Generating historical natural streets for urban development analysis

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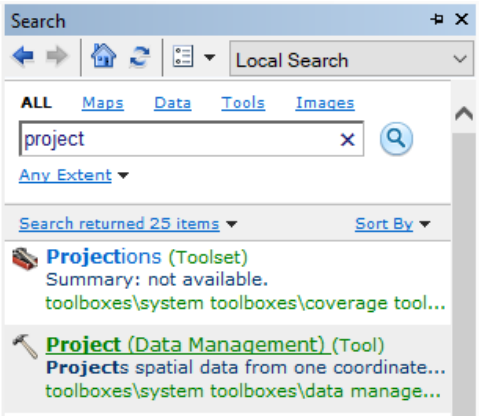
This tutorial shows how historical maps can be used to visualize development of the cities changing structure within ArcGIS. By using OpenStreetMap (OSM) data, historical maps and Axwoman, space syntax parameters of the evolving city is calculated with which the development can be analysed.

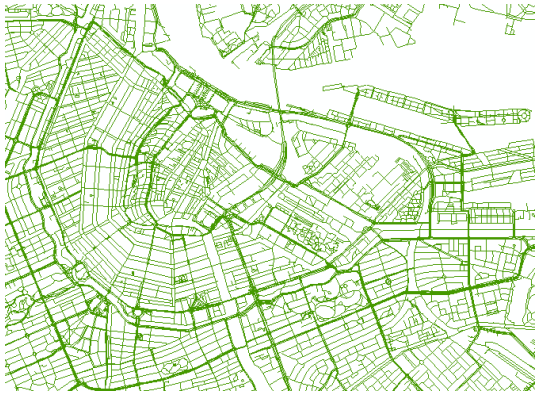
Data gathering and preparation

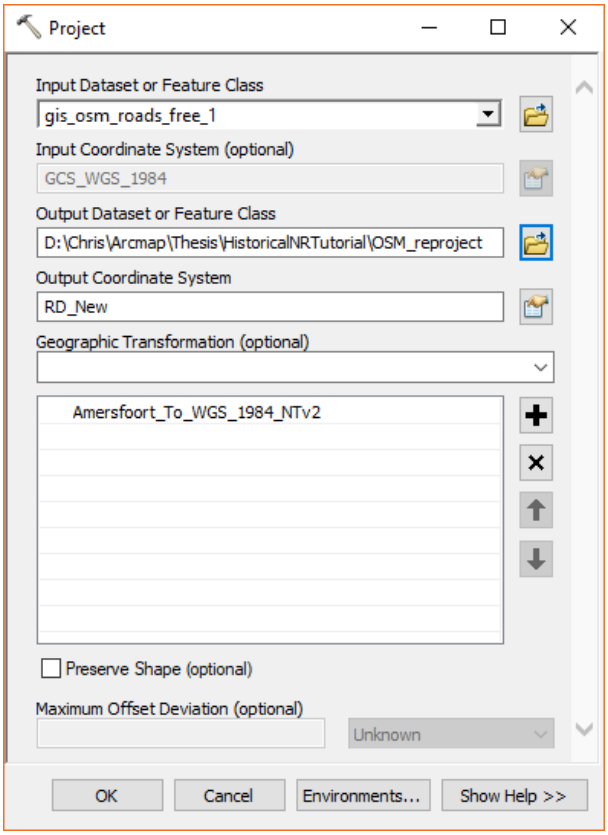
Throughout the tutorial Axwoman software (Jiang, 2015) is used, which means that it has to be installed before following this tutorial. The data interoperability extension must also be installed. If Axwoman is installed the next step is the gathering of the data. OSM shapefiles can be downloaded from Geofabrik (http://download.geofabrik.de). Next historical maps of Amsterdam are needed. These can be obtained from Jiang (2018) slide 32.

The first step within the data preparation is the creation of road data where each segment between intersections is its own segment. This is needed later on for the creation of the natural streets. To start with the correct road shapefile should be downloaded, opened and reprojected.

