Hypergraph formalism for urban form specification

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Abstract. This paper proposes a visual formalism, based on hypergraphs, devoted to existing urban forms analysis as well as morphological regulation design. By contrast with present illustrative techniques, morphological hypergraphs are considered as a usefull support for deduction and inference. It makes them best suited to argumentative practices.

1. Introduction

One basic characteristic of present information society is its increasing use of visual artifacts as a communication support tool. Nevertheless, the logical and exploratory functions of diagrams (interpretation, analysis and exposition) are more than often disregarded, especially since the growth of linguistically based reasoning. Urban regulation surely comply with this general statement. In continental Europe, a major shift from intention schemes to explicit rules, phrased in a prescriptive way, occurred during this century. In UK and US, when design control/review procedures still make an intensive use of visual artifacts, these instruments are mostly "illustrative". They offer few if any ground for rational argumentation. So the risk of discretionary abuse and lack of predictability often acknowledged by design review advocators [SHEE-94, PUNT-97].

Yet, if valid "deductive inference" consists in *making explicit an information that is only implicit in the information already obtained*, graphics and visual instruments would be a support of inference and argumentation as valid as other linguistic models of reasoning [BARW-96].

Diagrams are proposed here as an instrument that may fruitfully complement linguistical regulations. Hence diagrams force us to focus on the essential relations. Given their acknowledged information loss, they appear as a very efficient carrier of abstraction [GROS-88]. Furthermore, diagrams, as all generalisation mechanisms, can leave a controllable room for uncertainty in their interpretation/specialisation, which is compliant with morphological regulation idea to promote equivalence rather than identity. Finally a diagram visual content is maximal since each of its elements must be associated to some explicit semantic.

2. Morphological hypergraphs

Hypergraphs [HARE-88, BERG-70] basically represent sets of elements, figured by closed borders called "blobs". All blobs must be labelled through a specific identifier enclosed in its border. By contrast with other diagrammatic techniques, hypergraphs don't support implicit entities. Blobs intersection, for instance, will be considered as empty if they're not explicitly described through a specific blob.

By definition, blob inclusions represent set inclusions (instead of set membership as often assumed by other diagrammatic techniques). In addition to inclusion relations, hypergraphs supports hyperlinks which represent any kind of direct relation in between any pair of blobs.

Finally, cartesian products are represented by an hypergraph partition through a dashed line. Cartesian blobs labels are attached at the top of the figure. Labels located in each part of the blob represent the cartesian product components.

Let's illustrate these features by applying this technique to traditional urban environments (fu.c) descriptions. Such patterns can easily be characterised by a cartesian product between empty shapes and filled volumes (figure 1). This relation is written :

$$fu.c = (open\ spaces)\ ¥\ (built\ volumes)$$

which gives, at the second level of inclusion :

$$fu.c = (pl\ »\ ru)\ ¥\ (il\ »\ mt)$$

It means that any modification applied to one of the cartersian products member (cluster or any of its included bobs for instance) is directly affecting the other one (ru and pl in this case). This behaviour is compliant with the idea of a strict interdependency of urban open spaces and built elements in traditional patterns [DUPA-97].

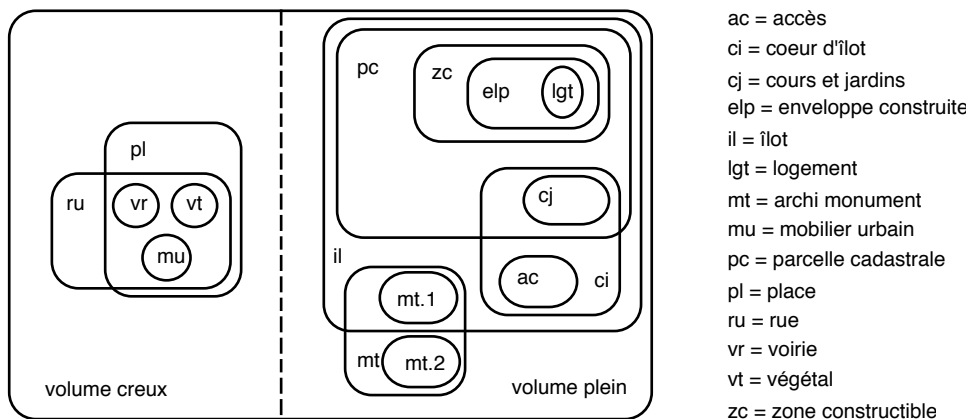|	
ac = accès	
ci = coeur d'îlot	
cj = cours et jardins	
elp = enveloppe construite	
il = îlot	
lgt = logement	
mt = archi monument	
mu = mobilier urbain	
pc = parcelle cadastrale	
pl = place	
ru = rue	
vr = voirie	
vt = végétal	
zc = zone constructible	

