Classifying urban form at a national scale
The case of Great Britain

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ABSTRACT: There is a pressing need to monitor urban form and function in ways that can feed into better planning and management of cities. Both academic and policymaking communities have identified the need for more spatially and temporally detailed, consistent, and scalable evidence on the nature and evolution of urban form. Despite impressive progress, the literature can achieve only two of those characteristics simultaneously. Detailed and consistent studies do not scale well because they tend to rely on small-scale, ad-hoc datasets that offer limited coverage. Until recently, consistent and scalable research has only been possible by using simplified measures that inevitably miss much of the nuance and richness behind the concept of urban form. This paper outlines the notion of "spatial signatures", a characterisation of space based on form and function, and will specifically focus on its form component. Whilst spatial signature sits between the purely morphological and purely functional description of the built environment, its form-based component reflects the morphometric definition of urban tissue, the distinct structurally homogenous area of a settlement. The proposed method employs concepts of "enclosures" and "enclosed tessellation" to derive indivisible hierarchical geographies based on physical boundaries (streets, railway, rivers, coastline) and building footprints to delineate such tissues in the built fabric. Each unit is then characterised by a comprehensive set of data-driven morphometric characters feeding into an explicitly spatial contextual layer, which is used as an input of cluster analysis. The classification based on spatial signatures is applied to the entirety of Great Britain on a fine grain scale of individual tessellation cells and released as a fully reproducible open data product. The results provide a unique input for local authorities to drive planning and decision-making and for the wider research community as data input.

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1. Introduction

Identification of recurring patterns in the built environment is deeply embedded within all schools of urban morphology. We can discuss Conzen's Plan Unit (Conzen, 1960), which evolved into Whitehand's morphological region within the British historical-geographical tradition, aiming to capture internally homogenous areas of a shared origin and spatial character (Oliveira and Yaygin, 2020). At the same time, we may talk about *tessuta urbana* or *urban tissue*, stemming from the Italian school of typo-morphology (Caniggia and Maffei, 2001), and sharing the notion of internal homogeneity, just detected by different methods reflecting the architectural perception of space more than geographic. However, it is a complicated pursuit to scale up morphological studies of these kinds without losing too much information. Traditional schools (both historical-geographical and typo-morphological) are generally not able to scale their methods to larger areas while keeping the detail. Another well-established school of urban morphology - Space Syntax, based on the work of Hillier and Hanson (Hillier, 1996), is different and can be considered scalable to metropolitan or even national extents (Space Syntax Limited, 2018). However, Space Syntax at these scales is limited to an analysis of street networks and their configuration, completely omitting patterns formed by plots, buildings, and open spaces. The same can be said about a broader range of network-based methods like Multiple Centrality Assessment (Porta et al., 2010) - while they can be scaled, their insight is inherently limited by the limited data input.

The recent growth of purely quantitative methods of urban form analysis, often nicknamed *urban morphometrics*, and their ability to scale without losing too much detail is opening a range of opportunities to give urban morphology a toolkit to analyse recurring patterns at metropolitan and national extents. After the first explorations in the works of Gil et al. (2012) or Hamaina et al. (2012), the methods are starting to mature as illustrated by recent publications of Multiple Fabric Assessment by Araldi and Fusco (2019), a series of element-based typologies by Berghauser Pont et al. (2019), gridded classification by Jochem et al. (2020) or hierarchical model following the biological methods of taxonomy creation by Fleischmann (2021). All share a similar approach, based on the an initial set of measured characters capturing the individual aspects of form-based patterns and subsequent unsupervised classification. As all methodological steps can be expressed as computer algorithms, they can potentially scale to nation-wide analyses, as already shown by Jochem et al. in the case of Great Britain (Jochem and Tatem, 2021). Is it to be noted that each of the existing methods has its limitations, often linked either to the a spatial unit that does not ensure internally homogenous urban patterns (Jochem er al., Araldi and Fusco), dependency on rarely available data (Berghauser Pont et al.) or a limited number of measured characters, which may omit some aspects of patterns and introduce selection bias in the method (Berghauser Pont et al.).

