A symbolic articulation of morphological structure

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Urban morphology faces challenges of how to articulate the structure of the urban fabric on at least two fronts. First, there are discontinuities between different morphological traditions (e.g. different schools, languages or locations of application) (Whitehand, 2012). Secondly, there is the apparent discontinuity between traditional qualitative methods (e.g. historico-geographical or typo-morphological) and more recent quantitative methods (e.g. computer modelling) (Stanilov, 2010). Resolving these challenges could be assisted by an explicitly symbolic or mathematical articulation of morphological phenomena.

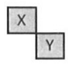
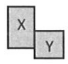
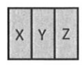
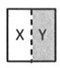
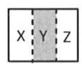
Just as the book of nature is 'written in the language of mathematics', so too can the built environment be expressed in mathematical form. Most essentially, a town plan is a work of geometric abstraction; to this we may add mathematical treatments as diverse as topological or graph-theoretical approaches (e.g. Krüger, 1979), the binary coding of 'morphospace' (Steadman and Mitchell, 2010), and formal ontological articulation of urban elements such as boundaries (e.g. Bittner, 2001). The 'mathematization' of morphology could in principle help overcome language barriers between different traditions, and its abstraction should allow application in any urban context. Mathematical precision could also help to clarify concepts, and avoid getting lost in a fog of morphological terminology. And a more explicitly mathematical approach could help, as in other fields, to make research more systematic and scientific.

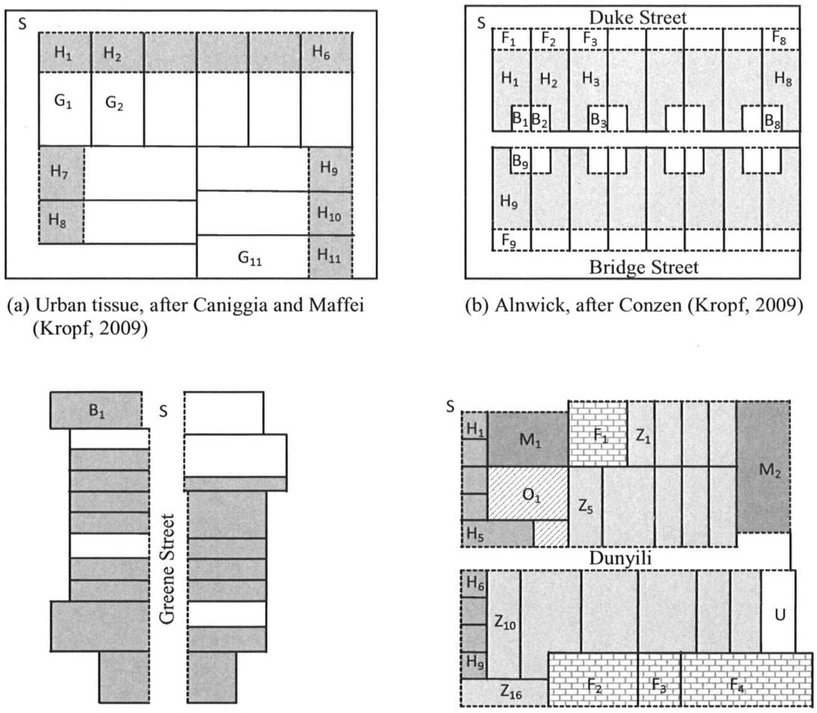
However, the more formally mathematical treatments may seem overly abstract and perhaps inaccessible to 'regular' morphologists. Moreover, computerized approaches often lack transparency: these are often perceived as 'black boxes', with their ontologies buried within software, inaccessible to the kind of scrutiny and independence of interpretation that should be a strength of a scientific approach.

Nevertheless, it is possible that a symbolic approach could help bridge between traditional and more consciously mathematical approaches to morphology. Alfred North Whitehead (1911, p. 60) classically asserted the importance of symbols to science, including their ability to be concise, precise and intuitive in their 'almost pictorial representation' of their subject. Some previous symbolic manipulations of urban morphology have been observed, in the work of Augusto Cavallari-Murat (*Forma urbana e architettura nella Torino Barocca*; noted by Bazzanella *et al.*, 2012) or the 'design operations' of Taeke de Jong (2012, p. 274), but these treatments have yet to be fully realized or integrated with mainstream urban morphology.

Presented here is an initial suggestion for a symbolic articulation of the urban fabric, based on 'area structures'. This could provide a common 'morphic language' that is simple enough for any morphologist to use but which could form part of a more systematic mathematical approach to urban morphology.

Table 1. Area structure relations

Relation	Description	Example
X·Y	'X touches Y at a point'	
X|Y	'X abuts Y'	
X□Z	'X is contiguous with Z'	
X||Z	'X indirectly abuts Z'	
X¦Y	'X abuts and accesses Y'	
X–Z	'X accesses Z' (directly or indirectly)	
X--Z	'X accesses but does not directly abut Z'	



(a) Urban tissue, after Caniggia and Maffei (Kropf, 2009)

(b) Alnwick, after Conzen (Kropf, 2009)

(c) New York (after Oliveira, 2013)

(d) Guangzhou (after Gu *et al.*, 2008)

Figure 1. Excerpts of urban fabric, interpreted as area structures. Dotted lines indicate boundaries with inferred access.

