An Algorithm for Spatial Popularity based upon the Inverse-Square Law of Gravitation

An algorithm for capturing clustering phenomena for any non-uniform distribution of elements in two dimensions is developed in this study.

In the most generic sense, when exact knowledge of the combination of forces that produced an observed distribution is unavailable, frequency within a superimposed grid is inadequate to quantify clustering on a per cell basis. This algorithm generates $p$-scores (popularity scores) which describe the extent to which each cell exemplifies the clustering behavior(s) that drove the observed distribution. This technique can be applied at micro scales, such as bacterial colony distribution in petri dishes, meso scales, such as the distribution of push carts described by The Mayor’s Push-cart Commission (1906) utilized in this study, and macro scales such as the distribution of galaxies in the Milky Way as seen from satellite-based observatories.

The 10th Ward of the Lower East Side of Manhattan offers a unique problem space for the exploration of human use of cities. Gardner (2001) noted that over 160,000 residents per square kilometer, the highest population density to ever exist in the United States, resided within the 10th Ward in the first decade of the 20th century. Hughes (1998) described it as offering nine square yards per resident, including streets and sidewalks. Eleven thousand sweatshops, packed into five- or six-story tenements, churned out goods. People streamed through on their way downtown or to the docks, adding to the over 70,000 residents, creating demand which could not be met by conventional shops. Push-cart vendors proliferated to the extent that the Commission labeled them an “evil.” The primary complaint was congestion, but complaints included increased fire danger, difficulty cleaning the streets, unfair competition, improper food sanitation, persecution, corruption, noise, odors, and even (most dubiously) a lowering of the standard of living. The densities seen in the 10th Ward are not a novelty, outlier or aberration. An ever larger proportion of humanity face such conditions by 2030. The NRC Committee on Preparing for Ten Billion on the Planet (2013) forecasts extreme population growth – especially in sub-Saharan Africa – within urban contexts. The 10th Ward is one model for such urban futures. Insights gained, variables quantified, and techniques developed are downward compatible.

The Algorithm:

$$p\text{-score (N9)} = 1526 = 5^2 (42) + 5^1 (18+30+16+14) + 5^0 (19+13+16+5+0+5+8+20)$$

Frequency Model  $p$-score Model

Social interaction, transportation infrastructure, and settlement patterns quantified by Bettencourt (2013) drive urban planning and policy. Proactive, designed responses to rapid urbanization – in lieu of hybridized organic development or divested capitulation to these forces – require techniques for evaluating the performance of urban spatial fabric. Modeling and simulation of that which has existed, which currently exists, and which might someday exist – especially design options – is the key to being proactive. Such techniques need to be refined until they are both accepted and widely adopted by both the research and professional communities if the dystopias of Davis (2006) and others are to be avoided.

Batty (2007) has explored human use of architectural and urban spaces, via agent-based modeling and other techniques, in his seminal book and has expanded these notions in The New Science of Cities (2013). The behavior of autonomous agents should be informed by the equivalent of mental maps, given that movement is both constrained by urban form and facilitated by experience, and not just goal states. Establishing a quantitative foundation for agent navigation of urban space was the catalyst for this study.

Original Source for Frequency Model:

Data

Geolocated Data

Conclusions:

The resulting spatial matrix of popularity $p$-scores is intended for use as a resource for agent-based modeling. Agent scripting can be driven by agent attraction or repulsion from specific spaces or zones without the assumption of perfect knowledge, enhancing the construct validity of the navigation task within such simulations.

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