Visualize and interactively design weight matrices

Angelos Mimis[*1]

[1]Department of Economic and Regional Development,
Panteion University of Athens, Greece
Tel.: +30 6936670414

October 29, 2014

Summary

A GIS tool that permits to visualize, explore and interactively modify weight matrices is described. Weight matrices, created in various formats, can be imported and the spatial relationship, by using polylines, can be visualized. Scripts are developed to explore the structure of the weight matrix by illustrating basic statistics, to illustrate the full matrix and to compare different matrices. The spatial relationship can then be modified (by deleting or adding polylines) and exported in order to further use it in computations. The extension is developed in Python, is based in PySAL and matplotlib libraries and is implemented in ArcGIS.

KEYWORDS: weight matrix, interactive design, ArcGIS extension.

1. Introduction

The use of weight matrices is central in spatial analysis. They are used in the definition of segregation indices (Wong, 1993), in spatial autocorrelation (Anselin, 1995), in spatial econometric models (Anselin, 2010) and in network analysis (Barthélemy, 2011). Over the years, the majority of the research have focused on the philosophy captured in the weight matrices (Harris et al., 2011), the different definitions (e.g. theoretical topological or empirical as described in Getis, 2009) and on the effect these have on the evaluated results (Stakhovych and Bijmolt, 2008). On the other hand, little effort has been put on visualizing and interactively design the weight matrices. By visualize, you can map and explore the relationship between neighbouring points or areas intuitively without having to employ complex coding schemes. In that direction, Bivand et al. (2008), create a graph of neighbours in order to illustrate the polygon contiguities.

My approach adopts that idea and extends it, to not only visualize but to explore and modify the spatial relationship or even design it from scratch. In order to demonstrate this approach, an extension in the commercial package ArcGIS has been developed (same code could be used in an open source platform e.g. QGIS) and it is based on two freely available libraries. The first one is the PySAL library (Rey and Anselin, 2010) of spatial analysis and the second is the matplotlib (Hunter, 2007) plotting library. So by using the scripts, one can import many of the formats created in the most popular spatial software (e.g. GeoDA, Matlab). Further, exploratory analysis can be performed by displaying basic statistics of the weight matrix, capture in an image the sparseness of the full matrix, compare different weight matrices and visualize the linkage between neighbouring areas or points. Having explored the given weight matrix, one can proceed by modifying (deleting or adding) the linkages (polylines) between neighbouring entities. Finally, the relationship produced (weight matrix) can be exported in any format supported by the script and consequently used in ArcGIS or any other

[*] mimis@panteion.gr

spatial software using weight matrices.

This short paper starts by describing the ArcGIS extension, gives a realistic example of importing and altering the weight matrix of the Greek prefectures and concludes by discussing future improvements.

2. Program description

The weight matrix tool is implemented as an extension to ArcGIS using Python programming language. It is based on the python's libraries PySAL and matplotlib. The toolkit is organized into a) importing and exploratory functions and into b) functions permitting to design and export the weight matrix.

2.1. Importing and exploratory analysis

All the scripts are designed to import and export weight matrices created in the binary form of ArcGIS (swm), in contiguity (gal) and distance (gwt) based form of GeoDa and in Lesage's library form (dat) of MATLAB (Lesage and Pace, 2009). It should be noted that based on these formats one can import/export weight matrices in other software such as the R statistical software or Stata.

By importing a weight matrix, the elements of the matrix are visualized by creating links between the areal or point data that have got a connection. This creates an optical realization of the spatial relationship of the data and by using the capabilities of the GIS one can inspect that relationship in various scales. Further in order to be able to export it in one of the supported formats, the script ensures that the start and the end point of the link are within the relevant polygons. In the case of a multipart object, the link start or ends within the area of the polygon with the biggest area. Finally convex as well non-convex polygons can be treated.

As far as the exploratory part is concerned, one can generate basic statistics, graphically displays the non-zero elements of the full weight matrix and can compare two different weight matrices, as will be shown in the example application.

2.2. Design and export

The exploratory procedures described above might be followed by changes in the relationship of the data and export it in one of the weight formats supported. The layer keeping the links between polygon or point data is a polyline layer and so it can be altered in the usual way done in a GIS environment. So one can easily add a new polyline segment, remove a segment and alter the weights in the attribute table. When the designing part is finished, the matrix can be exported by using the appropriate script which permits the user to enforce symmetry and standardization.

