

Tutorial for Generating Natural Streets and Analyzing their Scaling Structure

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I. Introduction

The formation of natural streets is self-organized, naturally from individual road segments, based on the Gestalt principle of good continuity. Each segment joins with its neighbor according to some principles, such as every-best-fit, self-best-fit, and self-fit (Jiang, Zhao, and Yin 2008). The difference between these three principles is whether each segment considers every segment or only itself when choosing one (best) fit neighbor. For joining each segment with its most suitable neighbor segment, it is necessary to repeat the process of choosing the smallest deflection angle until the angle becomes greater than a given value. The result represents streets that are connected to each other and form a network topology. Natural streets differ from named streets that are identified by the unique names. The former (natural streets) has no problems with losses or errors of names, while named streets are difficult to implement due to the incompleteness of names. The concept of natural streets is widely used, such as computing the fewest-turn map directions or routes (Jiang and Liu 2011). Generating natural streets is the first and most important part in this tutorial.

The previous study by Jiang (2009) has illustrated the fact that urban streets demonstrate the scaling property, which refers to far more less-connected than well-connected. This tutorial uses two methods to analyze scaling structure of natural streets. One method is power law distribution which is a type of heavy-tail distributions that can present the scaling pattern. The other is head/tail breaks (Jiang 2013) which is a classification scheme that divides data with heavy-tail distribution into the head (which has a very few of large values) and the tail (which has a lot of small values). Data are classified around their arithmetic mean or average, recursively divided into head (above the mean) and tail (below the mean) by the use of head/tail breaks. The rest of this tutorial has four sections. Section 2 provides the download information of software and data resources. Section 3 is a detailed guidance for generating natural streets. Power law distribution and head/tail breaks are applied in section 4 and 5.

II. Data resource and software support

This tutorial takes a French city Avignon as an example, the data of OpenStreetMap could be downloaded from <http://download.geofabrik.de/>. In this website, select *Europe, France, Provence* under the *Sub-Region* and saved the shapefile data.

ArcMap 10.4 or latest version (<http://desktop.arcgis.com/en/arcmap/>)




Axwoman 6.3 (<http://fromto.hig.se/~bjg/axwoman>)

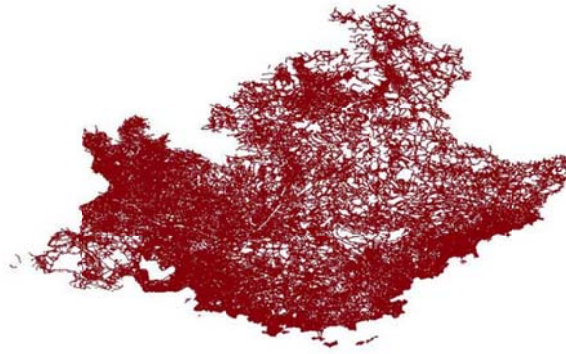
Head/tail breaks calculator (<https://github.com/dingmartin/HTCalculator>)

Pajek (<http://pajek.imfm.si/doku.php?id=download>)

Matlab (https://se.mathworks.com/downloads/web_downloads)

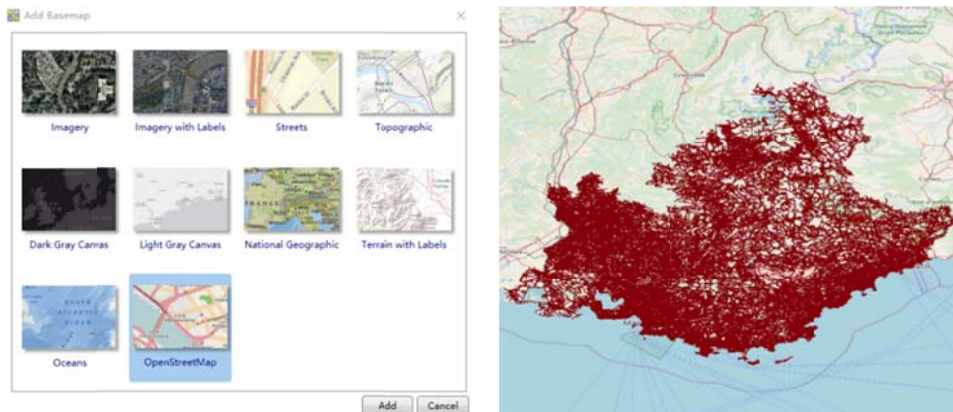
III. Generating natural streets

1. Start by opening ArcMap with a *Blank Map*, and import the data you saved before. Click the *Add Data* icon . Or Click the *ArcCatalog* icon  and connect to your data folder by clicking on the *Connect to Folder* icon , then add the *Roads* shapefile.

