Geocomputation Methods for Dyadic Relationships

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Abstract

We model the dyadic (pairwise) connections between a mentor's home and his or her protégé's home, as supplied from a school-based mentorship program in Santa Fe, New Mexico, USA. We find that in most cases, these instructionally-created mentorships span spatial and social boundaries that would not be typically pervaded given a random distribution of connections.

Keywords: Social networks, GIS, spatial modeling, statistics, U.S. Census data, social capital, institutions.

1. Introduction

Our interpersonal relationships are a driving factor in our behaviour in geographic space—where we go, where information is transferred, and how we can access our social support systems. Yet geolocated relationships difficult to model in an urban context because they are ubiquitous and hard to capture, ever-changing, hard to theoretically analyze, and difficult to map and assess using spatial statistics (as is a problem with spatial connectivity/interaction data (Fotheringham 1983, Rae 2009)). Despite these challenges, interpersonal relationships (such as dyadic relationships) should be integrated into GISystems and geocomputation so that urbanists and geographers can better understand how relationships are manifested in the built environment (e.g. Fischer 1982).

In this article, we examine the spatial dynamics of 112 mentor-protégé dyads (i.e. pairs) formed by the Monte del Sol Charter School (MdS) in Santa Fe, New Mexico. We perform a number of theoretically-driven tests to determine the extent to which (mentor-protégé) pairs represent relationships that may not have been realized due to distance (Hipp and Perrin 2009), lack of mutual friends (McPherson et al. 2001), other more convenient social opportunities (Stouffer 1940, Rozenfeld et al. 2002), the crossing of administrative boundaries (Preciado et al. 2012) or language differences (Takhteyev et al., 2012).

Discovering that these relationships cross a number of social and physical obstacles, such as different school districts, may indicate that MdS has instructively facilitated social capital (i.e. mentorships) for their students that would not have occurred by happenstance.

2. Data and Analysis Methods

2.1 Data

Each year, approximately 100 MdS students (ranging from 7^{th} – 12^{th} grade) participate in one or more mentorship experiences with a Santa Fe area adult mentor (in topics such as veterinary medicine or dance). According to MdS records, over 1% of Santa Feans have served as a mentor at some point.

For each mentorship pair, the mentor and protégé home locations are plotted in geographic space with edges depicting connections (Fig. 1). Addresses are sourced from MdS records and from mentor self-report. All addresses are jittered in visualizations to protect privacy and assigned to their respective U.S. Census Block centroid for statistical analyses.

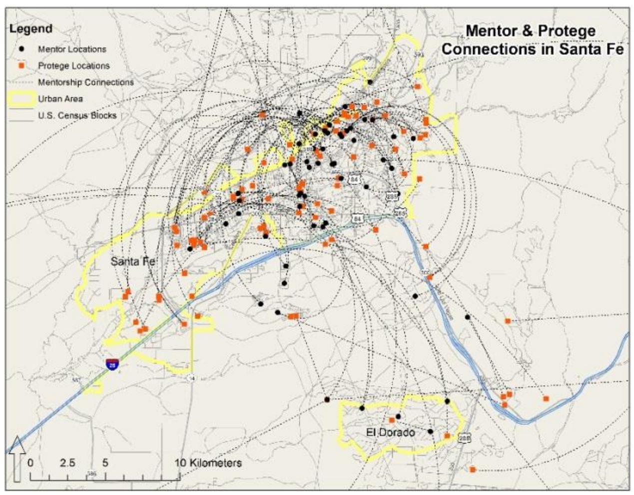

Figure 1. Mentor-protégé pairs in Santa Fe, New Mexico, USA and region.

2.2 Tests

We present seven simple tests (Table 1) to quantify the "specialness" of these relationships compared to 500 relationships (i.e. pairs) created randomly from pairs of Census Blocks in our study area (Fig. 1's bounding box). Computation is performed in the R Statistical and ESRI ArcMap environments. In this abstract, we report findings from the first six tests (Table 1) on both the MdS dyads and the random dyads.

Table 1. List of dyadic geocomputation methods.

Method	Cost Metric	External Data
Gravity model I	Euclidean distance	----
Gravity model II	Travel time	Road network
Gravity model III	Road network distance	Road network
Gravity model IV	High population	Population
Administrative boundaries	Lack of social ties	School zones
Socio-economic estimation	Statistical difference	Census variables
Commuter interaction model	Connectivity	Commuter flows

Road network and travel time (Gravity Model II and III) are computed using Mapquest API for slightly jittered original home locations (i.e. not Census Block centroids) to avoid excessive noise.