The toolkit requires a license of ArcGIS 10 and was tested in ArcGIS 10.2, by using PySAL 1.7 and matplotlib 1.3.

3. Example application

An example use of the GIS tool will be given for the prefectures of Greece (NUTS 3 level). A distance based weight matrix is created in GeoDA, in gwt form (with a given threshold). Then the weight matrix is visualized in ArcGIS by using the toolbox (Figure 1). This results in a polyline shapefile (Figure 2) having an attribute table (Figure 3) with the actual weights and the ids of the corresponding neighbours. So for example the polygon with id 30 (part of island Crete, south in the map of Greece) is considered as a neighbour of the polygons 10 and 40.

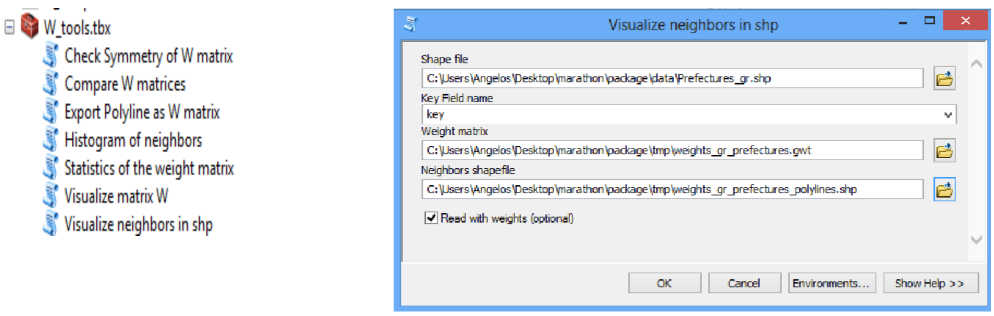
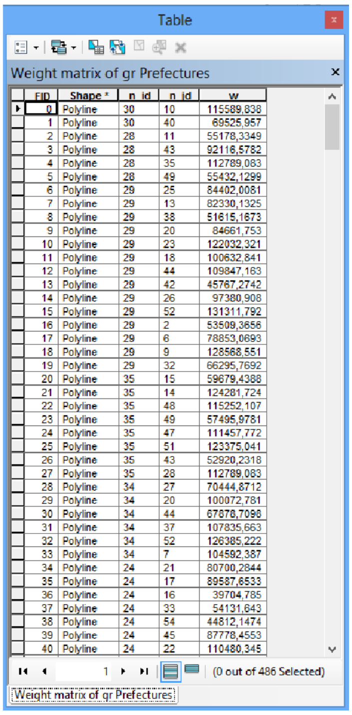


Figure 1. The weight matrix toolbox (left) and the "visualize neighbours in shp" menu script (right).

Figure 2. The weight matrix visualized.



FID	Shape *	n_id	n_jd	w
0	Polyline	30	10	115589,838
1	Polyline	30	40	69525,957
2	Polyline	28	11	55178,3349
3	Polyline	28	43	92116,5782
4	Polyline	28	35	112789,083
5	Polyline	28	49	55432,1299
6	Polyline	29	25	84402,0081
7	Polyline	29	13	82330,1325
8	Polyline	29	38	51615,1673
9	Polyline	29	20	84661,753
10	Polyline	29	23	122032,321
11	Polyline	29	18	100632,841
12	Polyline	29	44	109847,163
13	Polyline	29	42	45767,2742
14	Polyline	29	26	97380,908
15	Polyline	29	52	131311,792
16	Polyline	29	2	53509,3656
17	Polyline	29	6	78853,0693
18	Polyline	29	9	128568,551
19	Polyline	29	32	66295,7692
20	Polyline	35	15	59679,4388
21	Polyline	35	14	124281,724
22	Polyline	35	48	115252,107
23	Polyline	35	49	57495,9781
24	Polyline	35	47	111457,772
25	Polyline	35	51	123375,041
26	Polyline	35	43	52920,2318
27	Polyline	35	28	112789,083
28	Polyline	34	27	70444,8712
29	Polyline	34	20	100072,781
30	Polyline	34	44	67878,7098
31	Polyline	34	37	107835,663
32	Polyline	34	52	126385,222
33	Polyline	34	7	104592,387
34	Polyline	24	21	80700,2844
35	Polyline	24	17	89587,6533
36	Polyline	24	16	39704,785
37	Polyline	24	33	54131,643
38	Polyline	24	54	44812,1474
39	Polyline	24	45	87778,4553
40	Polyline	24	22	110480,345

Figure 3. The attribute table of the polyline shapefile created.