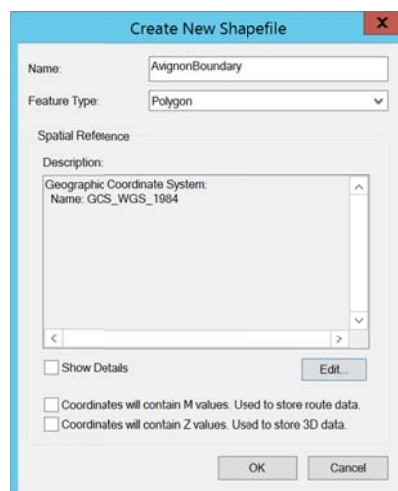


Note: In this tutorial, we only selected Avignon as an example so that it needs to be extracted from the data.

2. Avignon should be located from whole Provence. Adding a base map when looking for an area is helpful because it can display the boundaries, names and other information. (If you do not need to use base map, do step 3 directly.)
 - a. Click the *Add Data > Add Basemap*.
 - b. Choose one map you want.




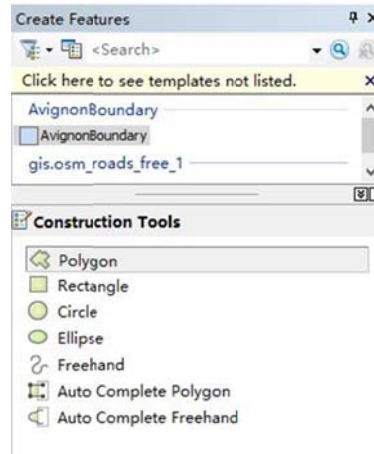
3. Create a boundary for Avignon so that it can be clipped.
 - a. Click the *ArcCatalog* icon, *Connect to Folder* you are working with.
 - b. Right click the folder, select *New > Shapefile...*
 - c. In the Create New Shapefile Dialog, type *Name* as *AvignonBoundary*, For the *Feature Type*, choose *Polygon*.
 - d. Click *Edit...* Choose the same coordinate system as the layer *WGS 1984* and Click *OK*.



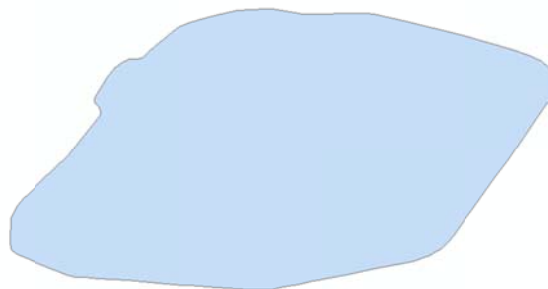
4. Edit the layer you created in the previous step.
 - a. Go to *Editor > Start editing* (If necessary, click *Customize > Toolbars > Editor* to active the tool), choose *AvignonBoundary*, click *OK*. (Click *Continue* if you meet the warning window.)



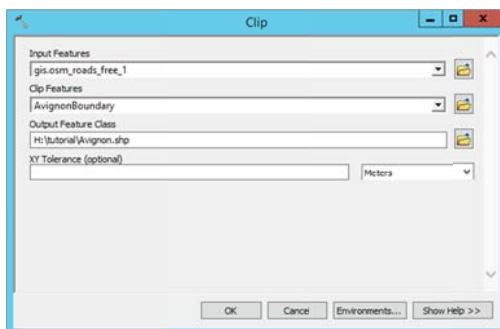
- b. From *Create Features* window (If the window isn't displayed, click the button ) , click *AvignonBoundary* and choose *Polygon* in the *Construction Tools*.