Figure 1 - Morphological hypergraph of traditional urban patterns

The hypergraph unveils the high level of structuration of traditional urban forms, which are characterised by i) a number of successive inclusions (building << built envelope << constructible area << plot << block << built volume) and ii) numerous blob intersections. For instance, the inclusion of cj in both pc and cl means that the private garden belongs to both private parcel and the empty block core. Note that if the cj blob hadn't been defined the cl-pc abstract entity wouldn't "exist" in hypergraphs semantics.

By contrast, discontinuous urban forms (fu.d) would be represented by hypergraphs like the one in figure 10 (fu.d). It is based upon Laguna West (US) street design standards [SOUT-95] and very typical of most US and european residential areas. These patterns are characterised by the distribution of filled volumes within the empty space (and no longer as its cartesian product). There is a growing autonomy of built elements and open spaces [DUPA-97]. More specifically, the buildings do no longer really structure the row whose form is much more defined by the road, trees, gutter, pathway and setback. In these conditions, the building is almost rejected outside the open space. The materialisation of the space limits is realised through combinations of surfacic (road, pathway, setback), linear (gutter) and punctual (trees) elements. By this ways, several visual sub-spaces can be embodied in each other in a very legible way.
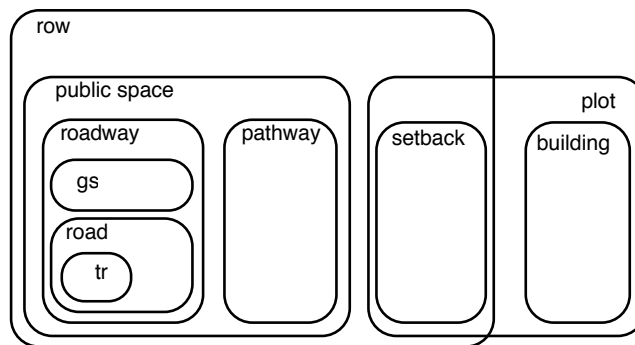

Figure 2 - Morphological hypergraph of a typical discontinuous urban form

3. Application to a real case-study : the cité-administrative in Liège.

Let's now apply this formal method to a real case study chosen in Liege (the administrative city). This place is characterised by a very ambiguous morphological organisation, which remains open to interpretation and discussion as will be illustrated by morphological hypergraphs.

In a short, the "place" was cleared through large demolitions within the traditional

mediaeval urban pattern. These demolitions occurred in the after-war period. Presently, the built environment consists in a very disparate set of modern and historical structures that results from successive interventions, rather accumulated than coordinated. Previous to the demolition, some traditional blocks had already been largely transformed. One of them was replaced by an important commercial complex, coupled with a high rise building (the administrative city) and an l-shaped colonnade. In addition, a historical building, wholly detached from its pattern, was preserved in a corner of the place.

