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REASONING WITH SPATIAL LOGICS

A prototype iconographic tool for deliberation in urban domains

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ABSTRACT

In this paper we report on some recent, exploratory research into development of a graphic tool for reasoning about urban community formations, as part of a wider UCL project 'Visualizing Community Inequalities', (supported by the Leverhulme Trust). This paper focuses on one section of the research relating to the challenge of integrating diverse and complex data derived from urban community settings. To address this challenge, we have drawn on insights from social and spatial analytical literature, including notions of class categorizations and spatial patterning and ordering. We sought to test how working with a set of visual, intuitive and interactive tools may help urban practitioners to reason about community formations, and to construct iconographic 'concept graphs' to represent their knowledge. To this end we led a participatory workshop, in which participants engaged with research data and explored some ways in which concept graphs might incorporate conceptual and spatial categories to build urban domain knowledge representations (KR). We do not offer firm conclusions in this paper, but outline a broad theoretical background to our approach, some of the basic methods we explored and employed, and suggest further avenues for research in KR for urban practice.

KEYWORDS

Urban practice, design knowledge, spatial logics, knowledge representation, graphic tools

1. INTRODUCTION

Urban 'design knowledge' can been seen as combining frames of rational problem-solving and of reflective practice (Doorst and Dijkhuis, 1995). The notion of the 'rational' frame suggests that the designer forms an informational process within an objective reality and seeks optimal results from poorly structured problems. The notion of the 'reflective' frame suggests that the designer constructs the 'problem situation' through creative practice.

Design knowledge requires practitioners to think of urban spaces in terms of their spatial and conceptual associations or implications, or rather their 'spatiality' and 'trans-spatiality' (Hillier and Hanson, 1984: 40-41; Sailer and Penn, 2009). Practitioners categorize urban spaces by combining representations of artifacts through associations and implications (cf. Lefebvre, 1991: 294-297), within the limits of spatial and temporal logics (ibid: 195-196). From these experiences and logics they extend 'image schemata' to represent their spatial cognitive and historical knowledge (MacEachren, 2004, 185-190).

To support their design knowledge, urban practitioners also make use of visual and spatial metaphors such as circles, triangles, planes, globes and scales. However, these metaphors may serve to enframe practical thinking (cf. Ingold, 2000: 209-218), and serve to conceal knowledge from discourse (Hommels, 2010). As such, our challenge is to 'unfold' knowledge (cf Ingold, 2000: 189-208; 2011, 229-243), to represent the environment intelligibly (Hillier, 2007, p.67-68), and to avoid abstract schema (Lefebvre, 1991: 301-302).

2. REPRESENTING SPATIAL LOGICS

Spatial logics of urban configurations have been described in various urban domain contexts. For example, urban spaces have been shown to bear patterning based on metric and topological distancing (Hillier, 1999; Hillier et al, 2010; Hillier and Vaughan, 2007). In another field, the Region Connection Calculus (RCC8) extends from basic relations of connection, intersection and contact (Randall et al 1992), to describe part-component and connective relationships (Berta et al, 2016). Elsewhere, Lakoff (1987) has offered several image schemata that relate to spatial relationships within urban domains (see Figure 1).

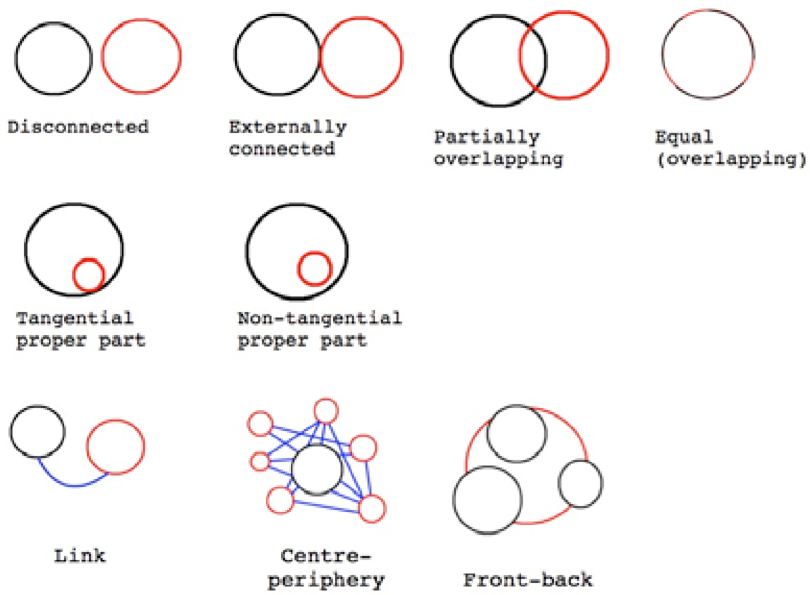

Figure 1 - A combination of spatial logic icons, derived variously from the RCC8 language and from Lakoff (1987)

Working with concept graphs allows us to model semantically rich domains that can include sets of beliefs, desires and intentions among community participants in a consistent and traceable way (Sowa, 2008; Kavouras and Kokla, 2007). Concept graphs based on simple logical constructions of domain knowledge may provide intuitive and portable schema for KR. As such they would constitute a toolkit for testing 'true' or 'false' entities – including facts, goals, implicit or explicit rules, their attributes, conditions and relationships (Chein and Mugnier, 2009, p.22).

