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# Morphological Regionalisation of French Cities – A methodology for street-based analysis of urban form

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Cities are the overlay of morpho-functional patterns evolving in time and space. When exploring urban space, city users are exposed to a diversity of cityscapes alternating vernacular centres, modernist developments, sprawling suburbia and very specific exurbs. The diverse forms of the urban fabric influence the functioning of cities, human perception, practices and uses, and pose different challenges for the urban technological and environmental transitions. This diversity must be recognized and accounted for to understand the city and to conceive place-specific interventions on it. A challenge for urban geographers is thus to identify the contemporary morphotypes, i.e. specific patterns of the urban fabric, organising buildings, streets, plots and site features, that are recurrent within today's cities, and to regionalize vast metropolitan areas on the basis of these morphotypes.

Since the second after-war, urban morphology and its different schools, has produced considerable knowledge of traditional morphotypes and their constitutive elements. The Italian school (Caniggia and Maffei 1979) highlighted the contribution of building types and their historical evolution to the formation of the urban fabric. The French school (Castex et al. 1980), studied the role of plot patterns. The British school (Conzen 1960) set out the most ambitious goal of regionalising urban space in terms of observable forms of the urban fabric (Larkham and Morton 2011). However, the identification and characterization of the urban fabric, as well as the regionalization of cities, remained challenging tasks. They relied on expert-driven and labour-intensive qualitative and manual measurements, which had limitations in terms of reproducibility and scalability.

Consequently, comparative studies across different urban regions were hindered. Additionally, morphological research primarily concentrated on historical central areas, overlooking the forms of peripheral and suburban growth prevalent in contemporary urbanization.

Lately, increasing availability of geospatial fine-grained data, greater computational power, and developments in spatial analysis, paved the way to a data-driven stream of urban morphology, referred to as urban morphometrics (Araldi and Fusco 2019; Bobkova et al., 2019; Dibble et al., 2019; Fleishmann et al. 2022; Gil et al., 2012; Oliveira and Medeiros 2016). Urban morphometrics, stimulated by the dialogue with traditional urban morphology, proposes innovative data-driven computer-aided protocols for the spatial analysis of urban form in general, and the urban fabric in particular, producing new insight on the internal morphological structure of cities. This presentation will focus on Multiple Fabric Assessment (MFA, Araldi and Fusco 2019). MFA is a computer-aided

urban morphometric protocol for morphological regionalization: it mainly differs from other protocols by using a street-based perspective, thus allowing a multiscale description of the built environment as observed from the public space of the street. The perceptive-based framework underlying MFA allows for the convergence of urban typo-morphology with streetscape analysis (Harvey et Aultman-Hall 2015) within a coherent analysis protocol. The pedestrian-based modelling approach proves essential in light of the renewed interest in the issues of perception, use, and design of public spaces. What is most specific to MFA and of particular interest to theoretical and quantitative geographers is its integration of geostatistically significant spatial patterns, along with machine learning methodologies, for the identification and characterization of morphotypes.

MFA has been applied to various urban areas in different sociocultural contexts and geographical scales (Fusco and Araldi 2017, Perez et al. 2019, Guyot et al. 2020, Fusco et al. 2021). Based on these experiences, MFA has undergone further development and upscaling to analyse and compare larger study areas. The presentation focuses on recent methodological advancements in MFA, which were needed to implement it on the largest French metropolitan areas. Advancements include: improved streetscape morphometrics; development of a building typology for the entire country prior to morphotype detection through MFA (Araldi et al. 2023); use of Gaussian mixture models to identify different values for each morphometric feature; creation of a new Bayesian clustering algorithm called INBIAC (Iterative Naive Bayesian Inference Agglomerative Clustering) to generate numerous clustering models; selection of the best clustering models based on log-likelihood; use of a hierarchical clustering algorithm to combine the best models and create a nested taxonomy of morphotypes for each study area; final hierarchical clustering of place-specific morphotypes using the original streetscape morphometrics to obtain a general nested taxonomy of morphotypes across all study areas.

The improved protocol opens the way to a multiscale comparative analysis of contemporary urban forms in France. It has been implemented over the eight largest metropolitan areas of France (Paris, Lyon, Marseille-Aix-en-Provence, Lille-Roubaix-Tourcoing, the French Riviera, Bordeaux, Toulouse, and Nantes) obtaining both place-specific morphotypes and a general taxonomy of the urban fabric in French metropolitan areas. The eight study areas could thus be regionalised using both their specific morphotypes and knowledge of their position within a common taxonomy. Common spatial structures emerge from regionalisation, as well as a few specificities linked both to site constraints and to the different spatial extent of morphotypes. These results are a first contribution to a national atlas of morphologically regionalized metropolitan areas.

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