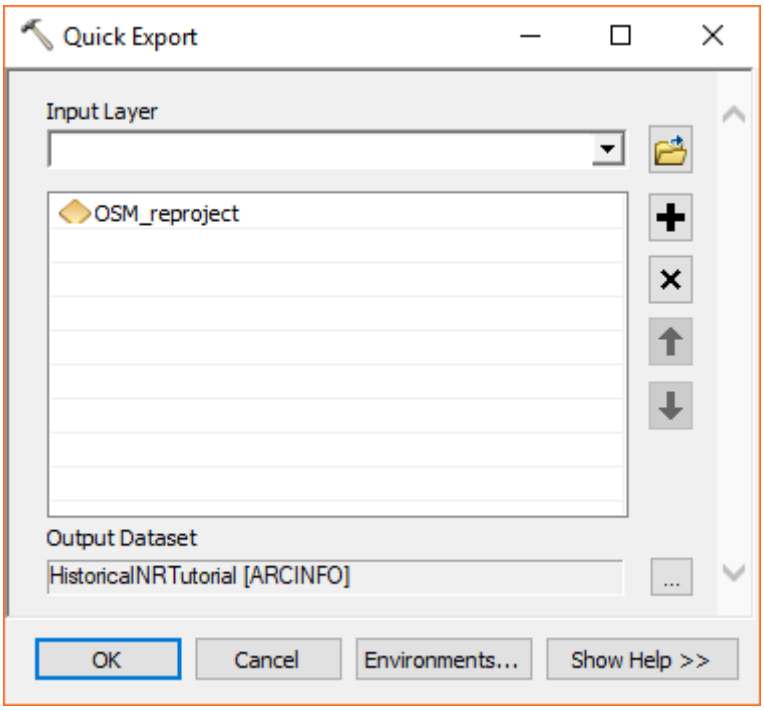
1. Download the OSM data from Geofabrik, for Amsterdam this is found by downloading the *Noord-Holland* sub-region found within the Netherlands.
2. Open Arcgis and click *Add data -> gis_osm_roads_free_1.shp*
3. Reproject the data by using the *Project (ArcToolbox -> Data Management -> Projections and Transformations)* tool to *RD_New (ESPG: 28992)*.



