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Urban morphology meets geo-knowledge graph

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Abstract:

Urban form plays an important role on the cities' capability of sustainable development. Urban form, also called urban morphology, refers to the spatial form of a city shaped by its natural, history, political, economic, social, technological and cultural factors, revealing the essential structure of the city. With global urbanisation, urban space of mega-cities is becoming more and more crowded, leading to an increasing scarcity of urban land. Furthermore, the United Nation Development Summit sets out the Sustainable Development Goal (SDG) 11 which calls for safe, resilient and sustainable cities (UN 2019). In addition, urban form of the cities is closely related to the cities' resilience (Marcus and Colding 2014), the capability to deal with adverse events, e.g., urban slums, climate change, traffic congestion and other issues. Designing a good urban form is an important issue in urban planning. Because it can ensure the rationalisation of urban space, the smooth functioning and the resilient structure of complex urban systems. Hence, the study of urban form helps scholars to understand the pattern of urban growth and explore the direction for urban sustainable development.

Previous studies in urban morphology have focused only on the geometric information of urban form, often neglecting the semantic information behind it. The earliest studies of urban morphology were qualitative. For example, the traditional conceptual modelling in urban forms includes three types i.e., medieval cities with concentric pattern, industrial cities with mechanical grids and ecological cities with polycentric pattern (Barth 2005). Subsequently, quantitative analysis has become increasingly important in academic research, and the study has taken two directions. (1) Indicator-based approaches that typically calculate geometric features of urban elements with numerical indicators describing density, scale, fractality, etc. (Boeing 2017; Chen *et al.* 2020; Li *et al.* 2021). (2) Image-based approaches that usually convert urban elements to binary images to characterise morphological features from a human visual and intuitive perspective (Huang and Wang 2019; Chen *et al.* 2021; Moosavi 2022). However, both approaches apply only the geometric information and ignore the semantic information about the city elements' attribute and linkage, such as land use, urban function, traffic flow, topological relationships. Two examples are demonstrated in Figure 1. In Figure 1 (a)(b), the two cities have identical spatial pattern but different morphological structures of urban functions. The left one is the concentric pattern and the right one is the sector pattern. And in Figure 1 (c)(d), the two cities also share the same spatial pattern of buildings. However, in contrast to the city on the left, the city on the right has an obstacle in the middle, such as a mountain, that breaks much of the connection between the south and north sides of the city. It also leads to a different urban cognition. In summary, the different semantic information can make a huge difference in urban morphology. Thus, the techniques for characterising urban form need to be further improved.

Geographical knowledge graph (Geo-KG) has a great potential to provide a new type of representation for the urban morphology research. Knowledge graph is an important tool for data science, designed to equip computers with the ability to organise, process and reason about knowledge. Geo-KG is a cross-disciplinary domain between computer science and geographic information science, aiming to improve the retrieval, representation, and information enrichment capabilities of geographic information systems using techniques related to knowledge graph. The Geo-KG has two potential advantages over previous quantitative methods of urban form analysis. First, Geo-KG can integrate multi-modal data including geo-spatial data, text information, relations, even images and represent them as a knowledge graph. It indicates that Geo-KG promises to essentially combine both the geometric and semantic information to represent a richer content of the urban form. Through encoding and decoding, universal patterns of urban forms from a more diverse information perspective can be uncovered, which is likely to be of interest to urban planners and designers. Second, Geo-KG is based on the graph data structure. In contrast to the image-based approach, the graph-based approach is not affected by anisotropy. Because the graph data structure is only concerned with nodes and relations and can be arbitrarily rotated and transformed. Thus, the graph-based morphological characteristics of the city are not biased by anisotropy and allow for a more comprehensive characterisation of the city as a whole. Therefore, the Geo-KG based method holds great value in quantitatively measuring general and comprehensive urban form.

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This work tries to explore urban morphology from a new perspective using geographic knowledge graph. It aims to enrich the traditional urban morphology with semantic information. The expected outcome is a technical framework for data, information and knowledge, and new findings on the patterns of urban forms.

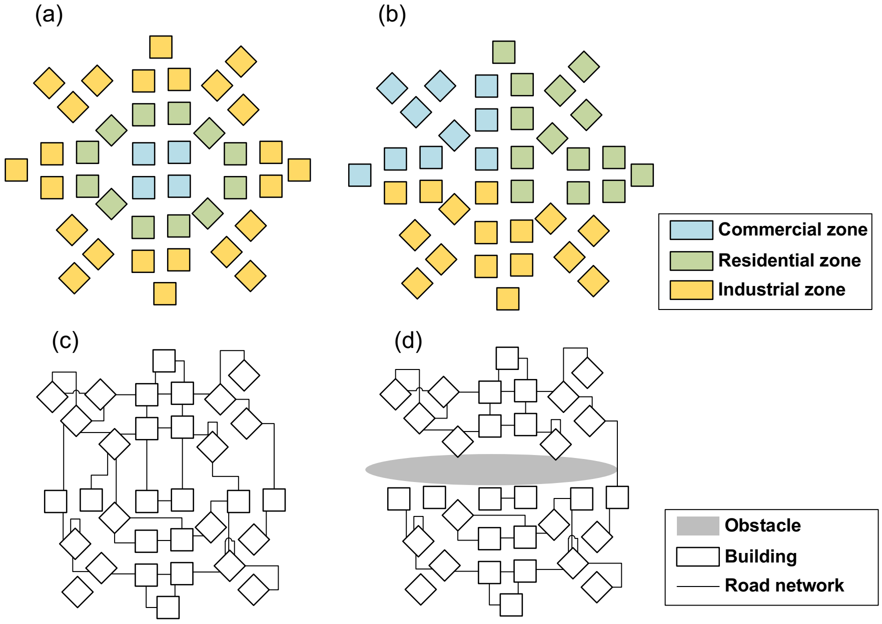

Figure 1. Differences in attributes and linkage make a decisive difference

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