Measures of Street Connectivity: Spatialist_Lines (MoSC)

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Background

How individuals move and interact between places is related to the spatial form of these places. Spatial form in cities can be conceived in terms of networks of streets and related routes, open spaces, clusters of land parcels and buildings. This physical infrastructure both accommodates and shapes circulation of different kinds (pedestrian, vehicular, public transportation). Therefore the form of physical infrastructure can either facilitate or impede this circulation and consequently human presence in public space.

Spatialist_Lines has been developed within the broader context of syntactic studies. Syntactic studies argue that the spatial structure of urban areas plays a significant role in pedestrian movement and land use distribution. Originally in space syntax the focus was on links that are defined as lines of sight or as lines of unobstructed movement (axial lines). A unit distance was associated with a link between one axial line and another, and thus the accessibility between streets was measured as a count of links that need to be crossed to move from one axial line to another. The actual length of a street is irrelevant as far as it can be represented by one line of sight. In this sense, the connectivity of the network was defined topologically and distance had no meaning.

Spatiality_lines introduces metric values into this framework so that the proposed measures combine topological and metric properties. It aims at contributing a way of measuring how a street grid becomes metrically denser or sparser, more or less intelligible and more or less easily accessible.

This approach might help to bridge the gap between understanding urban structure, urban design, and urban regulation. One practical outcome is to support the appropriate design of streets as part of urban developments. For example it can inform us on how the street network can be designed so as to ensure that some places, intended as retail hubs, business cores or local centres, will be more likely to attract higher densities of movement, whereas others, intended for residential uses, will remain quieter (Hillier, 1993).

Conceptual framework and theoretical underpinnings

One can distinguish four different approaches regarding description and evaluation of street connectivity (Ozbil *et al.*, 2011).

The first one resorts to typological distinctions between rectilinear, curvilinear and cul-de-sac layouts. These distinctions are supported by measures of the average properties of street networks, such as the number of intersections or cul-de-sacs by unit area.

A second one directly discusses the connectivity of street networks as a factor that affects accessibility and walking. The measures used include density of street intersections per area, block size per area, cul-de-sacs per area, proportion of four-way intersections, the ratio of intersections to cul-de-sacs, the links–nodes ratio, or the average distance between intersections.

A third approach uses measures that can characterize a particular location within a network such as the walking catchment area around a destination of particular importance or the directness of available routes from various surrounding origins to destinations of importance.

The fourth one takes a configurational approach and it is associated with space syntax studies. It involves measuring the accessibility of all parts of a network under consideration from each individual street element. The intent is to provide a generalized description of spatial structure and connectivity hierarchy without making assumptions about desirable or typical trips.

Following this last, syntactic approach, Spatialist_Lines defines accessibility in terms of *street connectivity as a* specific form of relatedness that arises according to the structure of street networks. Street networks are mechanisms that serve the purposes of connectivity in the broad sense. Connectivity is comprehended as a generator of urban potential. Urban potential can be thought of as the quantity of destinations that is available within a given distance of movement from a point. From the point of view of movement, potential access is the fundamental form of spatial relatedness.

Operational aspects

A research team from Georgia Institute of Technology has proposed three measures of street connectivity that can discriminate between the connectivity potential of individual road segments in adjacent or proximate positions. These are Metric reach, Directional reach and Directional distance (Peponis *et al.*, 2008). When averaged over an area, they provide robust measures of overall connectivity. In other words, the three aforementioned measures can be used to describe the aggregate connectivity differences between urban areas, as well as the internal spatial structure of a single urban area.

Stated simply, metric reach (Figure 1) measures the length of street which lies within a parametrically specified network distance from a point.

Directional reach (Figure 2) measures the length of street which lies within a specified number of direction changes from a point, with a specification of the minimum angular threshold that defines a direction change. While metric reach "grows" around a root point equally in all available directions, directional reach is "biased" according to the linear alignment of streets.

Directional distance measures the average number of direction changes, subject to a parametric angular threshold, that are needed in order to access the parts of a given metric reach. In order to characterize a network, the measures are applied to the mid-points of all road segments in a system. In principle, they can be applied to a more limited set of chosen points (for example to the entries to schools or shops) or to a larger set of points (for example to all street intersections in addition to all road segment mid-points).

Spatialist_lines is a JAVA-based software which has been developed at the Georgia Institute of Technology by Peponis, Bafna and Zhang, and is currently available "as is" upon request addressed to john.peponis@coa.gatech.edu without technical support other than provided in a simple manual originally intended for distribution to new members of the Georgia Tech research team. The software operates as a plug in to ArcView GIS.

