Towards a Computational Description of Urban Patterns

An Urban Formulation Ontology

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Abstract. This study is concerned with the formulation of solutions for urban problems. It departs from Alexander’s pattern language theory and urban design guidelines, to create a system for generating specifications or the ingredients of a plan, given a scale, a site and a community. It takes into account strategies, regulations, guidelines, physical features of the site, and furthermore, the social, cultural and economic characteristics of the population. This system, sorted by a sequence of events, through stages, categories, methods and agents, describes taxonomic levels and their inner relations. Such an ontology provides a pattern encoding structure towards a computational model within the capabilities provided by the spatial data modeling of GIS (GIS-O). The urban formulation model is conceived to increase qualitative inputs, reducing ambiguities, through a flexible while automate process applied to urban planning.

Keywords: Urban Formulation; Ontology; Pattern Language; GIS interoperability.

Introduction

The described research is part of a larger effort aimed at developing a methodology and a computer tool for conceiving flexible urban plans. This methodology is based on Alexander’s pattern language (PL) theory (1977); on Stiny’s shape grammars, and on Hillier and Hanson space syntax, and it foresees three systems: (1) a system for formulating urban programs based on pattern languages; (2) a system for generating formal solutions that satisfy specific urban programs based on shape grammars; and (3) a system for evaluating both urban programs and design solutions based on space syntax, thereby constraining generating towards specified goals.

This paper describes the first stage of the research concerned with the development of the system for formulating urban programs. The development of such a system, and particularly the development of a computer supporting tool, requires one to classify urban patterns into categories and then to identify the structure common to all the patterns in each category. This corresponds to the development of an ontology (Gruber, 1993) for urban patterns and it should facilitate the encoding of patterns into a computational framework and their future manipulation towards the definition of urban programs. The research phase herein described is concerned with the definition of such an ontology.
Methodology - the description of urban formulation

The ontology concept
Ontology is a philosophic theory that concerns the study of existence. The ‘Aristotle’s ontology offers primitive categories, such as substance and quality, which were presumed to account for All That Is. (...) In computer and information science, ontology is a technical term denoting an artifact that is designed for a purpose, which is to enable the modeling of knowledge about some domain, real or imagined’ (Gruber, 1993). An ontology is, therefore, a specification of a conceptualization (Ontolingua).

Application structure
Urban space shelters a wide range of human activities. Due to its complexity, the overall perception of urban phenomena requires an administrative representation based on a taxonomic methodology. A sorting applied to each urban phenomenon, ruled by type and classes, leads to a progressive ontological hierarchy of patterns. These definitions enable one to disclosure an urban space diagram, thereby

Figure 1
Urban Pattern Application
Ontology diagram
clarifying urban configurations.

This structure is used to describe urban patterns thereby allowing the definition of Ontologies. Each ontology encompasses different levels, namely, taxonomy, partonomy, mereology, chronology and topology.

The ‘Top Level Ontology’ describes relations at a macro scale; and an ‘Application Ontology’ specifies concepts at the site planning scale.

Specific Space Ontologies (explicit specification of a concept) are conceived as syntax and semantic rules to prevent ambiguity of results. The definition of a lexicon is possible due to the definition of ontological levels and their specifications.

The Ontological sequences are globally defined as. a) Top Level, which describes general concepts such as space, time, object, action, etc.; b) Dominion, which describes the vocabulary used in a specific field of knowledge; c) Task, which describes the vocabulary used in a specific activity of a field; d) Application, which describes concepts belonging to particular fields and which includes specific and detailed tasks; and e) Representation, which explains the concepts of formal entities.

The ‘Application Ontology’ standard relations are expressed through Taxonomy (is a, type of), Partonomy (part of), Mereology (‘part-of-all’ theory), Cronology (time between concepts) and Topology (boundary and limit theory). The heuristic diagram 1 shows an ‘Application Ontology’ describing urban space parameters, through patterns definition.

**An urban formulation ontology**

**Framework within the design process**

The urban formulation encompasses a specific chapter of the planning process, regarding the pre-design (PD) phase. PD consists in a phase of analysis that occurs before design begins. Usually, during the pre-design phase, studies are done to analyze requirement issues, the constraints, and opportunities of the proposed site (U. California). PD seems to comprise a higher amplitude of occurrences than those presented in the pattern language theory.

The proposed urban formulation ontology engages an overall process, starting with aims and strategies, and ending with a precise selection of urban patterns. In such an ontology, the ingredients of the urban planning process interact and operate within a systematic structure, aiming to assemble rules and classes.

