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Built form and cultural identity: Exploring spatial information to understand different spatial cultures

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Abstract

The idea that urban form embodies idiosyncrasies that express cultural identities seems to be a frequent assumption in urban studies. It has to do with the contextual role of custom and institutional settings, from regional idiosyncrasies assimilated to traditional ways of building to the dichotomies of planned and unplanned cities, shaped through top-down agencies or as chance-grown arrangements. However, can local cultures leave traces in urban space? Despite its persistence in the urban imagination, the problem of how built environments might embody specific cultural identities seems yet to be fully addressed in urban morphology. In this sense, historically- and culturally-informed quantitative methods are essential for uncovering forms and patterns resulting from city organisation processes. In this paper, we look closely into that assumption and address the question of whether cities find distinct regional characteristics or take on physically specific forms under certain cultural conditions. This problem implies examining the existence of contextualised ways of shaping cities – and features that might transcend context. We do so approaching the built environment's spatial configurations as a proxy of urban culture, looking into urban form's very constituents. Unlike emphases on street networks, our approach focuses on the elementary components shaping cities' tangible spaces: buildings and how they are aggregated in cellular complexes of built form. Exploring Shannon's information theory, we introduce a measure of information and entropy to analyse the probability distribution of cellular arrangements in built form systems. We apply it to 45 cities from different regions of the world as a similarity measure to compare and cluster cities potentially consistent with specific spatial cultures. Findings suggest a classification scheme that sheds further light on what we call "the cultural hypothesis": the possibility that different cultures and regions find different ways of ordering space.

Keyword: *Urban form, culture, information.*

Introduction

The idea that urban form embodies idiosyncrasies that express cultural identities seems to be a frequent assumption in urban studies. It has to do with the contextual role of custom and institutional settings, from regional idiosyncrasies assimilated to traditional ways of building to the dichotomies of planned and unplanned cities, shaped through top-down agencies or as chance-grown arrangements (Kostof, 1991). However, can local cultures leave traces in urban space? Despite its persistence in the urban imagination, the problem of how built environments might embody specific cultural identities seems yet to be fully addressed in urban morphology. In this paper, we look closely into that assumption and address the question of whether cities take on physically specific forms under different cultural conditions (Hillier, 1989). Differently from emphases on street networks (Hillier et al., 1993; Porta et al., 2006), our approach focuses on the primary components shaping the physical spaces of cities: buildings and how they aggregate in complexes of built form. It also means taking into account a feature that seems to differentiate cities from non-urban settlements: the systems of built forms arranged in urban blocks. Closely related to systems of streets and open spaces, the urban block uniquely define the shape of cities in urban societies emerged in regions and cultures seemingly with no contact with one another. We will look into 45 cities around the world and measure their spatial configurations to assess differences and similarities between them. To do so, we shall lay down an approach based on Shannon's (Shannon, 1948) measure of information and entropy. We will argue that Shannon's measure is particularly suited for the task of capturing amounts of information related to randomness and order in configurations of built form. Our approach takes the following steps: **1** Inquire into built form as 'spatial culture'.**2** Propose a measure of configuration of built form based on Shannon's entropy. **3** Apply this measure to examine cities of different regions of the world. **4** Finally, use the results as a similarity measure to compare and cluster the studied cities, as 'information signatures' potentially associated with specific regions or spatial cultures..

State of the art

One of the under-examined assumptions about the connections between society and urban form is that the latter may somehow express cultural identities that constitute the former. Hillier (Hillier, 1989) addressed 'spatial culture' as a 'distinctive way of ordering space' as spatial arrangements shape the field of encounters that animate different social cultures. Some studies looked into spatial features, logics or organising principles in comparative studies of cities consistent with distinct regions. Medeiros's (Medeiros, 2013) topological analysis of betweenness centrality and depth in the street networks of 164 cities in different parts of the world identified regional differences. Louf and Barthelemy (Louf and Barthelemy, 2014) searched for the 'fingerprints' of cities analysing the distribution of blocks extracted from street networks of 131 city centres.

In turn, our configurational approach focuses on buildings as the primary components shaping cities, and how they aggregate in combinations and complexes. By looking into frequencies of cellular arrangements representing buildings in selected cities, we wish to understand if and to what extent their configurations can be seen as particular cultural features, regardless of whether these features are intentionally embodied in urban space. For that, we shall explore Shannon's view of 'information' and 'entropy' to investigate whether spatial cultures entail 'distinctive ways of ordering space', as Hillier suggests.