The software takes as input street centre line information from standard GIS street network data bases or CAD files in DXF format. It provides as output the measures of metric reach, directional reach and directional distance. Results are also displayed in colour street maps.

Time length of calculation ranges from seconds to few hours depending on the size of the street network and the available computer power. A basic knowledge of GIS software is required to perform the calculation. Visuals maps are easy to be comprehended and there is no need for technical expertise to understand the differentiations and hierarchies of the urban grid in question.

Relevance for planning practice

The approach can inform urban design decisions in creating new streets or realigning existing ones. The notion that street layout can and should serve planning aims is an old one. What have been missing are measures of street connectivity that can support decisions about street layout design. The proposed measures are useful in this context. They mediate between urban planning and urban design. Urban planning is oriented towards principles of general applicability and tends to be concerned with the average or aggregate properties of areas. Urban design is concerned with the internal structure of areas and with the way in which street layout impacts the nature, orientation and performance of building developments for which it provides the context. Walking is, after all, a pre-eminently context-dependent activity, one that occurs according to the fine grain of environment, as well as its larger scale structure. This is why we need enriched models of street layout and urban form in order to better design for walkability. The fact that direction changes are as important as metric distance in describing street connectivity points to the role of cognitive factors. Traditional models of movement patterns are based on the consideration of distance and time, but they do not take into account the intelligibility of urban form. Integrating considerations of intelligibility can lead to enhance models of urban form and function (Ozbil *et al.*, 2011).

Spatialist_lines has been used to support design and planning decisions in practice. In summer 2010, the software was used to assist Perkins and Will in the master-plan for the King Abdullah University of Science and

Technology Science Town (KAUST) [1]. This is to be developed in Saudi Arabia, on a 790 acre site, north of Jeddah.

The Georgia Tech research team worked with the urban designers to ensure that the main road network, the linear pedestrian spine and the master-plan stipulations would work together as an intelligible, flexible and effective framework for the growth of a vibrant research, development and business community. Specific programmatic aims served by road and path connectivity include the support of serendipitous interaction and communication as well as the provision of an accessible and intelligible system of support functions such as social meeting places, retail, cultural centres, restaurants and other amenities.

The process of consultation included a design guideline which was discussed with urban designers in the beginning of the design process; analyses of the proposed network to confirm that it took the best possible advantage of connections to the pre-existing context (Figure 3) and that its internal structure was suitable for the phased development of the town ; proposals of specific urban elements (such as the "research souk") which would enhance the emergent pedestrian circulation system and finally calibration of the location of local hubs (such as open spaces, incubator complexes, or specific buildings), that will punctuate movement over the network of streets and paths.

Strengths and limitations

From a scientific point of view the proposed *connectivity measures* enrich a considerable body of literature that points to a relationship between the distribution of pedestrian movement and the spatial structure of street networks. They underline the importance of the street network as the long-term framework that impacts the evolution of important aspects of urban function, including walkability, and patterns of land use that benefit from walkability. Furthermore they are sensitive to the geometry and the metric properties of the spatial structure of street networks.

From a practice point of view the proposed *connectivity measures* are critical for understanding the relationship between urban network design and practical consequences. Measures that emphasize the average properties of areas can be useful in supporting general guidelines and policies, but cannot inform design decisions about alternative street alignments or alternative ways of fronting and orienting developments. The specific measures of connectivity affect the interface between urban design and urban planning. Understanding how pedestrian movement is distributed over an area is important to urban development and urban design, because it helps the design team determine the potential character of individual streets.

Planning practitioners adopted the proposed consultation process and measures with no negative reactions. More than that, it seems that their original decision to adopt the specific consultation process was mainly based on the academic performance of the method.

This argues against the underlining idea that the academic and the professional environments are two separate areas with completely different requirements and goals. On the contrary it seems that academic performance influences professional choices.

Accessibility in urban context is a complicated issue. All accessibility instruments are limited in the sense that they focus on specific aspects of the problem and consequently they cannot explain everything. Spatialist_Lines have not been tested extensively in practice as it is a new instrument. Judging from its nature and background we can anticipate that negative reactions probably will be similar with those concerning space syntax instruments (i.e., practitioners having too high expectations of the results, or being unable to translate results without a theoretical background). For the time being developers are testing the instrument in academic research