**Dominions and Inferences – the formulation design phases**

This ontology comprises two design stages; pre-design phase I (PD1) and Pre-design phase II (PD2) and it is organized by categories (strategies, regulations, data, and language), methods (described below) and users (the designer’s inner language).

**Taxonomic Methods - pre-design phase I (PD1)**

Prior to the final spatial characterization and the urban patterns definition and selection, some support information is required to identify objectives.

This characterization corresponds to the pre-design phase I (PD1).

Although Alexander’s Pattern Language embodies the theoretical basis towards the urban design, ruled by patterns, it contains operative limitations such as the lack of a pre-design (PD) data set.

The Preliminary Information (PI) contains support data such as key objectives, range, character and pre-existing information. In general, the main classes can be organized by purpose, period reach, deepness, amplitude, available sources, character, nature, object of study, environment, and available studies.

PI is described herein as;

1. Social, Economic, Cultural, and Political Strategies, within Strategic Urban Planning (SUP), enclosed by SWOT (tool used to evaluate the Strengths, Weaknesses, Opportunities, and Threats) and PEST (Political, Economic, Social, and Technological analysis) methods. SUP is now
considered a type of Governance.

2. According to Borja and Castells (1998), ‘the definition of a city project that unifies diagnoses specifies public and private actions and establishes a coherent mobilization framework for the cooperation of urban social actors. A participative process is a priority when defining contents, as this process will be the basis for the viability of the objectives and actions proposed. The result of the Strategic plan should not necessarily be the creation of regulations or a government program (although its adoption by the State and Local Government should mean the instigation of regulations, investment, administrative measures, policy initiatives, etc) but rather a policy contract between public institutions and civil society.’ There are several approaches to strategic planning but typically a three-step process may be used: Situation - evaluate the current situation and how it came about; Target - define goals and/or objectives (sometimes called ideal state); Path - map a possible route to the goals/objectives.

3. Strategic planning can be described as the following: Vision - Define the vision and set a mission statement with a hierarchy of goals; SWOT - Analysis conducted according to the desired goals; Formulate - Formulate actions and processes that can be taken to attain these goals; Implement - Implementation of the agreed upon processes; Control - Monitor and get feedback from implemented processes to fully control the operation.

4. Regulations, as urban rules, guidelines, requirements, and urban standards. The regulations have a precise application, varying according to the site and its context.

5. Site and Population Data, describing the physical features of the site, the social and economic characteristics of the population, within Site Analyses Data Compilation Categories (SADCC which also comprises design guidelines, codes, and requirements), among other statistical information.

SADCC is generally defined by a group of matters, namely:

a. climate:
   - prevailing winds (direction and velocity),
   - solar orientation (including shade and shadows),
   - temperature ranges and seasonal norms,
   - humidity,
   - precipitation,

b. site features:
   - b1 vegetation,
   - b2 wildlife,
   - b3 surface waters,
   - b4 topography (slope and aspect),
   - b5 land form and features,

c. environmental influences:
   - noise levels,
   - odors,
   - fumes,
   - dust,
   - smoke from adjacent sites,
   - air quality,
   - vibration,
   - general nuisances,

d. historical data:
   - previous uses (e.g., landfill, dumping, archaeological grounds, etc.),
   - existing structures,

e. land-use and regulatory controls (includes on-site and off-site considerations):
   - LRDP land-use designation,
   - urban codes and requirements,
   - design guidelines,
   - precinct or area plans,
   - site zoning and surrounding area zoning,
   - existing land-use type and density,
   - permitted uses and exemptions,
deed restrictions and covenants,
• setbacks (lot coverage, and height limitations),
• parking requirements,
• signage requirements,
• visual analysis,
• aesthetics,
• landform diversity,
• views and vistas to and from site,
• spatial patterns and structure,
• significant features,
• circulation and access,
• vehicular,
• bicycles,
• pedestrian,
• service,
• construction staging areas,
• emergency access.

**Taxonomic Methods - pre-design phase II (PD2)**

After the PI classification, an urban design space description is required, through the definition and selection of urban patterns, based on their particular nature and formalization.

This characterization corresponds to the pre-design phase II (PD2).

The development of this phase is centered on the principles described by Alexander’s series of books published in the 70s, unfolding a new theory of urban design. The ‘Pattern Language’ provides a language for building and planning that includes detailed patterns for things ranging from rooms to towns. The ‘Timeless Way of Building’ provides the theory and instructions for the use of the language, which is the discipline that made it possible to use the patterns to create a building or a town.