The open space delineation appears as largely undecidable (figure 3). It could as well consist in the u-shaped square encompassed by the colonnade and the historical building (figure 3 - left side) or as the larger one delineated by the traditional blocks and the new complex (figure 3 - right side). Each of these two hypotheses can be described through a specific morphological hypergraph (figures 4 and 5).
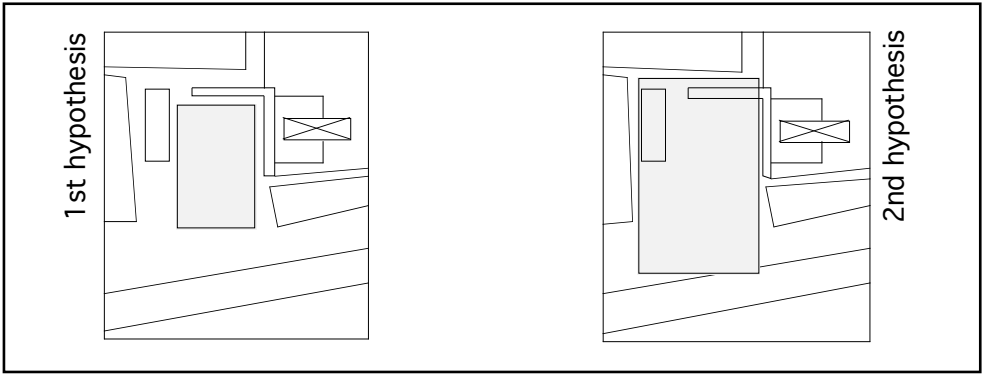

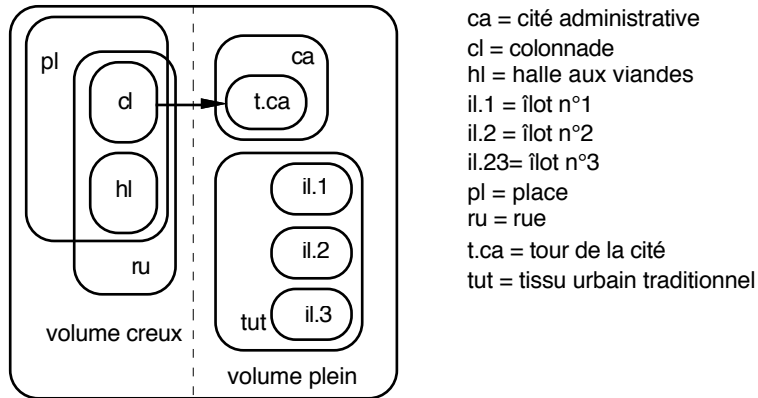Figure 3 - Two possible delineation of the space

ca = cité administrative
cl = colonnade
hl = halle aux viandes
il.1 = îlot n°1
il.2 = îlot n°2
il.23= îlot n°3
pl = place
ru = rue
t.ca = tour de la cité
tut = tissu urbain traditionnel

Figure 4 - First hypothesis hypergraph

ca = cité administrative
cl = colonnade
hl = halle aux viandes
il.1 = îlot n°1
il.2 = îlot n°2
il.23= îlot n°3
pl = place
ru = rue
t.ca = tour de la cité
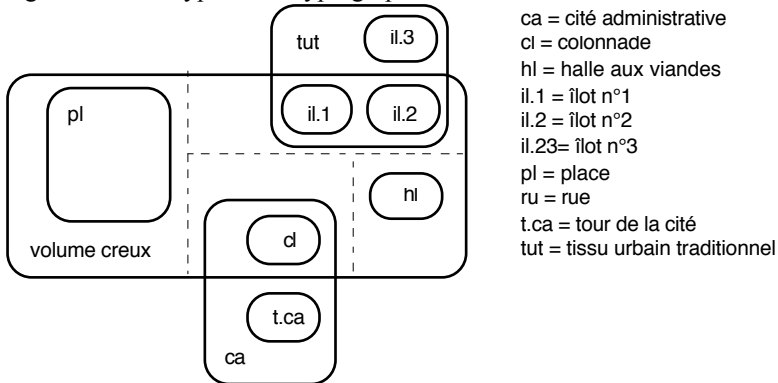tut = tissu urbain traditionnel

Figure 5 - Second hypothesis hypergraph

We won't go into a detailed analysis of each graph. Let's simply note that none of them is really convincing. The hyperlink between cl and t.ca in figure 4 draws our attention on the fact that the colonnade cannot be considered as an autonomous element included within the empty volume. This would be neglecting its strong connection with the administrative tower (t.ca). On the other hand, considering it as one of the place walls as in figure 5 is not much more convincing since the unbalance between this element and the halle (hl) and the background clusters (cl.1 cl.2).