- c. Draw the boundary along the edge of the city in the layer. Avignon is surrounded by walls, which can be used as a reference for the boundary.
 - d. When finished, click *Editor > Save Edits*, then click *Editor > Stop editing*.




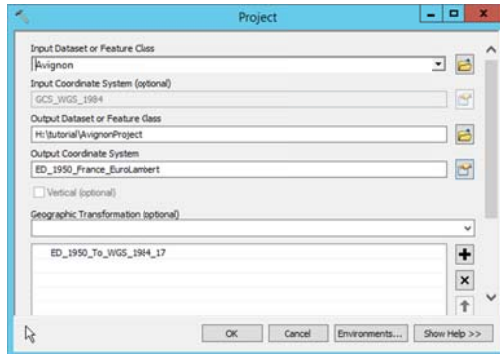
5. Clip Avignon from the whole map.
 - a. Use the tool by clicking on *Geoprocessing > Clip*.
 - b. In the Input Features, select *Roads* shapefile.
 - c. In the Clip Features, select *AvignonBoundary*.
 - d. Name your Output Feature Class as *Avignon* and click *OK*.
 - e. Add it to the layers.



6. This step is to make map projection. It is necessary to choose a more suitable projected coordinate



system to the layer.

- a. In *ArcToolbox* , double click *DataManagement Tools > Projections and Transformations > Project*.
- b. Input *Avignon* and name Output file as *AvignonProject*.
- c. Choose *ED 1950 France EuroLambert* to Output Coordinate System and click *OK*.

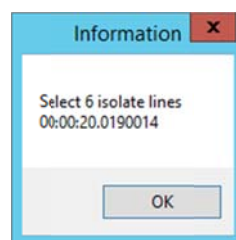



7. In the whole process of generating natural streets, a very important step is to deal with those isolated arc segments. You can edit them so that they intersect or connect with other segments, or delete them directly if they account for a very small proportion.
 - a. Click *Customize > Toolbars > Axwoman 6.3*. (If necessary, *Customize > extensions > tick Axwoman 6.3*)

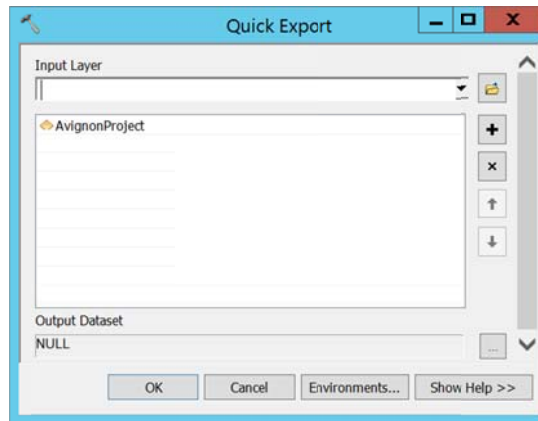



- b. Highlight the *AvignonProject* layer and click *Select Features* button .
 - c. Select one arc on the present layer and click the button *Get isolate lines*  in Axwoman toolbar.

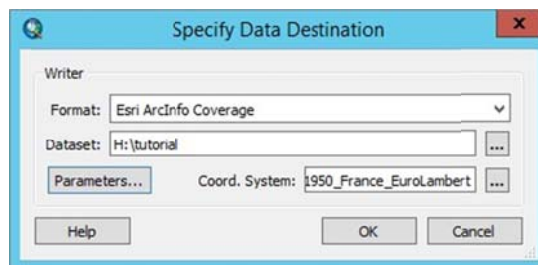
Note: After waiting for the process, we can see the number of isolated arc segments and they are marked.