Alexander’s premises address to the linguistics theory, which defines language as a combinatorial and creative method of communication, based on user instructions, through different contexts, within an index of vocabulary and procedures. Thus language allows users a creative mixture and an assorted manipulation of its ingredients.

The speech expresses a combinatorial characteristic of the language, which is crucial in the production of concepts. In planning, such characteristics are useful for a creative and flexible process. This speech is structured under syntax rules, defining the way words combine into phrases and sentences (Chomsky, 1957); similar to Alexander’s combination patterns.

The work of Alexander stirred the field but had little practical impact. A set of comparative examples detected debilities into the description of PL sorts: 1) PL taxonomy by scale seems to repeat similar urban solutions (example: patterns 57 and 68); 2) PL lacks some key patterns, such as structural urban grids; 3) some PL patterns are embedded by a very particular cultural background.

A large amount of PL patterns have no practical application to the site scale of our current study (4 to 12 hectares).

Towards a formulation of an urban model it is crucial a prior selection of patterns to apply to a specific context and the exclusion of patterns that are inefficient for that context.

An ontology draft defines the first two groups of excluded patterns: scale exclusion, and standard cultural exclusion.

In the patterns excluded by scale, a high number of those refer to urban facilities that are normally considered within a superior scale, the city scale (e.g. cemetery, sports facilities, etc.). However, it is useful to consider that these patterns, excluded at the outset, may be recovered and applied to the site planning, by particular demands in the pre-design phase I (PD1).

The patterns excluded by specific cultural background, concern larger difficulties in the selection. To surpass this difficulty it is critical to consider a methodology of analysis of these patterns, through the elaboration of questionnaires to potential users of the language. The Web platform, in this methodology of analysis, can provide results in a widened area, comprising a more direct monitoring for later conclusions.
A set of new patterns have to be introduced into the language to bring up the recursive data from the new knowledge domain, filling existing lacks.

Within the social knowledge domain, ‘The City Joust’ (Guterres, 2004), comprises an innovative and overall study within urban planning. The social metrics are enclosed into the ‘experience of the city’, gauging urban social space relations, empathies and social behaviours. This work presents an exhausting study on the social space sizing consequences, implicit on both public and private areas as well as densities. As a conclusion, it describes specific impacts on the quality of the populations’ quotidian life. These social indicators are supported by different theoretical sources, such as: Maslow 1954, Jacobs 1961, Hall 1986, Newman 1972 and 1980, Hillier 1984, Colleman 1990, and Sustainability Indicators. The neological (NL) social patterns are described as: Emphaty Distance (ea); Public Green (pg); Total Public Area (pta); Total Area With Sense of Sociability (tass); Private Areas With or Without Social Interaction (pawwsi); Public Area With Everyday Existence (pgee); Sidewalks With Social Interaction (ssi); Private Areas, or with Diaphragms, with Social Monitoring (padm); Pedestrian Areas (pa) and; Private Areas Without Social Interaction (pawssi).

Other crucial neological patterns are enclosed in the bioclimatic urbanism domain of a pioneering study by Higueras (2006), which assembles a set of relative studies, focused on data territory, climatic charts, and urban environmental conditions. The main outcome of this study is a set of design guidelines for green or open areas, buildings, and volume orientation, etc., supported on energy and environmental sustainability criteria.

Other central study encompasses the grid generator pattern, conceived by Leslie Martin, which is a critical base for the planning design process.

The designer’s language
The particular language used by the designer to develop a plan seems to have analogisms with linguistic theory’s, psycholinguistics, and cognitive science. In linguistic theory (Three pillars) the language ‘is situated in the mind of the user’ (‘mentalism’ concept) and is oriented by semantics/meaning, based on ‘cognitive schemas’ (CS), which represents mental models of different aspects of the world. CS contains knowledge, beliefs, assumptions, associations, and expectations, as an inner creative resource of the planner.

Generally, the fundamental specific resources of the language defined in linguistics are: structuring sounds into digitized segments (phonemes) which are sequenced into fixed combinations (words/morphemes); treating these sequences as symbols for concepts (meanings) that can be used in many different situations; organizing sequences of words/morphemes into hierarchical phrases and sentences (syntactic structures) whose meanings are constructed systematically from the meanings of the words. These are similar to syntactic and semantic key attributes of the urban pattern language. In PL these specific resources can be described as; individual elements/such as land, sun, orientation, etc. (words/morphemes), ideas/concepts/ such as social behaviors, climatic conditions, etc., (meanings); and urban patterns (syntactic structures).