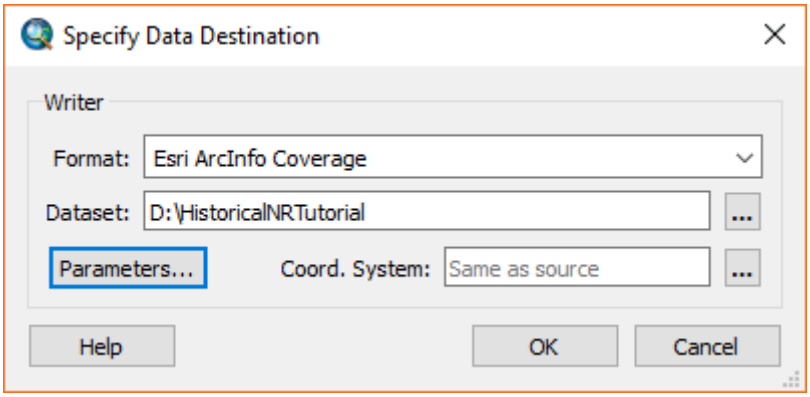




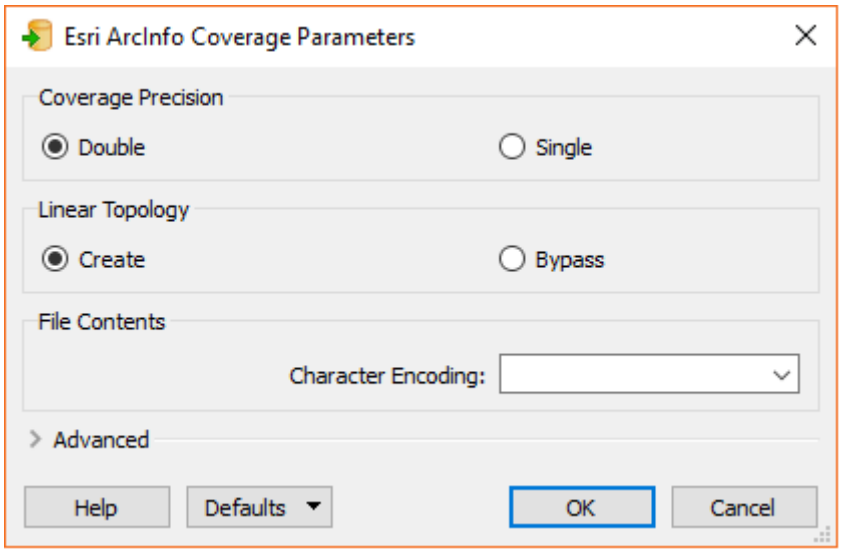
4. Remove the original OSM shapefile and change the coordinate system of the data frame to *RD_New* as well. (*Data frame properties -> Coordinate system*).
5. After the data is reprojected *Quick Export (ArcToolbox -> Data Interoperability)*
    a. Input the newly created *OSM_reproject* layer.



    b. Click the ... button located under *Output Dataset* to *Specify Data Destination*. For the *Format* choose *Esri ArcInfo Coverage* and for *Dataset* choose a folder. Select the same *Coord. System* as the input layer.



    c. Click the *Parameters…* button and make sure *Double* is selected for *Coverage Precision* and *Create* is selected for *Linear Topology*.



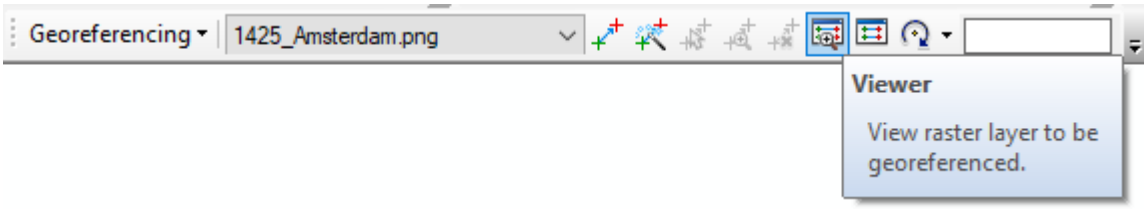
   d. After the process is finished add the newly generated *arc* file to ArcGIS, and remove the older *OSM_reproject* layer.