Concept graphs can represent entities and relationships using generalized or categorical concept nodes and relation nodes. Every concept has an abstracted type, which can be either specified or non-specified. Concept graphs can be used to configure and test assertions by 'projecting' or 'simplifying' sets of abstract concepts into specific instances (and vice versa). Conceptual graphs represent this schematization using arcs (or edges) that connect concepts to relations, for example:

```
[Concept_1] -> (relation) -> [Concept_2]
```

Concept and relation types are arranged hierarchically based on a generalization order; this means that one type can subsume another. Graphs can be projected in the sense that their nodes can be changed into specific sub-types or general super-types and then tested for logical composition. Projection also supports graph unification whereby sets of nodes between graphs are generalized (preserving their arguments and values), and then compared with similar graphs to identify their similarities (isomorphisms).

The linear form graph, below, demonstrates how a generalized graph projects into specialized graphs. This shows how agents interact with entities (and their themes), and also their position within the conceptual hierarchy: `{*}` demarcates the top super-type and `*x` the bottom sub-type (being the specific instance), while `?x` can demarcate uncertainty:

```
Generalization:
  [Identity:Name {*}] <- (Agnt) -> [Activity] -> (Thme)
  -> [Space:Characteristic]
Projections:
   [Girl:Alice *x] <- (Agnt) -> [Sleep *x] -> (Thme) ->
   [Hole:Deep:Curious *x]
   [Animal:Rabbit *x] <- (Agnt) -> [Running ?x] -> (Thme)
   -> [Door:Small *x]
```

Using these and other logic tools, conceptual graphs allow high-level generalizations to be agreed among a community of domain practitioners, and specialized with more specific or concrete instances of those general categories. Conceptual graphs may be constructed through a top-down (general-to-specific) or bottom-up (specific-to-general) process. A 'middle-out' extension to this well-established graph process has been developed by Berta et al (2016) in the field of 'urban ontologies'. To paraphrase their approach, the specifications of relational concepts (ontologies) are extrapolated through domain practices. The extrapolation process is limited selectively according to the *scale of representation*, the *historical significance* and the *'relational functionality'* (in terms of logical composition) of the urban elements under analysis. The ontologies are shared as a compositional template, which includes spatial and functional classes, spatial data properties and their logical relationships from a given set of domain phenomena.

2.1 PROOF OF CONCEPT

To test the practicable viability of incorporating spatial logics into conceptual iconographic schema we conducted a prototyping workshop involving a group of planning and design urban practitioners. The participants were invited to engage with mapped data visualizations produced from an earlier community data gathering exercise, in which the community participants had 'mapped' significant features of their local environments (O'Brien et al, 2016). These maps where digitized with a GIS and the points data were manipulated to produce a range of visualizations, including the example in Figure 2.

