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Urban Form from the Pedestrian Point of View: Spatial Patterns on a Street Network.

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Introduction

The analysis of urban form represents a vast research field in its own. At the same time, it is a main research step in other fields of urban studies: the morphology of a city represents the canvas where events draw their occurrence patterns. Variables describing one or more aspects of urban form may carry different meanings, at different scales and with different effects on human behaviour and activities as well as on the evolution of the urban form itself (Levy 2005). In the Italian, French and English traditional schools of urban morphology, the analysis of urban form, and more specifically the analysis of the urban fabric, has focused on three main aspects (Pinon 1991): (i) the identification of urban form components (urban network, buildings and parcels), (ii) their geometrical description and (iii) the analysis of their spatial relationships. The analyses of the traditional school of urban morphology were normally carried out at the scale of a city neighbourhood, with manual calculations and a focus on the historical process behind observable urban forms. Geoprocessing of urban morphology within a GIS environment has become more widespread in the last twenty years, allowing for larger scales of analyses, but often losing the fine grain of the constituent elements of urban form (like in Berghauser Pont and Haupt 2010, or in Fusco 2016). Our research focuses in particular on the urban street network and the built-up space, which are the aspects of urban form more directly observable by pedestrians moving in urban space. Parcel structure plays a more important role in the historical of urban form and has been omitted in our research.

Thanks to computational evolutions, the analysis of the spatial relationships between the two selected aspects, have been developed from the natural movement hypothesis. The assumption underlying these studies takes into consideration the way pedestrians move in urban space: on the one side visual-based movement (i.e. SSx, Hillier 1996), on the other physical impedance-based movement (i.e. MCA, Porta et al. 2006). Both approaches see human behaviour as a way to link elements of urban form: the former considers visible space as influencing urban movement and consequently the reachable places and elements. The latter analyses what is visible/reachable, considering walking position and movement (with a space or time impedance on the network).

With this paper, we propose and test on empirical case studies a new method of analysis of the form of urban fabric from the pedestrian point of view, mixing the relations considered by classical urban morphology with the computational possibilities of geoprocessing. We consider the two main activities that humans do in the space simultaneously: walking and perceiving the urban landscape. As a consequence, we will be able to analyze the interaction between form elements combined with their geometrical description. At the same time, we will stop short of applying the configurational calculus (whether SSx or MCA) and of studying urban form perception as revealed by mental maps of city dwellers (Lynch 1960). Unlike classical urban morphology, we will consider that urban form is not observed on a plan or as an aerial view, but from the pedestrian perspective. A new spatial unit definition will follow: this new space element is determined by the urban network segment (representing human movement and the main channel of perception of urban form) concurrently with its surrounding space limited to a given visual depth. Through this procedure, urban fabric will be defined as spatial patterns filtered through the possible perception of city users. The proposed approach is particularly powerful, as it allows computing on a larger scale and with geoprocessing methods what in previous research had been done manually or limited to a local urban project scale. Expert judgment becomes less crucial in the characterization of urban fabric (an advantage when the study area is a vast metropolitan area) and the bottom-up approach, by identifying spatial patterns through geostatistical analysis of form elements in the context of their surrounding environment, eliminates the problem of statistical analysis on pre-defined administrative boundaries.

Methodology

A. Study Area. Our analysis is applied to the French Riviera conurbation, in Southern France. Once the independent Principality of Monaco is included, this area has a population of more than one million inhabitants over 1500 km^2. This space is a unique conjunction of natural and urban landscapes: firstly, the topography, with elevation ranging from the sea level up to 1700 meters of the pre-Alps (passing through hills and valleys differently sloped). Secondly the socio-political and historical influences on the urban planning. Traditional villages, are spread around three high density urban areas. From east to west, we find: Monaco and its skyscrapers, the most densely populated sovereign nation in the world; the urban agglomeration of Nice with a regular meshed core inspired by the Turin model (Graff 2000), surrounded by hilly and less tightly planned areas. And finally the urban agglomeration of Cannes-Grasse-Antibes characterised by land irregularity together with the car-centred sprawl development of the lasts 50 years (Fusco 2016). The combination of all these elements produces a sequence of urban centres and peripheral areas of different size and different morphology. This study area will give us the opportunity to test our method and to identify in a bottom-up approach different urban fabrics, which is a preliminary phase of future modelling of the relationship between urban form and functions.

B. Defining elementary spatial units. As introduced earlier, we consider a new division of urban space resulting from the combination of two elements: the urban street network, a connected set of segments allowing pedestrian movement, and the planar extension of urban space. A generalization of Thyssen polygons is thus created around each street segment to identify the portion of planar space conventionally served by the segment. For several morphological indicators, we only consider a double-sided proximity band of 20 m total width within this polygon, in order to approximate visible space (Fig. 1).