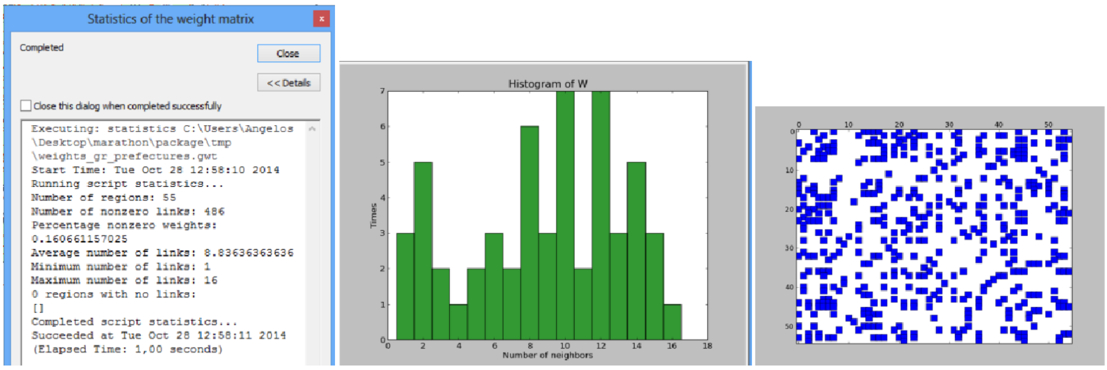


Figure 4. Basic statistics of the weight matrix.

So by using the functionality of the GIS, one can explore the spatial relationship of prefectures captured in the shapefile. Further, by using the statistics scripts, the percentage of nonzero weight (16%), the average number of links (8.8), the existence of islands etc as well as the histogram of the number of neighbours and the image of the nonzero elements of the full matrix is displayed (Figure 4).

Finally, one can edit the polyline shapefile and thus changing the neighbouring relationships. So for example one can delete the link 12-50 and add the new links 36-50, 36-12 and 36-30. Then you can export the polyline shapefile in one of the supported formats by keeping the spatial relationship and the relevant weights (Figures 5 and 6).

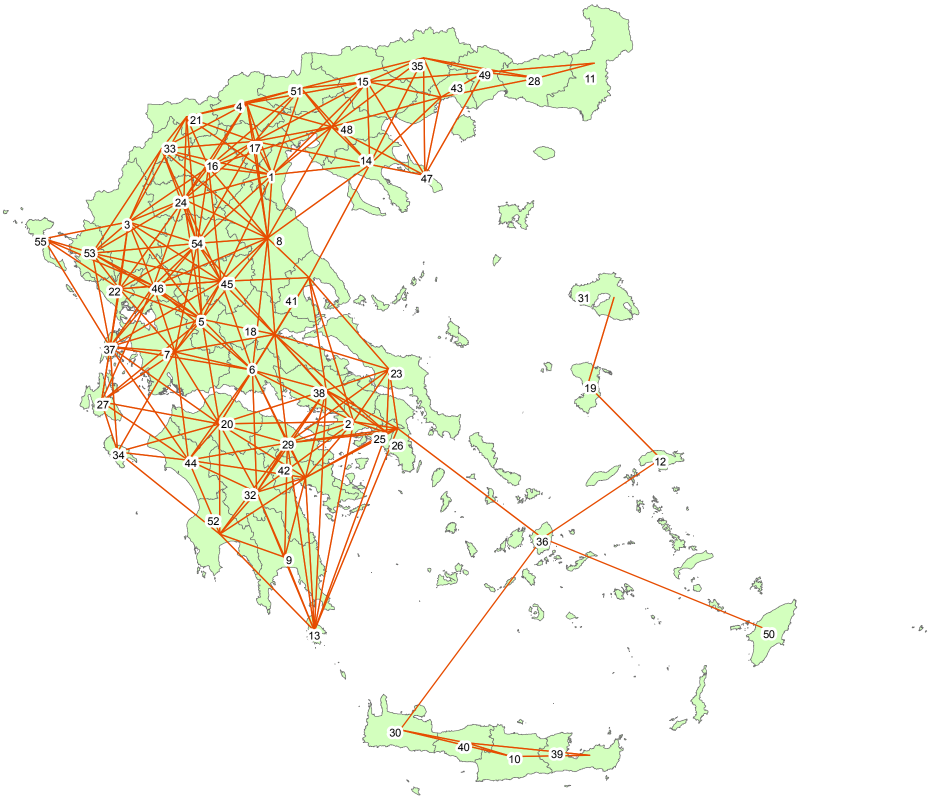
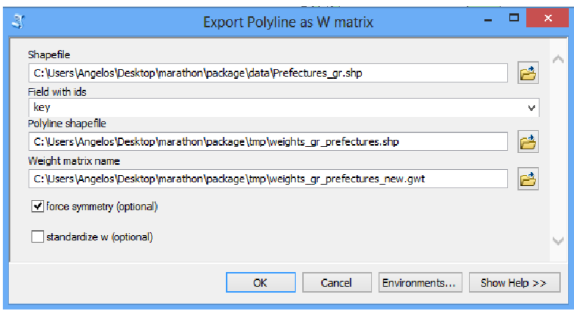