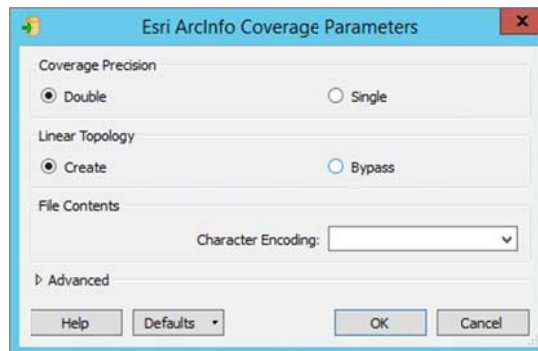
- d. Go to *Editor > Start Editing*, Click *Edit Vertices*  to edit isolated arcs in order to connect with other segments. Or press *Delete* on the keyboard if the number is small.
 - e. Repeat the step c. and d. to check isolated arcs again until there is no isolated arc.
8. This step is to chop arcs at each junction into segments. It is an important step to choose one most suitable neighboring street segments to form a good continuity.
 - a. Go to *ArcToolbox > Data Interoperability Tools > Quick Export*.
 - b. Input *AvignonProject* layer.



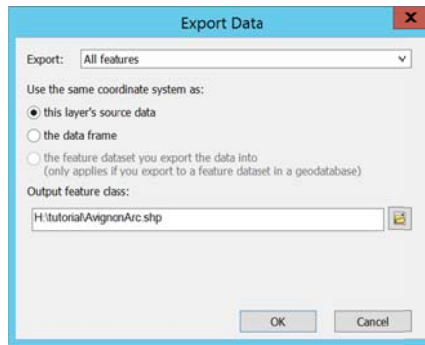
- c. Click  button to activate more options for the output dataset. Choose *ESRI ArcInfo Coverage* for Format and choose the *folder*. Select the same coordinate system as the layer.



- d. Click the *Parameters* button, tick *Double* for Coverage Precision and *Create* for Linear Topology.



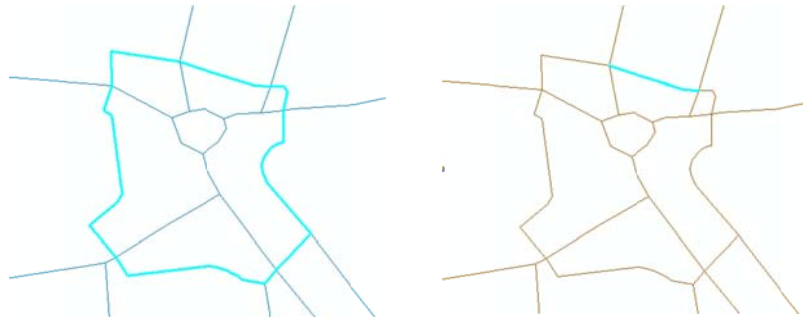
- e. Click *OK* in each window to finish Quick Export.
 f. When it shows Quick Export Completed in the results window, add this layer which is automatically named as *avginonprojec arc*. Right click the file and choose *Data > Export Data*. Select the storing folder and named as what you want and click *OK*. Add the exported data to the map as a layer.




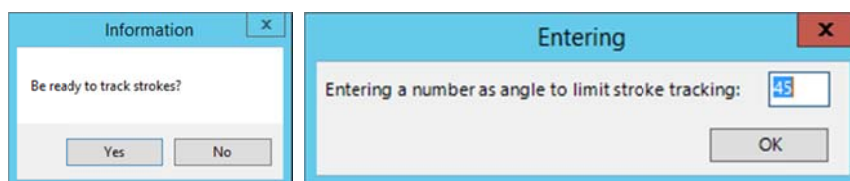
- g. There are some unimportant arcs outside the area that can be deleted directly. Go to *Editor > Start editing*, highlight the layer and click *Select Features* icon to select the arcs that should be deleted. Press *Delete* on the keyboard.



Note: When you finish step 8, zoom in the layer and check the arcs whether be chopped like the picture below. (The left figure is original, the right one is chopped.)

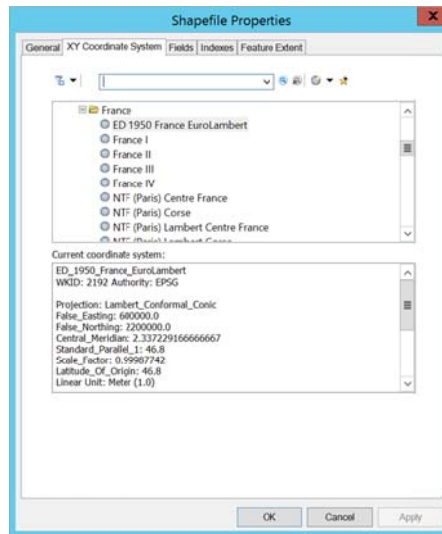


9. You can use Axwoman to generate natural streets automatically.
- Check isolated arcs again by repeating the step 7 to ensure that there is no isolated segment.
 - Highlight the layer and click *Tracking strokes at junction by a limited angle*  in Axwoman toolbar. You can choose to keep the default angle and click *Yes*. Save the strokes to a shapefile and name it as *AvignonNR*.




