Bottom-up Approach to Studying the Street Structure and Human Movement Patterns

Position paper by Bin Jiang

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This position paper concentrates on a multidisciplinary approach to studying the street structure and human movement patterns - an approach that is bottom-up in nature with a focus on the interaction of individual agents. In the past years, we have been adopting this approach in various studies for a better understanding of the street structure, human movement patterns, and in particular how the movement patterns are shaped by the underlying street structure. In what follows, I will present an overview of the studies and elaborate on how the approach constitutes some basic thinking in our research.

Inspired by the striking morphological difference between Europe and US cities, I started a comparison study of cities in order to illustrate this difference in a quantitative manner. We took a topological perspective to assess how individual streets are interconnected in terms of what street connects to what other streets. The street-street interaction is modeled through a connectivity graph, consisting of nodes representing streets, and links if the corresponding streets are intersected. This unique topological graph allows us to assess the status or ranking of individual streets in a connected whole. As it turns out, we found a topological pattern that seems universal to all kinds of cities. This pattern can be described by the 80/20 principle: about 80% of streets are less connected by 4 other streets (4 being an average), while 20% of streets are highly connected (above the average) (Jiang 2007). A further study illustrated that human movement is significantly influenced by the same pattern, i.e., a minority of streets account for a majority of traffic (Jiang 2009). Fundamental to the street-street interaction, or the kind of the topological perspective, is the network thinking that features the science, technology and society of the 21st centenary, an emerging new science of networks (Newman, Barabási and Watts 2006).

In the above studies, the individual streets are considered to be the individual agents that interact with each other to form a connected whole. The individual streets are generated from smaller units - individual street segments or arcs, in a self-organized manner. Due to this fact they are also called self-organized natural streets (Jiang, Zhao and Yin 2008). This generating process runs like this: every segment has to negotiate with all its adjacent segments to determine which segment (i.e. the one with the smallest deflection angle) to join together in order to form a natural street that has good continuity from the perspective of Gestalt psychology. This process continues until the deflection angle is larger than a preset threshold (e.g., 45 degrees). It is through this kind of segment-segment interaction that individual streets are generated. This process is bottom-up in nature. There is no average street in the sense of an average human (in terms of height or weight), but streets of all sizes. In other words, street length is very diverse and bears a power law distribution. There are far more short streets than long streets, another expression of the topological pattern.

The human movement we refer to is constrained by streets, and it is done through continuous interaction between moving agents and a street network, i.e., car-street interaction. Relying on this interaction, we developed multi-agent simulations that involve both random and purposive moving agents to assess movement patterns. We find that aggregate flow, assigned to individual streets, is mainly shaped by the underlying street structure, and that human moving behavior (either random or purposive) has little effect on the aggregate flow (Jiang and Jia 2010). This finding implies that given a street network, the movement patterns generated by human beings (purposive walkers) and by random walkers are the same. This somewhat surprising result proves that no cognition is involved in the formation of human movement patterns. The study also provides a compelling example about the idea of using multi-agent simulations to understand seemingly complex natural and social phenomena.

Currently we have been exploring a fourth interaction - car-car interaction that extends the car-street interaction in order to better understand traffic jams, .e.g., how traffic jams are related to car density, car behavior, and the underlying street structure. Hopefully, by the time of this workshop, we would have some primary results to show and to discuss with the workshop participants. To this point, we have already seen how the street structure and human movement patterns can be understood from the bottom-up via the interaction of individual agents. We have talked about four kinds of interactions: street-street, segment-segment, car-street and car-car interactions.

Finally in line with the bottom up approach, I would like to speculate on how geospatial data collection follows the same approach. Conventionally, geospatial data collection, and maintaining alike, is the business of national mapping agencies. This is a top-down approach. There are also private sections involved in the business, e.g., Tele Atlas and NEVTEQ. This is still deemed a top-down approach. On the other hand, the pervasive nature of GPS units makes geospatial data collection an easy and affordable task. Nowadays, most taxi, parcel delivery and logistic companies have their vehicles GPS equipped. In one of our studies for illustrating human movement patterns, we collaborated with a local taxi company, collected over 6 GB GPS data from which we extracted over 70 000 trails for some statistical analysis (Jiang, Yin and Zhao 2009). It is a bottom-up approach in terms of data collection. Using GPS data, aerial photos and many other free data, OpenStreetMap contributed by volunteers has emerged as an important geospatial data source that can compete with those data sources collected using top-down approach in terms of both quality and quantity. This trend of geospatial data collection has captured the attention of mainstream GIS literature (Goodchild 2007).

In summary, the position paper elaborates on the bottom-up approach from geospatial data collection, modeling and simulation. It covers some concurrent research topics such as volunteered geographic information, complex network analysis, agent-based simulations which all bear this bottom up nature. We have seen how the fundamental thinking has been adopted for studying human movement patterns. Beyond that, I believe that it will have a significant impact on geographic information science research in more general.

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