Several works have explored information and entropy measures concerning urban systems, beginning with Wilson's (Wilson, 2011) pioneering study of utility-maximising systems in 1970. The entropy-maximising paradigm was used to derive model formulations for spatial interactions and urban distributions, microeconomic behaviour and input-output analysis (Batten, 1981). Batty developed studies on entropy in spatial aggregations and interaction since the early 1970s (Batty, 1972, 1974, 1976). More recently, Batty et al. (Batty et al., 2014) proposed a measure of complexity based on Shannon information able to grasp the complexity of cities as they vary in scale, size and spatial distribution of population. Entropy measures have also been applied to purely urban morphological problems, namely in street network analysis. Gudmundsson and Mohajeri (Mohajeri, 2013) developed a method based on Shannon's entropy to measure angular variation between streets, applied to 41 British cities. Boeing (Boeing, 2019) used Gudmundsson and Mohajeri's method to analyse 100 cities around the world focusing on street networks downloaded from Open Street Maps (OSM). These applications do not seek to uncover spatial information patterns, focusing instead on entropy as a measure of variation in street angles and lengths. More comprehensively, Haken and Portugali (Haken and Portugali, 2003, 2014) focused on how basic cellular arrangements and categorisations of building facades convey different amounts of information. In turn, our approach will explore Shannon entropy to measure levels of randomness and disorder in physical space, namely in cellular arrangements of built form.

Method

Our first procedure involves a reduction of urban form to two-dimensional arrangements based on building footprints. The Nolli map provides a spatial data-driven method to analyse and study the urban form and circulation networks that structure human activities and social relations (Boeing, 2019). Our second procedure looks into different cellular arrangements and attempts to characterise their configurations. We do so analysing the probability distribution of built form configurations, by estimating the Shannon entropy (Shannon, 1948) of Nolli maps of different cities of the world. Of course, this has to do with the level of randomness in the cellular arrangements of built form in cities. By analysing cellular arrangements, we capture the structures of urban blocks in relation to the open spaces of streets and public squares. We characterise the spatial information encoded in two-dimensional configurations of buildings measuring Shannon entropy, operationally estimated by looking at the sequence of bits 1 and 0 representing built form cells and open space cells.

The next step involves the preparation of our set of empirical cases and the conversion of city maps into Nolli maps. We selected cities for their importance in their region or country. The selection also had to take into account the availability of information on built form. Many cities, particularly in Latin America, Africa and Asia, have incomplete information regarding building footprints, i.e. their precise location, position and shape. For methodological reasons, we selected areas within these cities for the application of our measure (for details in this procedure, see link). Considering our database of 45 cities from North America, Europe, Asia, Oceania, Africa and South America, our goal is to develop a classification scheme based on the similarities and differences between the entropy levels of the sampled cities. The next step consists in performing a proximity network analysis based on the measured entropy values, to identify the presence of communities or clusters of cities sharing similar entropy levels. (For the estimation of the Shannon entropy of the considered 2D cellular arrangements and classification method, see link).