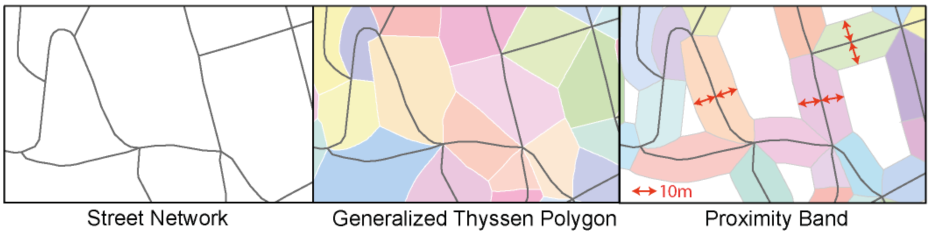

Figure 1. Generalized Thyssen Polygons around Street Segments.

The rationale for this spatial unit definition is that a street segment should not be considered the limit, but rather the core of a fragment of urban fabric. This is often the case in European cities where discontinuities in urban fabric normally coincide with double carriageway boulevards, which produce two different spatial units. Moreover, this approach is the most consistent with the pedestrian point of view: when standing in public space, people perceive the urban fabric on both sides of the street not the elements within the four sides of a block. In our study area, 113.668 elements were thus identified with a street segment length between 4 and 300 m and an average area of 13000 m^2 (1670 m^2 when only visible space is considered).

B. Urban Form Indicators. As anticipated, the street network morphology and the built up forms are the main components of urban fabric considered in this research. Nine indicators, obtained through geoprocessing in GIS, were calculated for each spatial unit.

Network morphology is analysed through the ***Linearity*** (or inversely, the ***Windingness***) of its segments, computed as the ratio between the real and the straight-line distance between its nodes, together with the ***Local Connectivity,*** given by the combination of the degrees of the two nodes defining the segment.

Built-up morphology is represented not only by the classic ***Coverage Ratio*** index (ratio between building footprints and spatial unit surface). The same ratio is calculated for four different groups of built-up units (union of contiguous buildings) reflecting the presence of different building typologies within our study area: 0-150m2 (independent houses), 150-600m2 (row-houses of small multi-family buildings), 600-2400m2 (compact urban block or big buildings), larger than 2400m2 (mainly functionally specialized big buildings). We thus obtain a ***Built-up Type Coverage Ratio*** index, relative to each class. Urban density (total floorage space per surface unit) is omitted as it is redundant with building height (considered in the next section).

Network-Building Relationship indicators describe the building geometry analysed in relation with the relative position to the street segment. For this reason, they are computed only on the proximity band around the street segment, hence respecting the pedestrian perspective assumption. The ***Street Corridor Effect*** indicator (ranging between 0 and 2) is the ratio between the total length of the façades (built-up perimeter) being parallel to the street segment and the latter's length. The ***Proximity Band Coverage Ratio*** indicator is obtained by applying the classic coverage ratio limited to the proximity band, while the ***Proximity Band Building Height*** indicator is the average ration of buildings in the proximity band.

Finally, the ***Surface Slope***, implemented as the ratio between the high-sloped (30°) surfaces and the total spatial unit surface and the ***Street Acclivity*** are used as measures of the Site Morphology and its influence on the street network design.

Table 1. The Indicator Set for the Analysis of Urban Fabric Morphology.

Urban Fabric Component	**Indicator**	**Definition**
Network Morphology	Linearity/Windingness	Ratio between segment length and Euclidean distance
	Local connectivity	Node degree
Built-up Morphology	Coverage ratio	Ratio between space-unit surface and total built-up
	Built-up type coverage ratio	Ratio between space-unit surface and 0-150m2 built-
		Ratio between space-unit surface and 150-600m2
		Ratio between space-unit surface and 600-2400m2
		Ratio between space-unit surface and >2400m2 built-
Network-Building Relationship	Street corridor effect	Ratio between parallel façades and street length in
	Proximity band coverage ratio	Buildings coverage on the 10 m proximity band
	Proximity band building height	Ratio between building vol. and surf. inside 10 m
Site Morphology	Surface slope	Ratio between total and high sloped space-unit
Network-Site Relationship	Street acclivity	Computed as tan(arcsin(D/l))=d/l/sqr(1-(d/l)^2)

C. Spatial statistical analysis - Once the indicators are calculated for the whole study area, the following step is to find how their values are associated in space so that larger scale urban features (urban fabric) can be identified. Spatial clustering indicates where a phenomenon of interest has high/low incidence level, outlining hot/cold spots; several methods have been developed, in different research fields and perspectives. Local Moran's I indicator of spatial association (LISA, Anselin 1995), based on Moran's I spatial correlation measure (Moran 1948), was identified as a valid geostatistical method. Despite its large application in other research fields, it has so far been used relatively little in the study of urban form (Tsai 2005, Musakwa and Niekerk 2014). In order to test the pedestrian perspective assumption, we analysed and compared the planar application of local Moran's I statistic LISA with the corresponding network-constrained I-LINCS (Yamada and Thill 2007, 2010). To our knowledge, this is the first attempt to use the LINCS approach to the analysis of urban form. Several network and planar depths were considered, following a topological queen contiguity approach. With an *ad hoc* geometric model, GeoDa was used to calculate these statistics (Anselin 2003).

