Understanding Human Movement Patterns Shaped by the Underlying Street Structure (Abstract*)

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Understanding human movement patterns or traffic flow is a topic of theoretical interest and practical importance in various disciplines such as epidemiology, traffic forecast, and urban planning. Human movement patterns have been found to follow Levy flight behavior based on individual movement data. At a finer spatial scale, human movement has been found to be predictable for individual streets. To put it simply, well connected streets tend to attract more traffic than less connected streets. As to the mechanism underlying the human movement patterns, some researchers attempted to seek an answer from the human side, such as people's conceptualization of distances, and people's tendency of minimizing trip length or maximizing trip efficiency. In this study, we attempt to argue, based on both simulated and observed evidence, that human traveling behavior or cognitive effects have little effect on aggregate flow distribution. It is not people but the underlying street structure that shapes the movement patterns. Even though we put some monkeys in the street network, the ultimate movement pattern by the monkeys would be same as that generated by human beings.

What do we mean by street structure then? It refers to a street-street relationship as to what street connects to what other streets. More specifically, the street-street relationship is represented by a connectivity graph, consisting of nodes representing individual streets, and links if the two streets are connected to each other (*c.f.,* Figure 1 for illustration). The street structure is then defined and characterized by a range of graph theoretic metrics for ranking the importance of individual streets. This study is further motivated by challenging the conventional wisdom in the literature that closeness centrality (or integration in terms of space syntax) is a default indicator for aggregate flow. We will prove empirically that Google's PageRank, its modified version - weighted PageRank, betweenness and connectivity centralities are the better metrics than closeness centrality to capture the aggregate flow.

Two kinds of moving agents are designed and implemented to simulate movement in a street network. The first is random walkers (RW) that can hop arbitrarily from one street to another. The hopping behaviour is defined at a topological level with the connectivity graph. On the other hand, the simulation has yet to be based on a geometric level to mimic a sort of network constrained movement. That is, within an individual street, the RW persistently move along the street until they reach the next street that intersects with the current one. As soon as the RW reach the intersection, a decision as to which will be the next street has to be made (again randomly decided, but sometimes with a higher priority to highly connected streets), and then move towards the next intersection, and so on and so forth. The random behaviour is obviously occurring at the topological rather than the geometric level.

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* This abstract is extracted from our full paper Jiang B. and Jia T. (2010), Agent-based simulation of human movement shaped by the underlying street structure, http://arxiv.org/abs/0910.3055

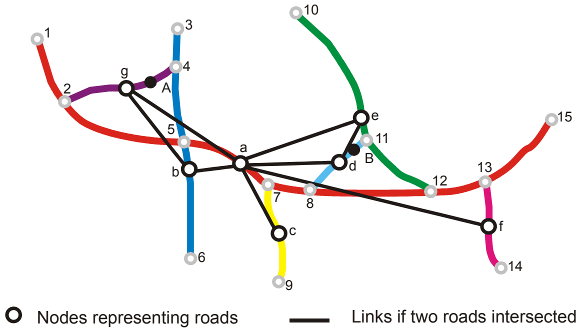

Figure 1: (Color online) A connectivity graph based on street-street interaction

The second type of moving agents is more realistic and goal oriented – purposive walkers. Suppose that a person wants to go from location A to B (Figure 1), located respectively in street g and street d, he/she would walk (1) along street g and toward intersection 2, (2) along street a, and toward intersection 8, and (3) along street d, and toward location B. This is just for illustration purposes. In a large street network, numerous purposive walkers would randomly decide their goals and then target them. Once they reach their first goal, they randomly choose a second goal and so on and so forth. The purposive walkers have no preference in choosing destinations or goals. This is the first type of purposive walkers (PWI). The second type of purposive walkers (PWII) give a high priority (with a probability of 80%) to closer locations within two steps of topological distance, while a low priority (with a probability of 20%) to farther locations beyond two steps. This is based on the observation that most people travel only short distances, while a few regularly move over hundreds of miles.

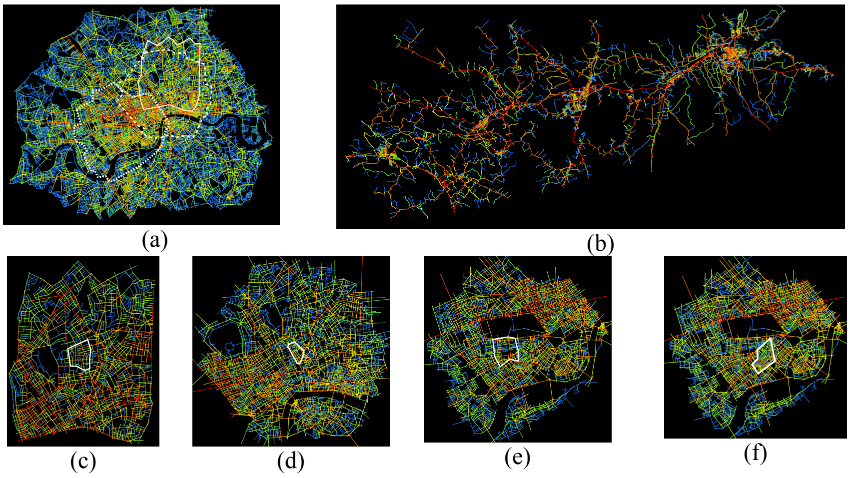

Figure 2: Human movement patterns visualized by spectral color ranging from red (highest) to blue (lowest) according to weighted PageRank scores: (a) London and the three area-outlines: Barnsbury (solid), Clerkenwell (dashed) and South Kensington (dotted), (b) Gävle, (c)-(f) Enlarged view of the three areas and the observed sites (highlighted patches): Barnsbury, Clerkenwell, South Kensington, and Knightsbridge

We adopted two data sources respectively representing two forms of streets: axial lines and natural streets (Figure 2). The data sources are publicly available (http://eprints.ucl.ac.uk/1398/, and http://fromto.hig.se/~bjg/PREData/). To characterize street structure, we adopt seven metrics including weighted PageRank (WPR), standard PageRank (PR), connectivity (Cnt), control (Ctr), betweenness (Btw), local integration (Ltg), and global integration (Gtg). We examine the metric-flow correlations, in order to (1) see how aggregate flow can be captured by the metrics, or equivalently, to see how movement patterns are shaped by the underlying street structure, and (2) check which metrics are the best indicators for predicting traffic flow at a collective level.

We relied on three different moving agents to explore the mechanisms underlying the emergence of human movement patterns in some large street networks, and we found that moving behavior has little effect on movement patterns. We further examined the disparities among the metrics, and found that closeness centrality is not a good indicator for predicting traffic flow. Even the local integration is far from the best indictor. Instead we suggest some alternatives: Google's PageRank, its modified version – weighted PageRank, and betweenness and connectivity centralities.