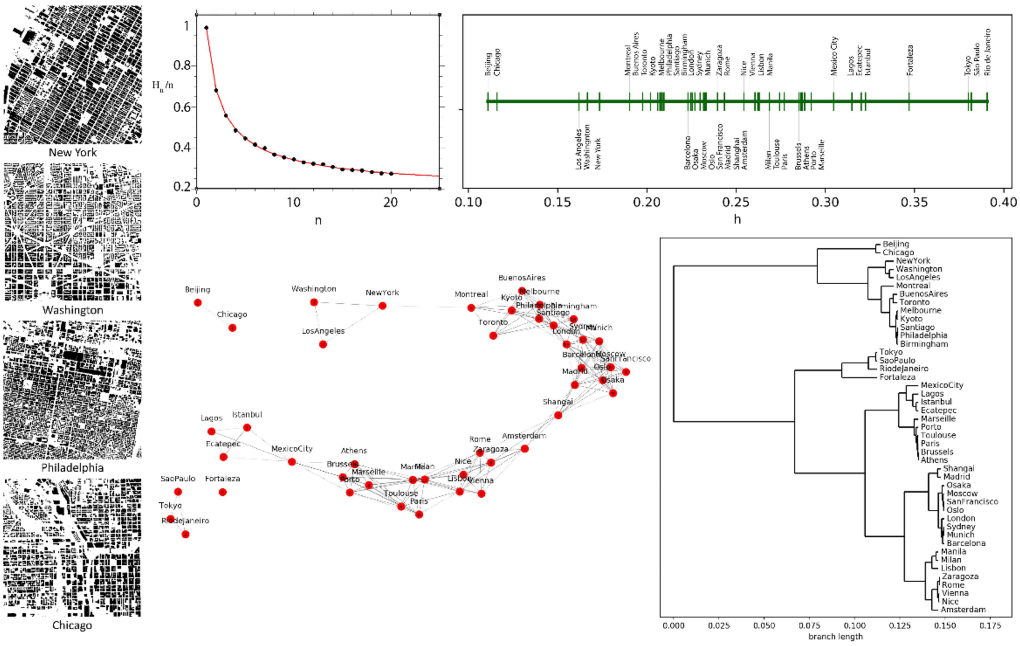

Figure 1. *op left: An example of the estimated values of Hn=n for the city of Los Angeles. The continuous line represents the best fitting of our data using the function of equation 3. All the analysed cities present a very similar behaviour. Top right: Estimated values of h for the 45 cities under analysis. Bottom: Proximity network and dendrogram of North American, European, Asian, Oceanian, African and South American cities under analysis.*

Results and Discussions

When we take the 45 cities into account, we notice three main branches in the hierarchical clusters (figure 1). A first cluster emerges with cities with the lowest levels of entropy in the sample lower entropy cases. It is further divided into three initial branches. Beijing (h =0.111) and Chicago (0.116) have the lowest levels of entropy and are in a branch of their own. Beijing is an exception in the Asian context, which generally has higher entropy values, from Shanghai (0.243) and Kyoto (0.206) to Tokyo (0.380). Beijing is probably the most strictly planned city in China. Planning was implemented rigorously along cardinal directions (East, West, South, North) following a tradition traced back to early Ming dynasty (1368-1644 AD), in turn, based on 'regulations of construction' from the Fifth century BC, as expressions of both regal power and social order (Wainwright, 2016). Buildings and urban blocks frequently display regular forms and aligned facades. In turn, Chicago epitomises the US tradition of planning cities based on orthogonal grids – and it does so with great regularity in urban blocks and building surfaces. Other branches bifurcate into a group with major American cities New York (0.174), Washington (0.167) and Los Angeles (0.162), and configurations with the lowest entropy levels from other world regions, like Kyoto, Melbourne and Birmingham, along with other US/Canadian cities Montreal (0.190), Toronto (0.202) and Philadelphia (0.208). Interestingly, Buenos Aires (0.198) and Santiago (0.209) cluster here, quite apart from other cities in Latin America, with high entropy levels. This somewhat surprising result runs counter the first aspect of the cultural hypothesis: the similarity in entropy levels for cities within the same culture or region. This might have to do with the evolution of these cities, founded in the Sixteenth century in a rigid orthogonal pattern, in comparison to others in Latin America.

The second cluster highlights the highest entropy group in the sample, comprised of Brazilian cities Rio de Janeiro and São Paulo, in Latin America (h = 0.391 and 0.382, respectively), followed closely by Tokyo (0.380) and another Brazilian city, Fortaleza (0.347). The third main cluster divides into communities from high to middle entropy. This cluster further bifurcates into a group with slightly lower entropy levels, Mexico City (0.303) and Ecatepec (0.320) in Mexico, Istanbul (0.322) in Turkey, and Lagos in Africa (0.315). Another bifurcating branch between the opposing clusters comprises Southern European cities Marseilles, Porto, Toulouse, Athens and Paris, along with Brussels. A final large branch of middle to lower entropy cities bifurcates into cities from diverse regions, like Manila (0.274) in the Philippines, Milan (0.277), Rome (0.260), Lisbon (0.268), Zaragoza (0.260) and Nice (0.262) in Southern Europe, and Amsterdam and Vienna in Northern Europe; and into more diverse groups with lower entropy cities, like Shanghai and Madrid, Moscow (0.231) and San Francisco (0.233), Sydney (0.224) and Munich, London (0.223) and Barcelona.