6. Finally add the individual historical maps to the *Table of Contents* as images without spatial information.

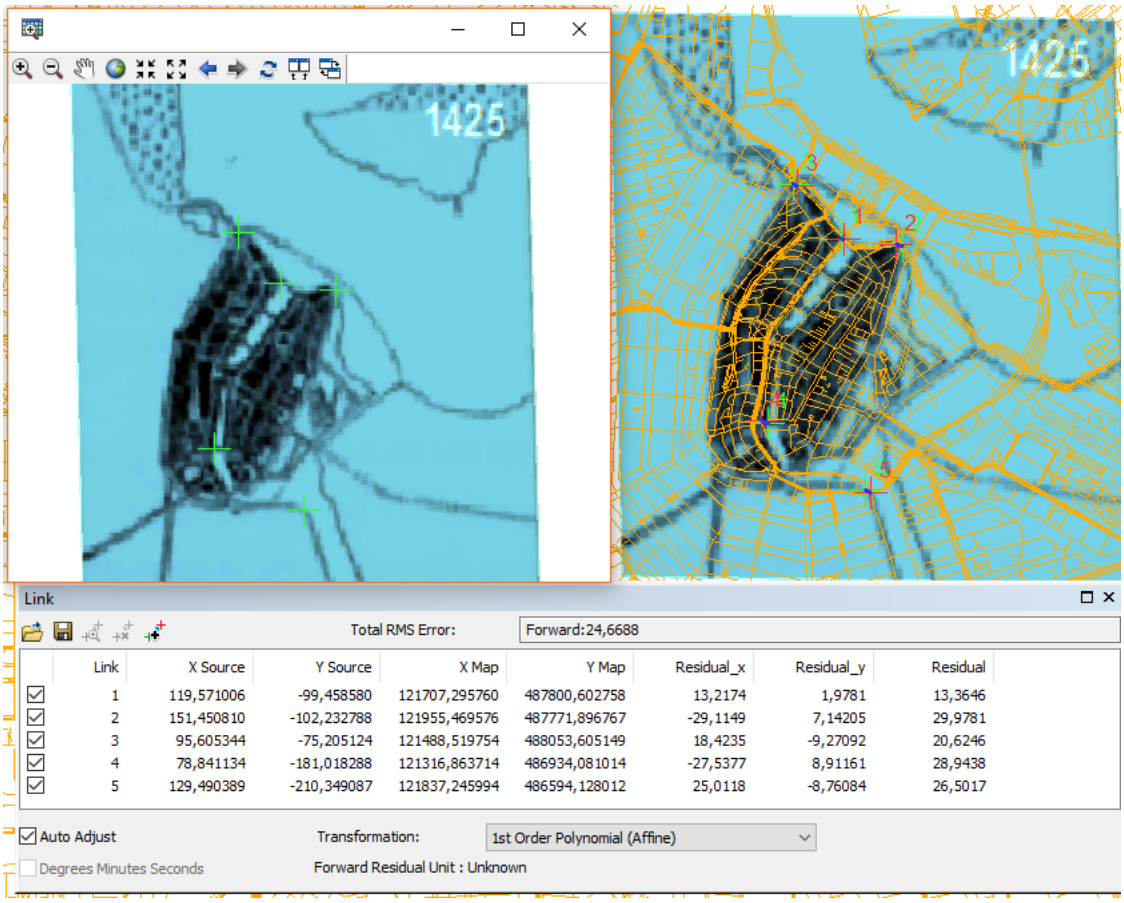
Georeferencing historical maps

In this part the historical maps are given spatial information by georeferencing them to the *OSM_arc* layer.

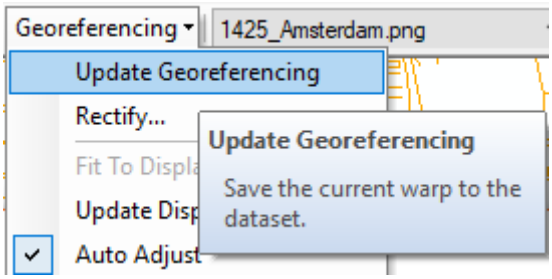
1. Make sure the *Georeferencing* Toolbar is active, if it is not activate it by going to *Customize -> Toolbars -> Georeferencing*.
2. Select one of the images to georeferenced within the *Georeferencing* toolbar and click on the viewer.



3. Within the *viewer* window click  to zoom to the selected image. Then click  within the *Georeferencing* Toolbar to start georeferencing. Find points on the image which correspond with the road layout of the *OSM_arc* layer. First click within the viewer to create a link and then click within the data view to create a link. If the image disappears after the creation of a link, click  again to zoom back to the image. Delete links by opening the *link table*  and either untick links or delete them completely.