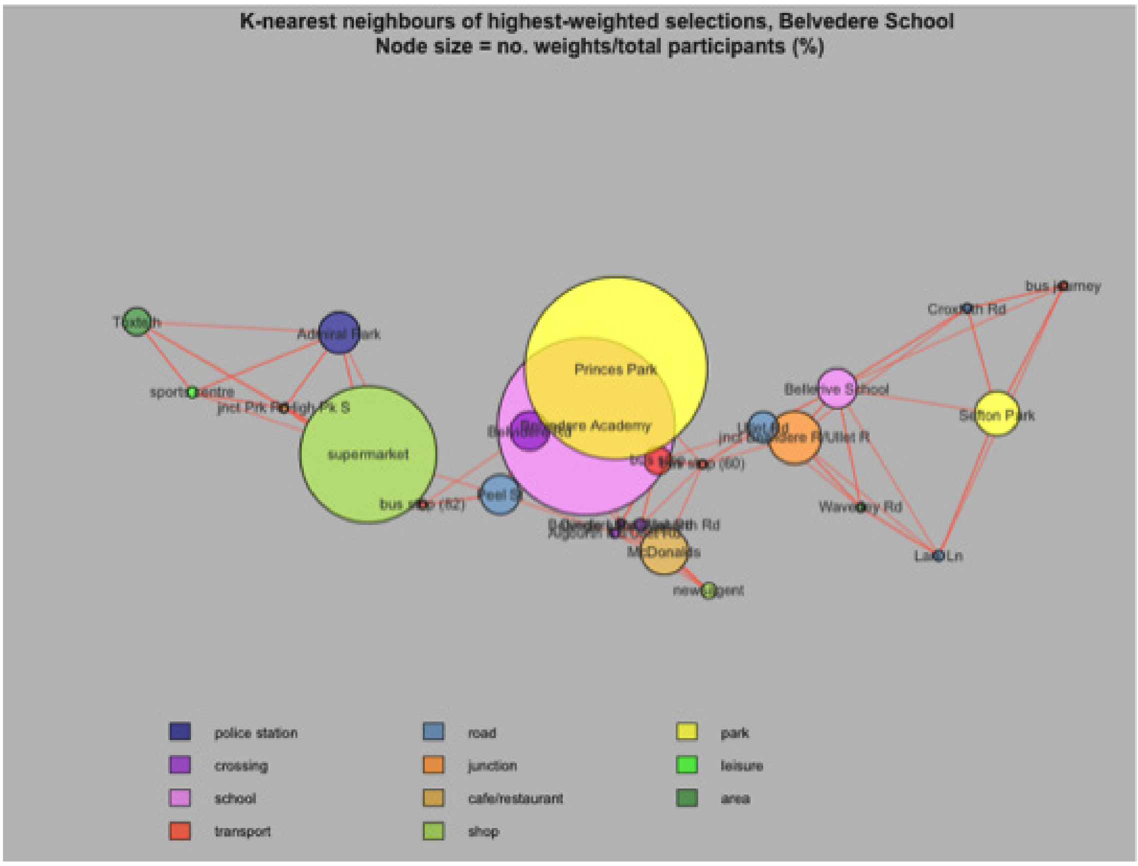

Figure 2 - A visualization of urban community data from the 'VCI' project at UCL, representing the 'significance' of local features weighted by node size

The practitioners were then presented with a set of graphic icons that represented the range of structures, scales and other features selected by the community participants. The practitioners were also presented with graphic representations of spatial logics (Figure 1) to describe ways in which these structures and scales might be arranged. The participants were invited to build a basic (roughly defined) concept graph to describe any discernable patterns pertaining to community formations within the mapped data. Figure 2 presents one example of the concept graphs produced by the practitioner participants.

Figure 2 - A visualization of urban community data from the 'VCI' project at UCL, representing the 'significance' of local features weighted by node size

The participant's concept graph shown in Figure 3 represents a possible journey from home (left) to a supermarket (right), which crosses busy roads carrying local (pedestrian/velomobile), city-wide (light/heavy authomative), and regional (heavy automative/transit) traffic. The journey has a negative dimension involving a road junction (e.g. for hindering pedestrian access). The supermarket contains a café as a positive dimension (e.g. for social life), represented here using an RCC8 icon for 'tangential proper part' (TPP). From this illustration we may construct a concept graph:

```
Generalization:
  [Origin:Name] <- (Agnts) -> [Activity] -> (Thme) ->
  [Urban entity:Type] -> [Movement:Scales] -> (Thme) ->
  [Urban entity:Type] -> [Logic relation:RCC8] ->
  [Destination:name]
Projections:
  [Home-shop] <- (Parent+child) -> [Cross road] -> (Neg) ->
  [Junction] -> [Traffic:Local+City+Regional] -> (Pos) ->
  [Shop] -> [RCC8:TPP] -> [Café]
```

Other participants in the workshop were able to use RCC8 icons to describe urban community relationships in terms of being 'externally connected', 'disconnected', 'tangential proper part' and 'non-tangential proper part' (NTPP). Interestingly, the latter instance of NTPP was used to refer to an activity taking place in a public park, which perhaps speaks to the production of a local social-space (a sporting activity) that is part of, but not physically integrated with, the public open space. In observing this and other examples of successful graph constructions, we feel confident in developing and refining this prototyped technique.

4. CONCLUSIONS

The proof-of-concept exercise described above demonstrated the viability of incorporating spatial logics schemata into a concept graph. The participants' overall positive engagement with sets of graphic icons (representing urban spatial entities, movement scales and spatial relationships), evidenced an intuitive method for dealing with complex urban community data. However, we acknowledge that this has not yet produced a practicable tool for KR in urban domains. Towards this objective, we will next test how the graphic icons can be organized into an informational 'flow' to support domain diagnostics and decision-making.

One possibility in this area is to arrange these icons within an argumentation schema. Arguments often derive from expert opinion, from metaphors, analogies or precedents, or from practical reasoning (and, negatively, from ignorance, misinformation or prejudice). Challenges to an argument can be made by posing critical questions that serve to interrogate their inherent assumptions, premises and logical formulations (Walton, 2013, p.28). We anticipate that the field of argumentation may provide a range of informal logic schema for enriching and testing iconographic conceptual representations of domain knowledge. Testing this hypothesis will form our next phase of work.

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