- c. Now you can see natural streets layer has been added. Check its coordinate system and

change it if it is not the same as the layer. In Catalog window, right click *AvignonNR* shapefile > *Properties*. In Shapefile Properties window, click *XY Coordinate System* tab, then choose the coordinate system and click *Add*. Then click *OK*.

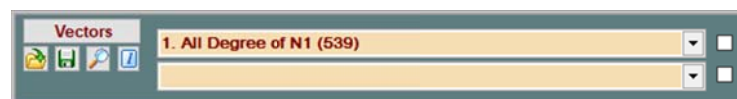



IV. Examining power law distribution

1. MATLAB software is used to examine if the degree distribution of the street network fits power law distribution. First, the degree value should be calculated by using Pajek.
 - a. Convert natural streets shapefile *AvignonNR.shp* to Pajek's net file, refer to Miao's tutorial.
 - b. Open Pajek Software and click *Read Network*  in Networks field to open the converted net file.



- c. Click *Network* in the menu > *Create Vector* > *Centrality* > *Degree* > *All* to get the degree values of Avignon street network.



- d. Save the vector file by clicking *Save Vector*  in Vectors field.



2. Start MATLAB and click *Browse for folder*  to connect the folder you are working with.

*Note: Make sure the degree vector file and Clauset MATLAB code files (Clauset, 2009) *plfit.m*, *plplot.m* and *plpva.m* are in this folder. (Go to <http://tuvalu.santafe.edu/~aaronc/powerlaws/> to download these MATLAB code files.)*

- a. Use Notepad to open the vector file and delete the first raw and save it as a text file.
 - b. In the command window, type the code `x=importdata('AvignonNRdegree.txt')` and press *Enter* on the keyboard to import the degree data of Avignon street network.

```

Command Window
>> x=importdata('AvignonNRdegree.txt')

x =

    71
    19
     3
     3
     5
    22
     4
    15

```

- c. Type $[alpha,xmin,D]=plfit(x)$ and press *Enter*. This step intended to get the alpha and minimum value using power law fit function.

```

Command Window
>> [alpha, xmin, D]=plfit(x)

alpha =

    2.5600

xmin =

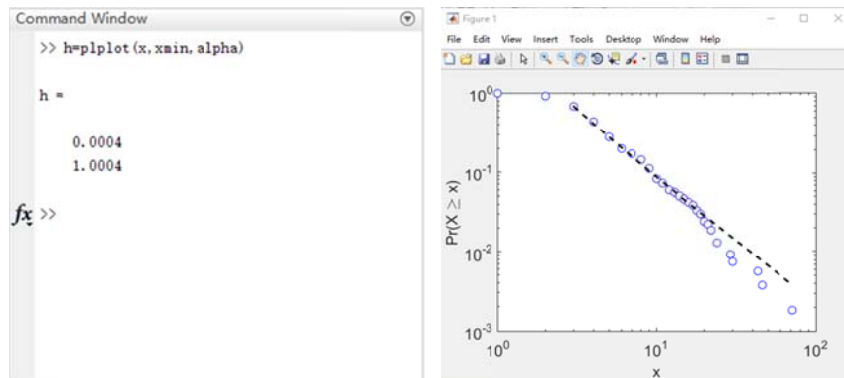
     3

D =

 -795.6069

```

- d. Next, use power law plot function, type $h=plplot(x,xmin,alpha)$ and press *Enter*. A figure will display that shows power law distributional model of Avignon street.