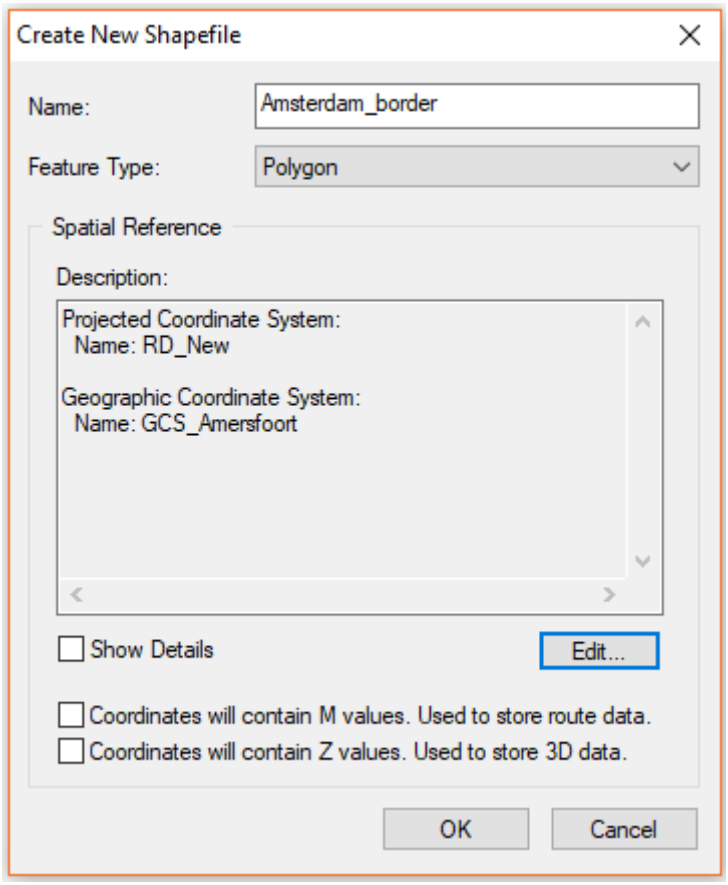
4. When you are satisfied with the georeferenced image, save the spatial information by clicking on *Georeferencing -> Update Georeferencing* within the *Georeferencing* Toolbar.



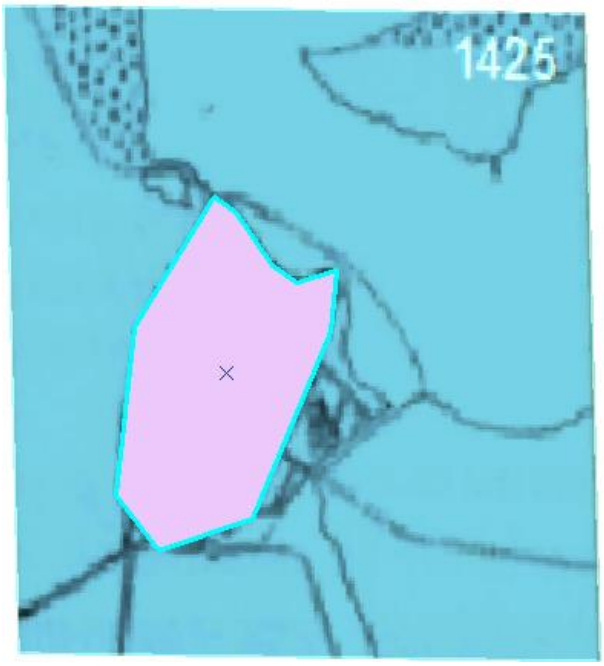
Digitizing the city border

The next step is the digitization of the changing border of the city through the years.

1. Start by creating a new shapefile from within the *catalog*. *Right-click* on your working directory and go to *New -> Shapefile…*
2. *Name* it *Amsterdam_border*, select *Polygon* as *Feature type* and select *RD_new* as coordinate system by clicking on the *Edit…* button.



3. Next make sure that the *Editor* toolbar is active, if not go to *Customize -> Toolbars -> Editor*.
4. On the *Editor* toolbar click *Editor -> Start editing*. In the window that pops up select the *Amsterdam_border* you created in step 2 of this section and click *OK*.
5. In the *Create Features* screen select *Amsterdam_border* and as *construction tool* select *polygon*. Then draw a polygon around the first historical map (*double-click* to end the creation of a polygon).

