

# **Spatial Signatures**

## ***Dynamically building the built environment***

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ABSTRACT: Blah blah blah

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## 1. Introduction

Fleischmann et al. (2020a) is king.

## 2. (Urban) form and function

Research studying urban form has a long tradition (Geddes, 1915, Trewartha, 1934), whilst urban morphology as an independent area of research has established in the 1960s. It originated independently in geography (Conzen, 1960) and architecture (Muratori, 1959), reflecting its inherently multi-disciplinary nature, which was later reinforced by the inclusion of socio-economic component in works of Panerai et al. (1997). The original methods are predominantly qualitative, and this tendency persists (Dibble, 2016). First notable quantitative approaches date to the late 1980s and 1990s, reflecting advancements in computer science and newly available data capturing built environment. Two strains of research have emerged, one based on cartographic (vector) representation of the urban environment, assessing its boundaries (Batty and Longley, 1987), street networks (Hillier, 1996, Porta et al., 2006) and other elements (Pivo, 1993). The other one based on earth observation exploiting remotely sensed data to capture the change of footprints of urban areas (Howarth and Boasson, 1983) or classification of land cover (European Environment Agency, 1990).

The distinction between two approaches based on their primary source of data can also be applied to the recent literature reflecting the state of the art of characterization of urban form. A quantitative branch of urban morphology, or urban morphometrics, working predominantly with vector representation of elements of urban form has rapidly grown and offers an abundant selection of measurable characters describing different aspects of form (Fleischmann et al., 2020b). Methods focusing on a single aspect (Porta et al., 2006) were replaced by others aiming to better reflect the complexity of urban form by combining multiple morphometric characters into a single model, often leading to a classification of some sort (Song and Knaap, 2007). The focus on classification is becoming more present in recent years, starting from small-scale studies classifying blocks and streets (Gil et al., 2012) to larger areas and higher granularity (Schirmer and Axhausen, 2015, Araldi and Fusco, 2019, Bobkova et al., 2019, Dibble et al., 2019, Jochem et al., 2020).

In parallel, advancements in remote sensing led to a range of classification frameworks based on various conceptualizations of the urban fabric. However, there is one significant difference between classification derived via morphometric characterization and the one of remote sensing origin. Where the former is mostly unsupervised (Araldi and Fusco, 2019, Schirmer and Axhausen, 2015), the latter tends towards supervised techniques, capturing classes defined prior to the analysis (Pauleit and Duhme, 2000). Two most prominent classification models used as an input (i.e. training set) are Local Climate Zones (Stewart and Oke, 2012) defining ten built-form types and seven land cover types, used by Koc et al. (2017) or Taubenböck et al. (2020), and Urban Structural Type, a generic typology based on the notion of internal homogeneity of types (Lehner and Blaschke, 2019).

However, all the methods above have certain limits, mostly related to detail, comprehensiveness and scalability, lacking at least on them. Detail reflects spatial granularity of resulting classification, where more granular, i.e. more detailed, unit has the ability to capture smaller nuances of the urban environment and better reflect local characters or a place. Methods based on a unit which can be further subdivided (Dibble et al., 2019, Jochem et al., 2020, Araldi and Fusco, 2019, Gil et al., 2012), therefore does not ensure internal homogeneity, can result in classes driven by the heterogeneity instead of the unit instead of the actual pattern of urban form. Comprehensiveness refers to the number of characters (variables) used in the classification procedure. Small sets of characters as in Bobkova et al. (2019) or Serra et al. (2018) are prone to a selection bias and will less likely reflect the complexity of the urban environment. Finally, scalability reflects the ability of the proposed method to scale up to large extents of metropolitan areas or national-level studies. While some works illustrate such a potential (Jochem et al., 2020, Schirmer and Axhausen, 2015, Bobkova et al., 2019, Araldi and Fusco, 2019), others which may overcome other issues are less likely to scale from their original limits (Dibble et al., 2019). Furthermore, computational scalability can be limited by data availability. Methods dependent on a high amount of detailed vector data (Bobkova et al., 2019) can be hardly applied in other contexts where such input is not available.

### 3. Spatial Signatures

#### 3.1 Definition

#### 3.2 Building blocks: the Enclosed Tessellation

This section proposes a novel and theoretically-informed delineation of space to support the development of spatial signatures. Since spatial signatures are conceptualised as highly granular in space, considering the ideal unit of analysis at which to measure them is of utmost importance. This process involves identifying the fundamental building block that partitions space in a way that may later be meaningfully aggregated into organic delineations of spatial signatures. This step is worth spending energy and effort for two main reasons. First, if ignored, there is an important risk of incurring the modifiable areal unit problem (MAUP, Openshaw, 1981). The urban fabric is not a spatially smooth phenomenon; rather, it is lumpy, irregular and operates at very small scales. Choosing a spatial unit that does not closely match its distribution will subsume interesting variation and will hide features that are at the very heart of what we are trying to capture with spatial signatures. Second, and conversely, we see adopting a meaningful unit a step of analysis itself. Rather than selecting an imperfect but existing unit to try to measure and characterise spatial signatures, delineating our own is an opportunity in itself to learn about the nature of urban tissue and better understand issues about distribution and composition within urban areas.

Let us first focus on what is required from an ideal unit of analysis for spatial signatures. We need a partition of space into sections of built *and* lived environment that can later be pieced together based on their characteristics. The result will feed into an organic delineation that

captures variation in the appearance and character of urban fabric as it unfolds over space. To be more specific, a successful candidate for this task will need to fulfill at least three features: indivisibility, internal consistency, and exhaustivity. An ideal unit will need to be *indivisible* in the sense that if it were to be broken into smaller components, none of them would be enough to capture the notion of spatial signature. Similarly, every unit needs to be *internally consistent*: one and only one type of signature should be represented in each observation. Finally, the resulting delineation needs to be geographically *exhaustive*. In other words, it should assign every location within the area of interest (e.g. a region or a country) to one and only one class. A unit that is indivisible, consistent, and exhaustive can thus form the basis of meaningful aggregation of space into spatial signatures.

The existing literature does not appear to have a satisfying candidate to act as the building block of spatial signatures. Without pretending to be exhaustive in the review, the vast majority of existing approaches to delineate meaningful units of urban form and function fall within one of the following three categories. The first group relies on administrative units such as postcodes, census geographies or municipal boundaries (e.g. XXXrefsXXX). These are practical as they usually are exhaustive of the geography and readily available. However, their partition of space is usually driven by different needs that rarely align with the measurement of spatial signatures, or indeed those of any morphological or functional urban process. For example, Puente-Ajovín et al. (2020) compare the size distribution of urban areas in Spain across several definitions and conclude they are fundamentally different; similarly, Taubenböck et al. (2019) rank world's largest cities based on their administrative size and on an alternative methods they proposed following built-up area, reaching similar conclusions and even going on to argue that “*administrative units obscure morphologic reality*”.

### 3.3 *Embedding form and function into Spatial Signatures*

## 4. Illustration

## 5. Conclusions

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