- e. Calculate p-value by using power law pva function. Type $[p,gof]=plpva(x,xmin,'reps',500)$ and press *Enter*.

```

Command Window
>> [p,gof]=plpva(x,xmin,'reps',500)
Power-law Distribution, p-value calculation
Copyright 2007-2010 Aaron Clauset
Warning: This can be a slow calculation: please
n = 539
xmin = 3.0000
reps = 500
[1] p = 0.0000 [0.00m]
[2] p = 0.0000 [0.00m]
[3] p = 0.0000 [0.00m]
[4] p = 0.0000 [0.00m]
[5] p = 0.0000 [0.00m]
[6] p = 0.0000 [0.00m]
[7] p = 0.0000 [0.01m]
[8] p = 0.0000 [0.01m]

Command Window
[477] p = 0.0483 [0.19m]
[478] p = 0.0482 [0.19m]
[479] p = 0.0481 [0.19m]
[500] p = 0.0480 [0.19m]

p =

    0.0500

gof =

    0.0354

```

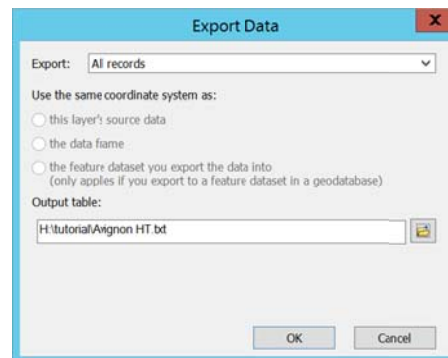
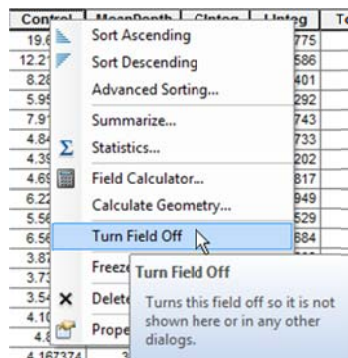

Note: If the p -value is greater than 0, the data fits a power law distribution. For Avignon, the p -value is equal to 0.0500 greater than 0.

V. Conducting head/tail breaks

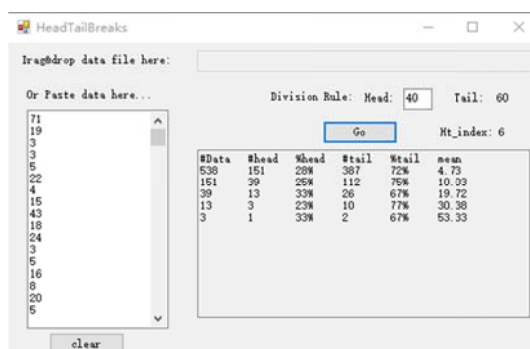
1. You may need to calculate the spatial syntax parameters of the street network for more research. This step is also achieved through the function of Axwoman.
 - a. Highlight the layer *AvignonNR* and click *Calculate parameters in case of lines with lines* and click *OK*.
 - b. This process takes a few minutes and the results are like the figure below.



2. The step intended to apply the head/tail breaks method to classify natural streets by using head/tail breaks calculator.
 - a. In ArcMap, right click the *AvignonNR* layer and open attribute table.
 - b. In the table windows, click *Table Options* and *Export* the *Connect* column as a text file. One way to export the only Connect column is to turn off the other fields.



- c. Open the head/tail breaks calculator and *copy* the data from the text file to the left blank box and *delete* the first title row, then click *Go*. The result will show up.



Note: You can also classification manually using the calculate function in ArcMap, refer to Wu's tutorial and can get the following results.

#Data	#Head	%Head	#Tail	%Tail	Mean
538	151	28.07%	387	71.93%	4.7273
151	39	25.83%	112	74.17%	10.0331
39	13	33.33%	26	66.67%	19.7180
13	3	23.08%	10	76.92%	30.3846
3	1	33.33%	2	66.67%	53.3333

After completing above exercises, you have learned how to generate natural streets, conduct head/tail breaks and examine power law distribution for data. When using ArcMap to generate natural streets, it is recommended that you may check the coordinate system at every step, because this may cause some errors. In addition, installing and activating the software and tools correctly is an important step in getting the results.

Acknowledgement:

I would like to thank Prof. Bin Jiang for his guidance and help in preparing this tutorial.

References:

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