5. Morphological constraints visualisation
All three basic hypergraph relations (inclusion, hyperlink and cartesian product) can be attached to morphological rules, either quantitative or qualitative. By assumption, we consider that morphological hypergraphs follow a specialisation mechanism. High level/qualitative rules are located at the root of the graph.

Specialised/quantitative at its terminal nodes. Hypergraphs can then be considered as a visual instrument for constraints manipulation and definition.

Let's illustrate this by a very simple case, the determination of the maximal building height at the corner of two streets. Traditionally, in Belgium, maximal building height on a street is defined by the street width measured in front of the plot to be built. For corners, two sets of rules are thus potentially triggered, with eventual conflicts when the streets do not share the same width. A first solution may consist in applying the most stringent rule (figure 6-up). The second , often applied in municipal building codes, consider that a "report rule" must be applied at all buildings located on the corner (figure 6-mid). This report rule considers that the greater of the two heights can be observed in the narrow street along a certain distance from the corner. The third solution would be to consider the corner as an exceptional building, eventually much higher than its adjacent buildings (figure 6-bottom).
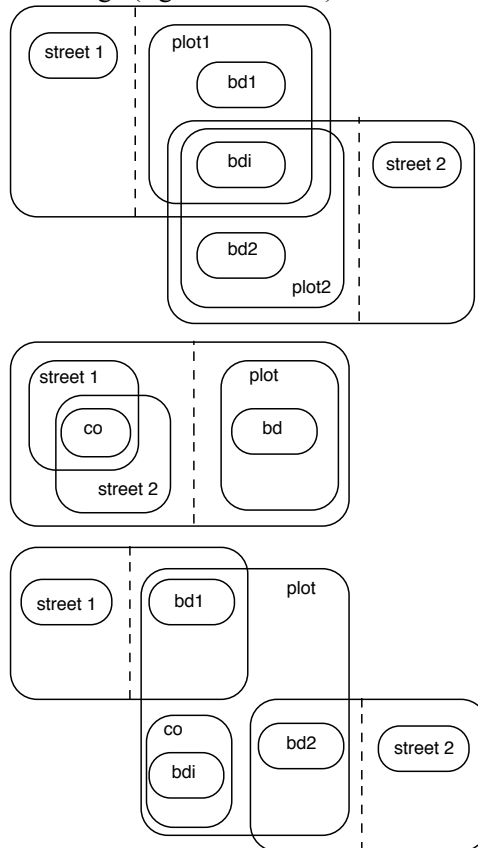
This application is very different from the previous example (the cité

administrative). It is no longer an existing space that is analysed and described, but several design options that are synthetically formalised. In this case, the *expository nature* [MONM-93] of morphological hypergraphs plays a crucial role, given the conflictual nature of the regulation design.

4. Discussion

Current "virtual studio" techniques, if well adapted to illustration, are weak for analytical purposes. Quoting from [BUTT-90], "concerns with validity in illustration differs from the analytical domain, since in this domain (illustration), constraints are often predetermined, and GIS users know, in a sense what they wish to see". As morphological specification is all but consensual and definitive, this requirement would hardly be achievable.

By contrast with these techniques, the Liege administrative city example illustrated the deductive and argumentative value of morphological hypergraphs. They offered a reliable way to formalise our two hypotheses about the open space structuration. It could be rapidly observed that none of them was really "convincing", namely *compliant with our feeling of space along with hypergraphs grammar* (homomorphism principle).

Furthermore, the availability of two possible graphs, realized by the same author, should not be considered as relative to different interpretation of the same space. Interpretation should be understood as the subjective selection of the fundamental elements and relations of the hypergraphs according to specific purposes (neglecting building differences within blocks for instance). In this case, both graphs are divergent despite they try to focus on the same basic elements/relations. It draws our attention on the fact that the open space legibility itself is weak as its basic structure remains ambiguous. And this was not necessarily a desired quality of the place.