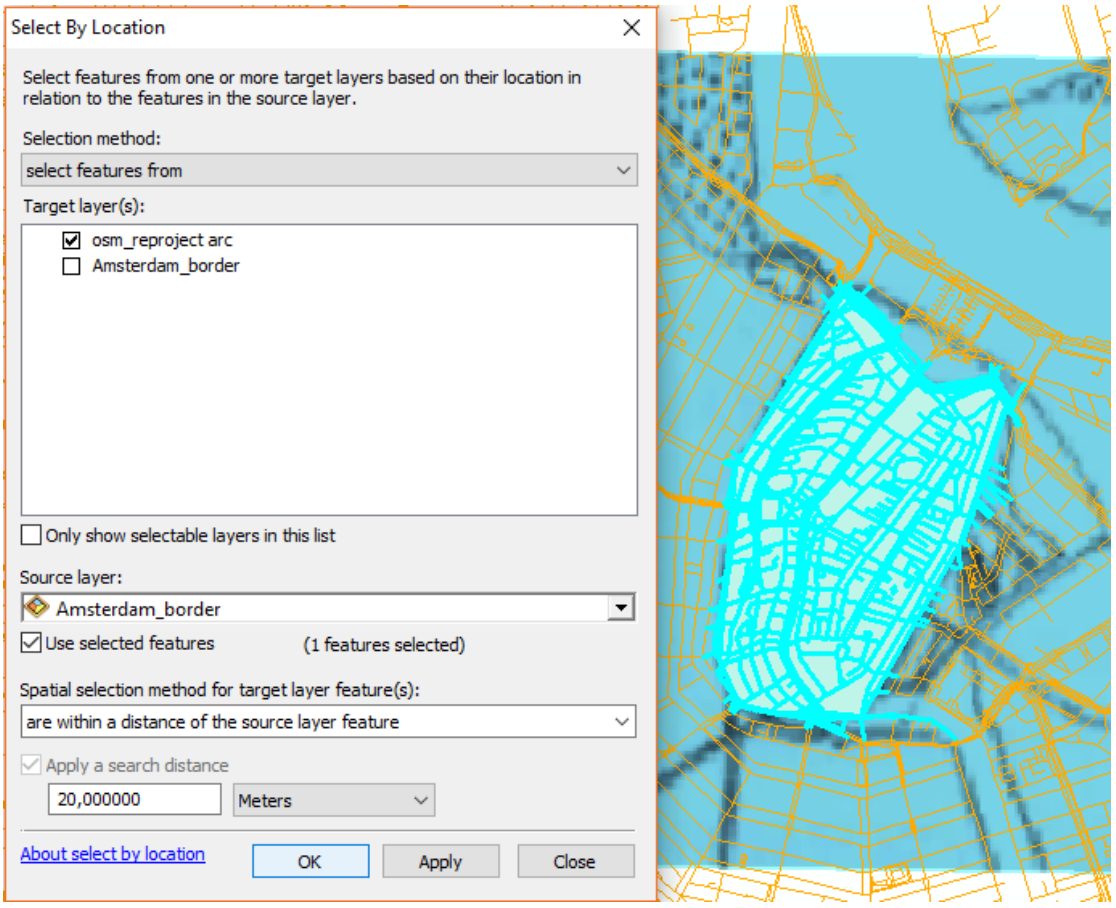


6. Next open the *Attribute Table* of *Amsterdam_border* and within the *id* field (NOT *FID*) enter which number of historical map you digitized the border of (1 for the 1st map, 2 for the 2nd map, etc.)
7. Continue digitizing all historical maps, numbering the polygons created for each map within the *Attribute Table* until you end up with a shapefile with all the different city borders matching the different historical maps.
8. If you are finished click *Editor -> Save edits* and *Editor -> Stop editing* on the *Editor* toolbar.