This paper presents *spatial signatures*, a method of characterisation of space based on its form and function, and focus specifically on its form component, able to delineate internally homogenous areas of urban form based on an extensive set of morphometric characters. The method is applied in the case of Great Britain, deriving an exhaustive classification of both built and non-built environment. The remainder of the paper outlines the method (Section 2), including the introduction of the Enclosed tessellation as the spatial unit, presents resulting classification (Section 3), and discussed its implications on the analysis of urban form (Section 4).

2. Method

Urban morphology tends to consider form only when trying to understand urban environment, leaving aside its functional aspects from population and amenities to green and blue spaces. However, one can argue that only combination of form and function can provide deeper insights into the complexity of cities. The notion of *spatial signatures* combines both aspects into a single model, defined as:

A characterisation of space based on form and function designed to understand urban environments

Spatial signatures then provide a typology of space defined by both form and function together, encoding the interplay between the two. On the other hand, not all questions can be answered using both components at the same time. Each of them, form as well as function, can be studied independently when needed. This paper explores form component of spatial signatures characterisation and derives form-based signatures as a single-aspect classification of space.

Spatial signatures are conceptually defined as an aggregation of granular elements into contiguous areas based on the homogeneity of their characterisation. That poses a first methodological question - which spatial unit should be used for capturing of such characterisation? The optimal unit should be *indivisible* - when split into smaller components, none of them would be enough to encode character of a signature; *internally consistent* - each observation should reflect single signature type; and geographically *exhaustive* - every location in the area of interest, both built-up and un-built, should be covered.

Literature tends to be split into three groups when it comes to unit of analysis. One uses predefined administrative boundaries (REF) but that can be seen as a suboptimal solution as their definition follows different goals and some even argue that "administrative units obscure morphologic reality" (Taubenböck et al., 2019). The other employs uniform grids, in some cases linked to a spatial index (like hexagonal H3 grid (Brodsky, 2018)) or to other types of data commonly distributed on grids (e.g. Jochem et al. (2020)). However, grids cells are rarely indivisible and often internally inconsistent as their definition does not reflect the spatial configuration on the ground. The most common approach in urban morphology is to use structural elements as buildings (Hamaina et al., 2012), street segments (Araldi and Fusco, 2019) or plots (Berghauser Pont et al., 2019) as a unit. However, these are not exhaustive as they are not present in un-built areas. Plots would theoretically provide geographical exhaustiveness but since their conceptual definition is not stable and geometric representation varies (Kropf, 2018), they are unfit for a large scale analysis.

We propose to use an alternative spatial unit named *enclosed tessellation cell* (EC), defined as:

The portion of space that results from growing a morphological tesselation within an enclosure delineated by a series of natural or built barriers identified from the literature on urban form, function and perception.

Martin: [We should somehow cite the conceputal paper when we talk about signatures and EC]

The ECs are generated in three steps. First, a defined set of spatial features, that divide space into smaller parts, is integrated into a single set of boundaries. Such boundaries are usually formed by linear features as street network, railway or rivers. Second, these boundaries are used to subdivide space into *enclosures*, a smaller areas delimited from all sides by at least one boundary feature. Third, enclosures are combined with building footprints taking the role of anchors in space and subdivided into ECs based on proximity to each building, using a morphological tesselation algorithm (Fleischmann et al., 2020).

Martin: [Figure?]

Resulting ECs are indivisible and internally consistent, as they are very granular and linked at maximum to a single building, and exhaustive as they cover entirety of space thanks to contiguous geometry of enclosures. Their structure and scale adapts to the environment and can take a form of a small-scale granular mesh in city centres of historical origin as well as large-scale polygons encoding the vast natural open spaces.

3. Results

4. Discussion

5. Conclusions

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