Hypothesis formulation, assessment and discussion is an essential part of analytical reflection. When natural language will remain the main support of reasoning, we think it could be usefully complemented by graphical techniques which offer a more formal and synthetic ground for inference. It should however be noted that hypergraphs do not evade some subjective interpretation, especially in their definition. A given space may be modelled through a number of ways by different users. We will never pretend to generate them automatically. They solely constitute a uniform grammar, sharable by various actors and open to reasoned criticism and justification.

The next example (maximal building height) highlighted how morphological hypergraphs could be used to visualise various regulation modes, with eventual exceptions handling. As stated by [YANG-95], "relaxation, adaptation, exception" mechanisms, inherent to any regulation application, makes the definition of rules and constraints quite dynamic over time. Yet current regulation practices surely miss some

means to visualise and monitor the coherence of this process. Given the high level of abstraction of morphological hypergraphs, these instruments would probably provide some limited answer to this question. Actually, they provide means to formulate high level policy intents and visualise their "connections" with more prescriptive rules, which could eventually be relaxed/adapted when they don't strictly apply to the case at hand.

Additionally, morphological hypergraphs offer a unified formal language to describe / analyse a wide range of urban spaces. As illustrated by our introductory examples, they fit traditional urban patterns as well as modern spaces despite the large differences in the nature of these two patterns (duality vs. autonomy, continuity vs discontinuity, volumic vs. linear/surfacic). In the same vein, this formalism has already been applied to a number of reference cases in Europe, amongst which the Grand place in Arras (mediaeval pattern), place de la Concorde (late french baroque), and piazza del popollo (early baroque). As such they appear as a valuable support for case-based reasoning.

Yet a series of questions about this formalism remains open. For instance, how is this formalism applicable by novice users ? This should be assessed through some real-world experiment, eventually led with our architectural students. Probably selected examples, as described here above, would surely help them to understand/apply this visual formalism. On the opposite, such examples would surely frame their creativity.

Another critical issue is to define a proper semantic for the constraints inherent to topological links. Is the formalism to be kept purely "qualitative" or may it be connected to effective regulatory constraints ? A limited experiment has been driven in this direction, through the application of ECA (event-condition-action) rules to topological links. For interesting the experiment may have been (it forces the user to explicitate what he means by topological relations), this attempt proved to be somehow contradictory with the intuitive nature of morphological hypergraphs.

Finally, how are comparisons amongst various graphs to be realised probably remains the most critical issue. Algebraic indices (connectivity, depth etc.) aren't probably well fitted such comparisons. Especially when they would be applied to morphological interpretation of existing spaces (as in the administrative city example). Actually, given the possibility to draw various graphs for the same place, they would mostly reflect their author perceptions about space. As such they would surely lead to tautological statements about the urban open spaces interpretation itself (the space is complex since it is interpreted as complex).

5. Conclusions

Previous attempts to apply computer techniques to morphological regulation often focused on the automation of rules inference inherent to some building codes

application. Expert systems [STON-88, HEIKI-92] or knowledge-based systems [DUPA-88] once appeared as the ideal technical solution to this challenge. These proposals often disregarded the inherent dynamic of the regulation itself, whose viability always relies on some rules "interpretation". As been stated by [TWEE-94], such interpretation must consider the rationale behind the rules which is hardly ever included in the codes themselves. So the point of including not only prescriptive rules but also their high-level justification, namely the basic urban project intents [DUPA-96].

Morphological hypergraphs provide with a reliable way to expose an open space intended structuration through abstract concepts. Exposition meaning here "to make public and thus open to criticism and collaborative improvement". They appear as a useful support for argumentation about regulation demands and internal coherency. Yet, graphs would never supplant verbal discussions. They simply facilitate it through a "common formal syntax" shared by all negotiation partners. In this sense, integrating graphics and words is the focus of our reflection [MONM-93], not the question of wether one is better than the other.

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