Isolating OSM roads for each different time period

This part will isolate each different time period and create a shapefile for each city border established in the previous section.

1. To isolate the different time periods the road segments belonging to each period are selected and exported. First select from *Amsterdam_border* the border and/or time period you want to extract. For the first one select the polygon which belongs to the earliest historical map. (Note: You can only do one at a time)
2. With only the polygon selected from the previous step, go to *Selection -> Select By Location*. In the screen that pops up select *Select features from* under *Selection method*. Tick *osm_reproject arc* under *Target layer(s)*. Select *Amsterdam_border* as *source_layer* and make sure it says *(1 feature selected)* and *Use selected features* is ticked. Then under *Spatial selection method for target layer feature(s)* select *are within a distance of the source layer feature*. Apply a search distance of 20 meters.

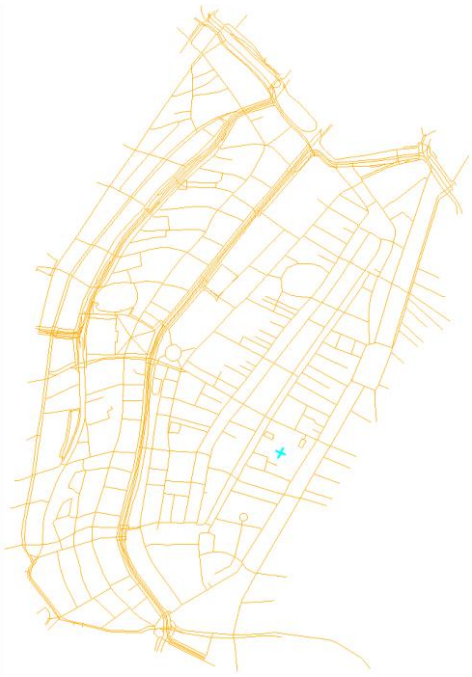


3. After you have selected the *OSM_reproject arcs* belonging to one of the city borders export it by *right-clicking* on the *OSM_reproject* layer and going to *Data -> Export Data*. In the *Export Data* screen make sure your export *selected features* and select *the data frame* under *Use the same coordinate system as*. Save it in your working (sub)folder with a recognizable name (e.g. Amsterdam1 for the first time period).
4. Repeat steps 1, 2 and 3 until all time periods have an individual shapefile with its roads. (Note: clear your selection between step 3 and 1)

Generating Natural Streets

This last section illustrates the creation of the natural streets for each time period.

1. First add all the different OSM time periods (6 in total) to the data view where each timeframe has its own data frame (*Insert -> Data Frame*).
2. Make sure that the *AXWOMAN* toolbar is visible, if not activate it by going to *Customize -> Toolbars -> AXWOMAN*.
3. Select the roads belonging to the first time period (*Amsterdam1*) in the *Table Of Contents*. Now most buttons on the *AXWOMAN* toolbar should light up. First isolated segments should be identified and deleted. Select one main segment connected to the majority of all roads and *click* on  . After ArcGIS is done processing it may have selected some isolate lines. These lines must be deleted or connected for the analysis to continue. To delete them go to the *Editor* Toolbar, *Start Editing*, select the layer you are working on and press the *delete button* on your keyboard to delete the selected files. *Save edits* and *Stop editing*.