The designer’s language crosses the full range of the pre-design phases (both PD1 and PD2), whenever it requires the involvement of the planner (from SUP until the specific definition of the urban patterns). However, it is a complex activity, associated to different knowledge domains. Lindeken (2005) describes a monitored design planning process, registering the evolution and the generation of planning solutions given by a planning team, and evaluates the type of language used to design. Meanwhile, the absence of conclusive outcomes within this concept invokes the need of an alternative planning action guide.

The methodology of evaluation
The system is evaluated by verification, based on a decision process and a quality tree structure; towards the objectives defined in the SUP process. The
Figure 2
Ontological diagram based on the Urban Formulation Process

PDP1
Pre-Design Phase I

SUP
Strategic Urban Planning

S.W.O.T.
P.E.S.T.

ST
Urban Standards, Rules and Guidelines
Application standards

SADCC
Site Analyses
Data
Compilation
Categories
Direct site evaluation

ST Population and environmental Statistics
Statistic Institutes

P2
Preliminary Information

PDP2
Pre-Design Phase II
Establishment of urban formulation patterns

Language
Urban Pattern
Language sorting

urban formulation process

Processes
instruments and methods applied in processes

Users
agents

Final Target

urban formulation process

Stages
within urban formulation process

Categories
subject analyses
evaluation can be described by
1. decompose the main objective into sub-objectives;
2. establish the weight of sub-objectives;
3. measure the satisfaction of each sub-objective;
4. calculate the final result (Duarte, J.P., 2005).

The SUP process, itself a product of an evaluation method, will provide to the urban formulation process a selected set of strategies and weights as criterion targets. That information will define the baseline draft to compare and analyze the particular urban study phenomena.

**Urban formulation model based on a pattern structure**

The urban formulation occurs in the exchange of information between the different agents and entities of the model, comprising an amount of inputs and outputs, within an interactive process.

There are two scales of exchange.

One related to the user’s perspective and the other under the outlook of the pattern language.

The first comprises the inner input patterns (designer’s language) and the second all the outer input patterns (through political, economic, social, etc. strategies and rules).

This information set encompasses general input patterns as guidelines for design. The output patterns are described by a design level and are shaped by all the input patterns.

**Urban data interoperability with GIS**

The core information system that will be used in the proposed formulation system to summarize urban space data is a spatial geo-referenced information system (GIS). To guarantee maximum compatibility of the core system with different GIS systems, the ontology will be based on the Spatial Data Transfer Standard (SDTS), approved by the Federal Information Processing Standard (FIPS) (SDTS 2008). It is a spatial geo-referenced information system (GIS) that supports operations between different computerized systems. It describes a data transfer philosophy, which includes geographic and cartographic information, as well as other relevant meta-data, applicable to specific case studies. At the basis of SDTS is a concept model, consisting of detailed specifications such as content, structure, and format.

The spatial data model structure is based on three types of object description: a) The ‘Spatial Entities Model’, which describes real spatial entities such as buildings, roads, rivers, and so on, through rate attributes. b) The Spatial objects model’, which describes spatial objects such as lines, polygons and dots, used to represent real entities in digital systems. c) The ‘Spatial descriptions model’, which describes entities related to the real world, objects related to the digital world, as well as spatial descriptions and connections that exist between them.

To guarantee data homogeneity and compatibility between data transfer, SDTS describes a formal list of entities. The actual list includes more than 200 entity types, 244 attributes and more than 1200 alternative terms.

The standard definition of entities includes the
following data structure: a) ‘Entity type’, a definition of a set of similar entities; b) ‘Entity instance’, an example of a specific formalization within a type; c) ‘Attribute Entity’, a feature that describes a type; d) ‘Attribute value’, a specific quality of an attribute; e) ‘Standard expression’, a stereotyped name for an entity or an attribute. f) ‘Integrated expression’, a synonym used to refer to an entity or an attribute, defined by SDTS rules.

The OpenGIS® City Geography Markup Language (CityGML) has a similar functional structure, within entities and classes definition, that can be applied into the urban study model.

**Conclusion and further research**

This urban planning ontology aims at sketching an urban formulation design tool, within an interactive and codified language, and a pattern system for exploring urban design solutions. This will ease the dialogue between the various participants in the urban design and implementation processes, such as community members, town halls, financing institutions, designers, promoters and developers. This language will be targeted at a specific site planning scale in order to focus the planning process.

The critical aim of the study is to define such an ontology for urban patterns allowing their codification into a GIS platform for future use by a system that will formulate urban programs. Future work will be concerned with the definition of a description grammar that encodes the rules for manipulating urban patterns and defining urban programs.

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