Gravity Model IV's cost metric is computed as the sum of the population between mentor and protégé Census Blocks (using a straight line) (similar to Rozenfeld et al. 2002), exclusive of the mentor and protégé blocks. This allometric cost, i.e. population, represents the number of people who are "closer" to the agents, wherein more people might indicate more convenient opportunities for an agent to complete his or her dyad. We use U.S. Census Decennial Census and American Community Survey (ACS) data to estimate population characteristics. We examine the socio-economic differences between of mentor and protégé neighborhoods, including population density, percent of adults (25+) with bachelor's degrees, and income data rendered at the Census Block level.

We test for statistically-significantly differences between the MdS-facilitated relationships, and relationships that were randomly derived.

3. Results

3.1 Gravity Models I, II, III, IV

Gravity models are currently unparameterized; attraction is computed as the product of the block group population at the mentor's and protégé's home locations and cost is computed as the cost metric squared. A two-tailed Kolmogorov-Smirnoff (KS) test confirms that the two data samples are highly unlikely to drawn from the same underlying distribution when cost is Euclidean distance ($D = 0.319$, $p < 0.001$), road network distance ($D = 0.294$, $p < 0.001$), travel time ($D = 0.301$, $p < 0.001$), and our allometric distance metric ($D = 0.331$, $p < 0.001$) (Fig. 2). From this analysis is clear that the two data samples are highly unlikely to drawn from the same underlying distribution, and that the MdS data show that relationships are made despite higher cost distances.

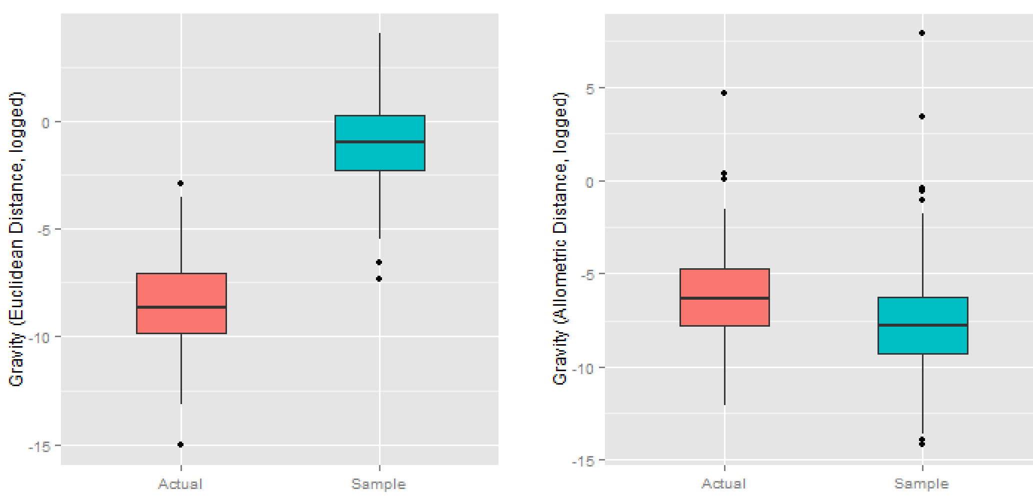

Figure 2. Distributions illustrate differences in observed (i.e. MdS) and simulated sample pairs using Euclidean (left) and allometric (right) distances. Data are plotted on a logarithmic scale (base 10).

3.2 Administrative Boundaries

Although mentor-protégé pairs are more likely (.844) than sample pairs (.804) to cross Santa Fe middle school district boundaries, the result is not statistically-significant. Agresti and Coull's modified Wald method estimates the 95%confidence interval (CI) for the sample pairs as [.752-.902]. Moreover, .574 of mentor-protégé pairs cross the Santa Fe public high school boundary, versus .486 in the sample data (CI [.474-.670]).

3.3 Socioeconomic Differences

Mentors hail from communities with 3% more people employed on average and 4% more residents with Bachelor's degrees. Each finding was significant using a Student's paired t-test at the .05 p level. Median household income did not approach statistical significance, although a visual pattern shows higher mentor income from students on the city outskirts, and lower for intra-city ties. We found no significant difference between levels of population density between the homes of the protégés and mentors.

4. Ongoing Research and Conclusion

In the future, we would like to augment the use of distance as a proxy for interaction potential with social network, telecommunications and movement interaction data—specifically a network of Santa Fe area commuters furnished by U.S. Census' Longitudinal Employer-Household Dynamics (LEHD) LODES data.

In summary, we determine that the MdS dyads are different from our random sample in some cases, but not others. We find that this experiment shows that socialization in the built environment, when curated by a formal institution or organization, can be facilitated and guided. MdS facilitates relationships that persist despite distance, high travel time and socially-constructed (namely, Hispanic/white) roadblocks to the creation of social capital and human interpersonal relationships ubiquitous in urban society.

5. Acknowledgements

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