These distinct clusters show that we cannot associate specific levels of entropy exclusively with specific regions, a first possibility of verifying the cultural hypothesis. We have to ask ourselves what in distinct regions could have triggered similar entropy levels. The idea of a planned-unplanned dichotomy suggests that we should look into the actual evolution and planning conditions existing (or not) in these different cities, many of them having faced considerable growth in the twentieth century. We checked the existence of modern planning rules that act specifically upon built form, namely: (1) Land parcelling: how land divides into urban plots, and whether there are rules guiding the shape and regularity of plots. (2) The layout of urban blocks and streets: what are the rules for layouts – say, whether they impose orthogonal systems or 'planned picturesque' systems like intentionally curved and varied block shapes and street networks. (3) Regulations on building design and location: whether there are rules that specify the position of buildings in plots (e.g. frontal and lateral setbacks), and neighbouring buildings. We examined the legislation in cases in Turkey, Nigeria, China, Brazil, Mexico, United States, England and The Netherlands. We found something that goes counter the planned-unplanned account of ordered and disordered cities: cities which have top-down planning may also exhibit high built form entropy. They do have rules and government agencies that regulate building and urbanisation.

But how can high entropy in the built form be somehow influenced by top-down rules? We found that cities from different regions – namely, Brazil, Nigeria, Mexico and Turkey – may have certain aspects of planning in common, which allow great variation in built form to come into being. For instance, these cities share emphases on parcel-based, piecemeal developments. Simple local rules focused exclusively on individual buildings rather than coordinated construction among nearest neighbours lead to a high level of fragmentation in built form. Going a step further, whole areas in these cities are urbanised and built by people's own hands in informal settlements, hence apart from planning regulations. In short, parcel-based, piecemeal developments, patchworks of different blocks and street networks, and fragmented built form are key features of highly entropic urban landscapes.

Conclusions

In this paper, we developed an approach to spatial information based on Shannon entropy. The approach was designed to measure the entropy characterising levels of order and disorder in cellular configurations present in 45 cities around the world. We applied the method to investigate the hypothesis of 'spatial cultures' as ways of ordering urban form. Our analysis brings some findings. First, proximity networks and hierarchical clusters show similarities in cities from different regions (e.g. high entropy cities including São Paulo, Tokyo, Istanbul and Lagos), with close entropy values even if they have geometrically distinct arrangements. It suggests that the measure does not necessarily generate specific values as exclusive 'information signatures' for each region, a first possibility of verifying the cultural hypothesis.

Second, despite that fact, the measure seems to capture something of the 'planning culture' of these regions. We found higher frequencies of specific regular arrangements in cities with top-down planning coupled with a strong focus on rules for coordinated modular construction, each building adjusting and aligning to those around, taking into account systemic consequences of ensembles of built form. The high frequency of specific arrangements can also be found in cases of bottom-up processes of cellular aggregation potentially involving path dependence. Built form systems can lock into specific configurations, reproduced in traditional modes of building – patterns that can be eventually institutionalised into formal planning rules. It seems to be the case, especially in the passage from pre-modern to modern urbanisation of European cities. On the other hand, we found plenty of variation in cellular aggregations in urban cultures that allow the construction of buildings in uncoordinated actions between individual developers. This leads to less regularity and higher unpredictability in what surrounding built forms will be like as cities grow. Summing up, in both top-down and bottom-up form-making processes, local rules guiding how to position buildings seem to trigger bifurcated developments as the built form system evolves in size and complexity, leading either into greater consistency or into greater fragmentation. But that is not the whole story, of course. We may find many possibilities in between those archetypal paths, or combinations of them in different parts of cities, like patchworks, or intermingled in layers of ordered and disordered aggregations. Think of the iconic case of Manhattan, based on the regularity of a gridiron street layout, and planning rules that made room for enormous variation in built form.

Third, although regions do not necessarily have exclusive values of built form entropy, individual regions do seem to converge around specific values. Our results show certain consistencies, grouping cities from the same region (e.g. Brazilian cities, American cities). To use Hillier's words (Hillier, 1989), this echoes the idea that societies create their own spatial cultures – their distinctive ways of ordering space and shaping cities. Such finding needs to be further examined through a larger sample of cities and comparisons with other approaches, along the lines we explored above. Of course, deep historical conditions and local contingencies are likely at play, and must be carefully taken into account.

Finally, differences between results obtained from street network-based measures and our measure of entropy shed light on the potential dissociation between the morphology of streets and the morphology of built form systems in every city. The endless combinatorial possibilities of configurations of buildings, missing from street network approaches, add complexity to urban phenomena and suggest the need for a renewed interest in built form systems.

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