Figure 5. The modified weight matrix.




```
35 15 59679.4
35 14 124282
35 48 115252
35 49  57496
35 47 111458
35 51 123375
35 43 52920.2
35 28 112789
36 26 136332
36 12 139220
36 50 241363
36 30 233516
37 27  38631
37 20 118603
37 22 59919.4
37 55 127733
37 54 130876
37 44 125559
37 45 121507
37 53 104079
37 34 107836
37 46 58931.8
37 3 127107
37 5 87535.9
37 7 50704.6
37 6 133929
```

Figure 6. The export menu (left) and part of the gwt file (right).

4. Conclusions

A GIS tool that permits to visualize, explore and interactively modify weight matrices has been illustrated. This can be used to create a weight matrix from scratch or modify an existing matrix created in a supported format. This toolbox can also be used as an educational interactive utility.

The tool is implemented as an extension in ArcGIS and several improvements can be made. Every time a script is used, the user should import the weight matrix. One can overcome this limitation by designing a separate tool incorporating the code and resulting in faster computations since the weight matrix will have to be read only once.

5. Biography

Angelos Mimis is an assistant professor of spatial analysis in Panteion University of Athens, Greece. His interests include GIS, spatial analysis, computational geometry and optimization. He teaches GIS and spatial analysis in undergraduate and postgraduate level. He is visiting the Geography department of Bristol University in the summer semester of 2015.

References

Anselin L (1995). Local indicators of spatial associations – LISA. *Geographical Analysis*, 27, 93-115.

Anselin L (2010). Thirty years of spatial econometrics. *Papers in Regional Science*, 89(1), 3–25.

Barthélemy M (2011). Spatial Networks. *Physics Reports*, 499, 1–101.

Bivand R S Pebesma E J and Gomez-Rubio V (2008). *Applied Spatial Data Analysis with R.* Springer, New York.

Getis A (2009). Spatial weight matrices. *Geographical Analysis*, 41, 404-410.

Harris R Moffst J and Kravtsova V (2011). In search of 'W'. *Spatial Economic Analysis*, 6(3), 249-270.

Hunter J D (2007). Matplotlib: A 2D graphics environment. *Computing in Science and Engineering*, 9(3), 90-95.

Lesage J and Pace R K (2009). *Introduction to Spatial Econometrics*. Chapman and Hall/CRC, Boca Raton.

Rey S J Anselin L (2010). PySAL: a python library of spatial analytical methods, In: Fischer, M. M., Getis, A. (Ed.), *Handbook of Applied Spatial Analysis*, Springer Berlin Heidelberg, pp. 175-193.

Stakhovych S and Bijmolt T H A (2008). Specification of spatial models: A simulation study on weight matrices. *Papers in Regional Science*, 88(2), 389-408.

Wong D W S (1993). Spatial Indices of Segregation. *Urban Studies*, 30, 559-572.