The system presented here is based simply on the town plan or urban morphological map interpreted as an 'area structure' – that is, a set of areas (polygons) and their relationships. In an area structure, each area is given a label, e.g. A, B, C. Each area represents a standard cartographical or morphological element, such as a building footprint, plot area or area of street space. A contiguous set of areas can be placed in square brackets, hence a plot series comprising plots P_1, P_2, … P_n can be denoted $[P_1, P_2, \dots P_n]$. Here, we use some existing mathematical conventions: 'Σ' for summation; '⇒' for 'implies' and '¬' for 'not'.

Table 1 shows a suggested set of basic relations of adjacency and access, their common language meanings, and graphic examples. All these relations are transitive, e.g. $X|Y \Rightarrow Y|X$. Some relations imply others: e.g. $X{\cdot}Y \Rightarrow X\square Y$.

These conventions can now be applied to specifically urban morphological structures. Figure 1 shows some examples of area structures interpreted from the urban morphological literature. Here, adjacency relations are directly taken from the originals, but access relations have been inferred.

In Figure 1(a), there are three contiguous terraces of houses: $[H_1, \dots H_6]$, $[H_7, H_8]$ and $[H_9, H_{10}, H_{11}]$. Within each terrace, $H_i|H_{i+1}$ (for i=1 to n–1, where n is number of houses in each terrace). Here, as it happens, all garden areas are contiguous with each other, $G_i\square G_j$, for any i, j. We may infer that all houses access the street, i.e. $\Sigma h_i ¦ S$. Houses are only indirectly accessible to each other: H_i--H_j (for any i, j). Ultimately H_i–H_j (for any i, j) but only via S. For each plot i we may infer $S ¦ H_i ¦ G_i$. We may also infer $G \neg ¦ S$; but G_i--S (via H_i). For each terrace, gardens abut consecutively but are not directly accessible to each other: $[G_i|G_{i+1}]$ but $G_i \neg ¦ G_{i+1}$.

In Figure 1(b), the structure is a little more complex by featuring both front (F) and back (B) yards. In this excerpt, $[H_i|H_{i+1}]$ (for $1 \le i \le 7$ and $9 \le i \le 15$); $H_i\square Hj$ for any $0 \le i \le 8$, $0 \le j \le 8$; or for any $9 \le i \le 16$, $9 \le j \le 16$. Here, $\Sigma H|S$ at the rear. If we infer rear access to the back yard (i.e. $S ¦ B$) then for each plot i, the access relation is $S ¦ F_i ¦ H_i ¦ B_i ¦ S$. As before H_i–H_j (via S) for any i, j. For any plot i, $F_i || B_i$. We infer no direct access between adjacent front or back yards, $F_i \neg ¦ F_{i\pm1}$, $B_i \neg ¦ B_{i\pm1}$. Each back yard is accessible only indirectly to the front yard:

B_i--F_i (either via H_i or S).

In Figure 1(c), a simple differentiation of landuse suggests no particular pattern of relations between the (lighter) residential and (darker) non-residential land uses; but the relations between buildings (B) and the street (S) are the same as in the earlier cases, i.e. on each side of the street, $B_i|B_{i+1}$ and B_i¬¦B_{i+1} (for i=1 to n–1); S¦ΣB; hence B_i–B_j (for all i, j) via S.

Finally, in Figure 1(d), we see some small sections of regularity within a wider pattern of irregularity. Here, in general, S¦X_i and X_i¬¦$X_{i\pm1}$ are inferred (where X_i is any area of any type), except in one case where a plot (O_1) appears to be 'boxed in' (i.e. S¬¦O_1). There are some consecutive series of buildings of the same type, namely a series of multi-storey flats [F_2, F_3, F_4]; two series of shophouses [H_1, H_2, …, H_5] and [H_6, …, H_9]; and three series of *zhutongwu* [Z_1, …, Z_4], [Z_5, …. Z_9] and [Z_{10}, …, Z_{15}].

Hence this kind of area structure analysis can be used to highlight regularities of structure, to compare structures, and deduce any common 'urban syntax' between cases (Marshall, 2009, p. 68). The symbolic treatment allows systematic articulation of structure in a way that is simple and intuitive – though abstract, it can be transparently related to the mapped morphology. It can transcend differences in language and nomenclature between different morphological traditions, and may also (like computer pseudocode) serve as a stepping stone between human-oriented expression and a more formal mathematical treatment amenable to computation.

The approach invites fuller formal definitions, further formal development (e.g. axioms of area structure) and applications to other contexts, whether building floor plans or any other morphologies expressed as area structures.

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The metropolitan skyline: researching the vertical dimension in urban morphology

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In response to the debate in this journal on the definition of urban morphology (Conzen, 2013) and the importance of strengthening the interconnection of research and practice (Whitehand, 2013), we wish to outline the case for research on the metropolitan skyline. In particular, we summarize a major new project on this topic.

The urban skyline may be broadly defined as the