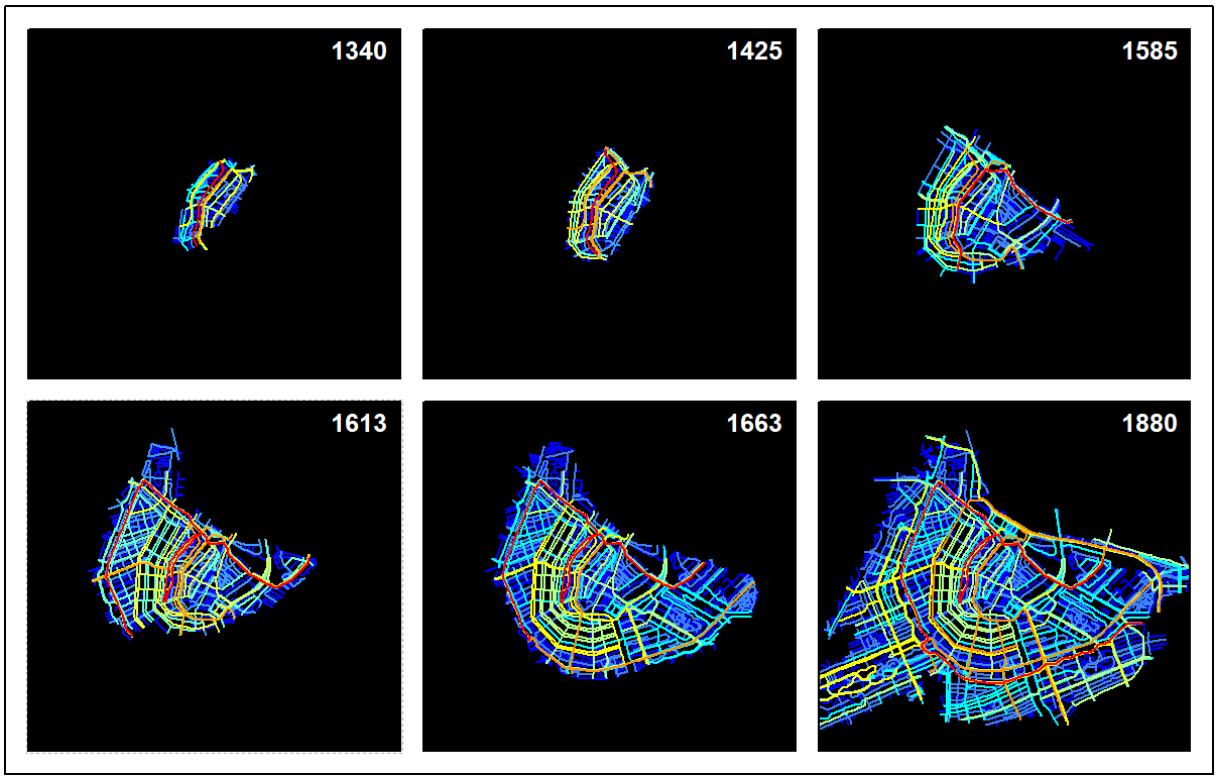


4. Repeat step 3 until there are no more isolate lines left in the major line group. After this is done the natural streets can be generated. Select the layer in the *Table Of Contents* again and click the *tracking strokes by limited angle*  button. Leave the default 45 degrees angle and save the file under a recognizable name again (e.g. *AmsterdamNR_1)*.

5. After the natural streets are generated space syntax parameters can be calculated for analysis and visualization. Select the newly generated natural streets layer and click the *calculate parameters in case of lines with lines* button. This calculates the space syntax parameters.
6. For visualization of the natural streets layer you can select different Head/Tail classification parameters by clicking on the *Symbolization based on Head/Tail breaks classification* H/T button. For the earlier years try for example a 90% head/tail distribution. (Note: Select the *Connect* layer for this visualization)
7. Repeat steps 3 to 6 until all time periods are processed.

Finishing up

After the generation and visualization of the natural streets over the different time periods you can create a layout which shows the development over time.



References

Jiang B. (2015), Axwoman 6.3: An ArcGIS extension for urban morphological analysis, http://giscience.hig.se/binjiang/Axwoman/, University of Gävle, Sweden.

Jiang B. (2018), A Geospatial Perspective on Sustainable Urban Mobility in the Era of BIG Data. (https://www.researchgate.net/publication/326304703_A_Geospatial_Perspective_on_Sustainable_Urban_Mobility_in_the_Era_of_BIG_Data)