Results, Discussion and Conclusions

The present analysis focuses on the Street Corridor Effect indicator. Applying LISA and ILINCS to the whole of the French Riviera conurbation produces a large, interesting set of results. The global Moran's I for the French Riviera is 0.38 with a planar approach and 0.45 with a network approach, with neighbourhood depth three. This shows both important spatial autocorrelation of the corridor effect and a better aptitude of the network approach to highlight the resulting spatial patterns. Global Moran's I is 0.32 with a depth of eight in the network approach, highlighting the local dimension of the patterns. In what follows, we will focus on a geographically more restricted area: the southern part of the municipality of Saint-Laurent du Var, west of the city of Nice. This coastal area includes an old village to the north, a marina in the south and diverse 20th century residential and retail developments in-between, with two important urban barriers severing the urban fabric: the railway and the motorway.

Fig.2a shows the distribution of the Street Corridor Effect indicator values: the Var river banks (east) and Mediterranean waterfront (south) are detectable due to their lower values, while higher ones characterize the old village. The apparently heterogeneous distribution of values in the rest of the area makes spatial clustering and pattern identification hard tasks. LISA and ILINCS can thus identify patterns of homogenously contiguous high/low street corridor effect as High-High/Low-Low areas. High-Low and Low-High are patterns of local discontinuities. Fig2.b and Fig2.d evaluate the difference between the two approaches at the same neighbourhood depth value of three. Firstly, as expected, a few misleading High-High and Low-Low LISA clusters disappear in the ILINCS approach because of the lack of network connections along the motorway (north-west in the map). Secondly, the network based approach identifies distinct clusters of high values, in addition to the old village. The spatial separation of these areas corresponds to the presence of the urban barriers, less/not detected by the planar approach. In both cases, features classified as not significant identify urban fabrics characterised by less clearly structured heterogeneity in the corridor effect. Increasing the contiguity depth value to eight (Fig.2.c), expands the extent of High-High clusters like the planar-based analysis; but now, urban barriers corresponding to bridges or underground passages are well visible thanks to the Low-High cluster segments.

In conclusion, the proposed method offers the possibility to identify spatial feature patterns from a pedestrian perspective through a bottom up procedure. Not depending on pre-established area boundaries, it can be easily applied in different contexts and contribute to inductive identification of urban fabric. Finally, the neighbourhood depth parameter allows its application to different scales of analysis of urban form. Future work will address the empirical Bayesian correction (Assunção, Reis 1999) to evaluate population size effect consequences: scarcely urbanised units could show higher variability of morphological indicators, biasing the calculus of spatial association. Once this problem solved, the research could tackle its last step where feature patterns from all indicators will be analysed and combined for a complete urban form classification.

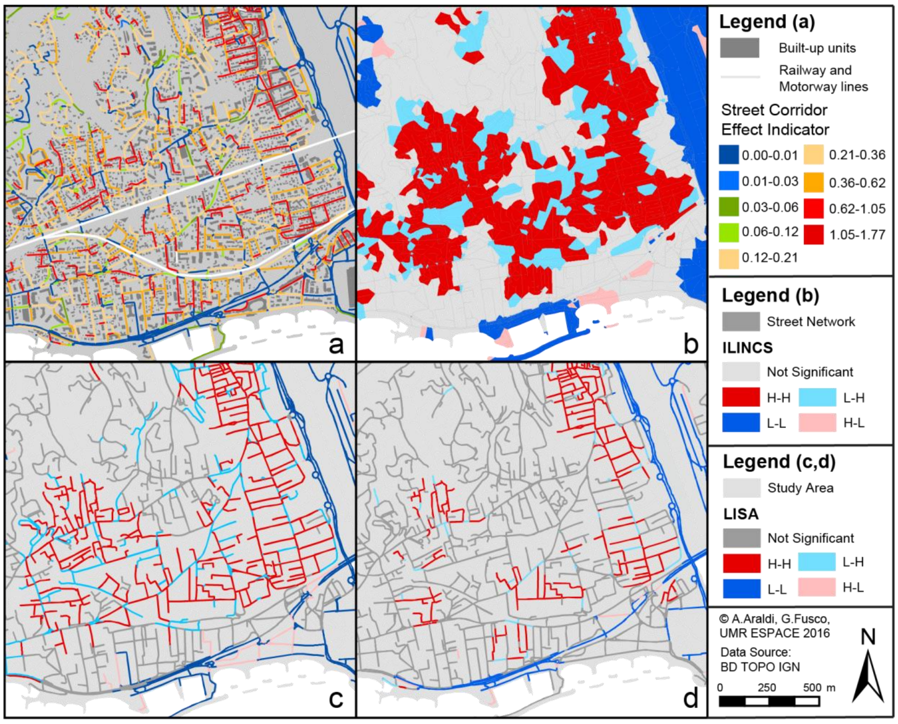

Figure 2. Spatial Analysis of the Street Corridor Effect in Saint-Laurent du Var.

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