References

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Figures

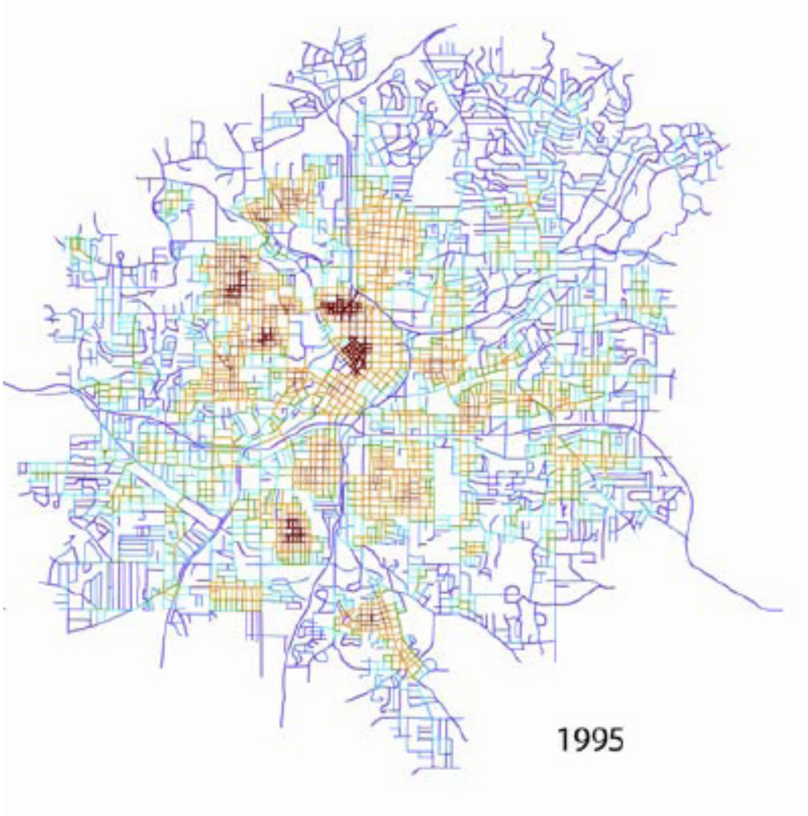

Figure 1 Metric Reach Map of Atlanta. The 10 interval colour range red-blue represents the spectrum from higher to lower values. (Source: Haynie *et al.*, 2009)

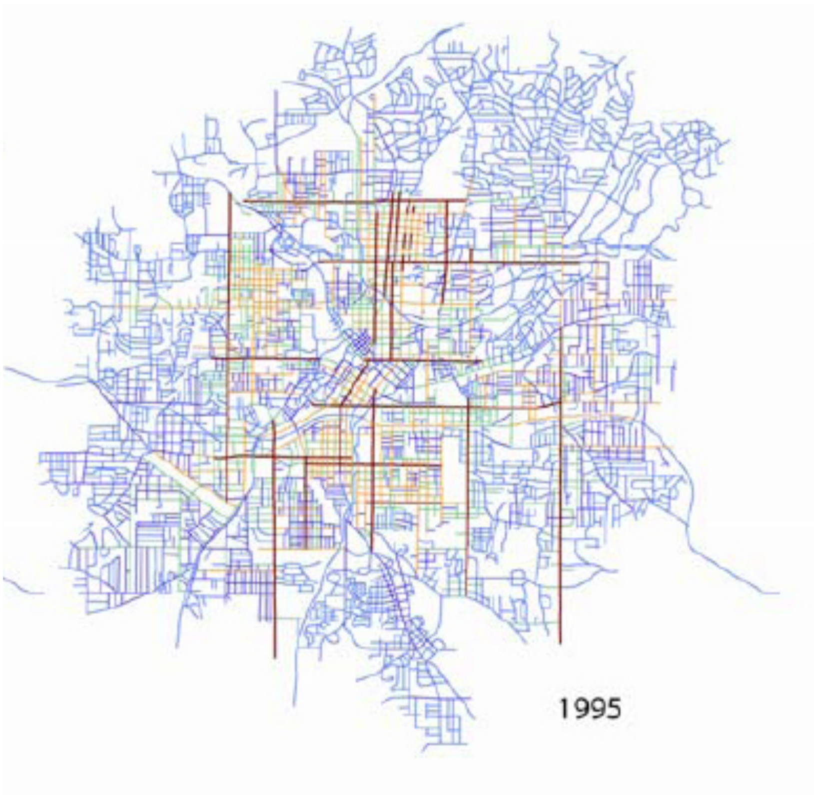

Figure 2 Directional Reach Map of Atlanta. The 10 interval colour range red-blue represents the spectrum from higher to lower values. (Source: Haynie *et al.*, 2009)

Figure 3 Directional Reach Map of KAUST . The 10 interval colour range red-blue represents the spectrum from higher to lower values. (Source: KAUST Masterplan guidelines)