directional Mean to find out linear directional mean and also linear orientational mean, you actually had already had the answers for circular variance.

Open the attribute table of the outputs of linear directional mean and also orientational mean.

Questions:

- What is the Spherical Variance of these ten lines based on direction?
- What is the Spherical Variance of these ten lines based on orientation?

[10] Include the answers in the lab report.

You should notice that these two numbers are different. This is easy to understand because of different definitions of direction and orientation.

Now, it's your turn to do some calculations using the formula on previous page and then compare the results with that from software.

Make a screenshot of the Excel sheet on which you did the calculations. The screenshot should show the calculations for both scenarios: based on direction and orientation respectively.

[11] Include the screenshot in the lab report.

Part IV – Line Density

Line Density measures the total length of lines within a unit size of area. The result is a surface which provides similar information for lines compared to finding "hot spots" for points.

Just like the point density map, the area unit will be square kilometers if the map unit is meter. And the area unit is square miles if the map unit is feet. However, you can change the area unit to other options such as square feet.

Ideally, Line Density analysis is good for a large set of lines. However, we are going to use the data we created anyway. Just for practice.

Use ArcGIS Pro and find the tool - Line Density.

The Input should be the shapefile of five lines that you created. Select "NONE" for "Population Field" and then define the output. For the output cell size, you can choose 100 (unit is in meters).

Before you click OK, you will need to click the Environments button first. Then select General Settings. You will need to set the Processing Extent to "Same as layer PG_Cnty_Bnd". Otherwise, the extent of the output will be the same as that of the line shapefile which has a smaller extent. (The default extent of the output is the Intersect of all inputs.)

Leave the rest as default. Make a screenshot of the result.

[12] Include a screenshot of your work in the lab report.

Extra practice for those who have time and interest:

- When the line density is calculated, a circle is drawn around each raster cell center using the search radius. The length of the portion of each line that falls within the circle is multiplied by its Population field value. These figures are summed and the total is divided by the circle's area.
- If the Population field is left blank, it is simply the total length of lines that will be divided by the circle's area.
- So, the Population can be considered as a weight factor. For example, when calculating the traffic density of an area, the number of lines/roads (hence, road length) can be multiplied with the number of vehicles on each road (which can be used as a Population field) to better describe the actual traffic density.

Now, if you have time and interest, you can try to use an appropriate field as the Population field and then calculate the line density.

Also, you can try to use different cell sizes. The density map may look quite different. After you have done all these tests, you can share some of your findings or understanding in the discussion forum on ELMS.

Part V – Caribou Migration Tracking

The data used for this exercise contains a point shapefile of GPS coordinates and dates for the locations of nine caribou (Cupid, Blixen, Donner, Isabella, Lucky, Lupine, Lynetta, Trudy, and Catherine).

Notice that the data is missing spatial references. So, before you import the point shapefile (CaribS02.shp), define its projection to "Geographic Coordinate Systems → Pacific Ocean → Alaskan Islands". Then project the data to a Projected Coordinate System, "NAD_1983_StatePlane_Alaska_1_FIPS_5001_Feet".

You will need to use ArcGIS Pro for this exercise.

Note:

- If using ArcMap, you will need the Tracking Analysis tools. Make sure that the extension for Tracking Analyst is turned ON.

Explore the attribute table of the shapefile a bit. You should see two important attributes. Firstly, the name of the caribou (such as "Blixen"). Secondly, the date that the GPS coordinate was recorded (the tracking location of the caribou as it migrates).

First, use the "Points to Line" tool to create a new data layer of line segments connecting the GPS coordinates for each individual caribou. Set the time field to DATE and the ID field to NAME.

Once you have created the output, set the symbology so that each caribou is a different color. Also, add end arrows for each line segment.

[13] Add a screenshot to your report. Include a legend that shows the color for each caribou.

Now, we want to calculate the average distance that a caribou travels. Using the steps mentioned before with the Linear Directional Mean tool to find out the average trend of the caribou.

[14] Add a screenshot to your report showing the individual caribou tracks as well as the mean directional line.

[15] What is the average distance that a caribou travels? Remember to include units.

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