Correlating street centrality with commerce and service location in cities

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1. Introduction

In this paper we are presenting a discussion of centrality in cities and a model, named Multiple Centrality Assessment (MCA) which helps in managing centrality for urban planning and design purposes. In so doing, we summarize a research that we have been undertaking for the last couple of years. In addition, we are hereby offering the results of a new line of research aimed at understanding the level of correlation between the centrality of streets and several other urban dynamics like the location of shops and services as well as that of workplaces. The whole research is worked out in a GIS (Geographic Information System) environment: the correlation analysis is addressed both directly (comparing centrality and dynamics on every arc of the street graph) and through a GWR (Geographic Weighted Regression) approach. Data are taken form real cities like Rome (IT), Barcelona (ES) and Bologna (IT).

2. Multiple Centrality Assessment

Centrality is not just at work at the heart of contemporary urban life, linking spatial forms and collective behaviours, but is rather at the heart of the evolutionary process that made our cities what they have always been, with a strong impact on how they still are in our days. Centrality has long been investigated in regional analysis and urban geography as a means to weight relationships between other functional factors (like market, jobs, services, goods production or housing) along communicational corridors like major road networks (Wilson 2000); in so doing, centrality is interpreted as accessibility, which measures how much two locations are close in terms of transportation cost. This is also the way transport engineers have dealt with centrality in urban networks and traffic modelling.

A different view was introduced by sociologists like Bavelas (1948, 1950) since the early Fifties: sociologists were interested in understanding how the relevance, or prominence, or leadership, emerged in favour of specific components of large social networks (like corporate or public organizations, or other social groups); in this line of research centrality was deeply investigated in itself, leading to many different definitions that give different results expressing different ways of "being central", all operating at the same time in complex networks. The "classic" set of centrality indices for structural sociologists included Degree, Closeness and Betweenness (Freeman 1977, 1979), where the first is again related to how much a place is close to all other places in the network, something similar to the accessibility indices developed in urban geography and transportation planning.

In mid Eighties a new effort in mapping centrality in cities was developed in London by a group of academics led by Bill Hillier under the notion of Space Syntax (Hillier and Hanson 1984; Hillier 1996). In this case, centrality was mapped as a property of just the topology of the system, like in structural sociology, but still mainly based on an index of closeness or accessibility, like in urban geography and transportation planning. However, centrality was here termed "integration", and the perspective was oriented to the field of urban planning and design: integration – it was claimed – is the key for understanding how cities evolve, where is the highest potential for a place to become a popular, successful and safe spot in the city. The Space Syntax approach has gained a great momentum in last years and is now well established in both the science and the practical development of neighbourhoods, districts and cities.

Drawing from this background, we have recently worked out an application of the approach of structural sociologists, which in the meanwhile encountered a wave of extraordinary development in the physics of large complex networks of all kinds (Boccaletti et al. 2006), to the urban networks of streets and intersections: in our approach, the consideration of the topology (how streets are connected each other) goes together with the metric of the system (distance is in fact computed metrically rather than just topologically), and a number of different centrality indices are taken into consideration (Porta et al 2006a,b; Cardillo et al. 2006; Crucitti et al. 2006a,b; Scellato et al. 2006); therefore, we named our model Multiple centrality Assessment (MCA).

3. Correlating street centrality and urban dynamics

Cities have grown in history following (to a certain extent) rules of centralities that are a factor of efficiency in making complex urban systems competitive in evolution. The idea is that we can actually see some clues of this in how several dynamics of particular relevance correlate on the ground to the spatial distribution of centrality. We have worked out a first test over the cities of Bologna and Rome, Italy, and the city of Barcelona, Spain. Here, we correlate the centrality indices of Closeness, Betweenness and Straightness, computed at the global and local levels, to urban factors that play a key role in sustaining and fostering daily urban life at the scale of the neighbourhood and the district, such as the location of community-level commercial activities and services.

Two different methodologies were addressed to investigate such correlations. On one side, we correlate variables on a street-by-street (arc-by-arc) basis: on each arc, each centrality measure is correlated to the density of shops and the density of services; density here is to be intended as the number of items divided by the length of the arc. GIS tools were applied to associate items (points) to streets (polylines) based on the shortest distance between the twos. We term this approach "direct correlation".

On the other hand, a different correlation methodology was then applied on the same datasets based on Geographical Weighted Regression (Brunsdon et al. 1996;

Fotheringham et al. 1997a,b). In this case, we covered the urban region with a grid made of 10mt edge square "cells", then we computed for each cell, within a certain radius (or "bandwidth") the three densities of centrality (one for ach centrality index, Betweenness, Straightness and Closeness), the density of shops and the density of services. We than correlated cell-by-cell such variables trying to understand to what extent the location of shops and services was "explained" by the centrality of streets. This second methodology, that we term "Kernel Density Correlation" (KDC) offers great advantages in that: 1. Can be applied on all sorts of spatial databases provided that they are coherently geo-referenced (no need for common fields to assign point event, i.e. shops and services, to line events, i.e. streets); 2. Nicely captures the real experience of urban space which appears to continuously and gradually distribute its "properties", i.e. centrality, according to distance with no steps whatsoever: in this case the "smoothing" character of the kernel functions applied is pivotal; 3. Captures the overlay of centrality values at street crossings which also appears to be a typical property of urban space, where in fact street crossings are considered hot spots for the location of community services and commercial activities.

Results confirm that all centrality indices "explain" a significant amount of the location of shops and services in all cases under scrutiny; the paper will illustrate the different behaviour of the three centrality indices in this explanation, and why the betweenness index actually shows the highest performance. The paper will then discuss statistical issues particularly related to the second methodology of correlation (KDC), like the use and mapping of local statistics. The rationale under the choice of the bandwidth and how to deal with the problem of autocorrelation.

7. References

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