Public Space Patterns

Towards a CIM standard for urban public space

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Abstract. *This paper describes public space patterns (PSP) used as basic elements of the City Information Modelling (CIM) model proposed within a larger research project that aims to develop an urban design support tool.*
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INTRODUCTION

This paper describes public space patterns used as a basic structure of a City Information Model (CIM) developed within a larger research project, called City Induction, aimed at developing a tool for urban design (Duarte et al., forthcoming 2011). The design tool is composed of three modules. The first module called the formulation module, analyses geographic spatial information in order to provide a description of the context and formulates the descriptions of the programme requirements for that particular context. The descriptions are provided in the form of urban ontologies (Teller et al, 2007) and spatial rules encoded into description grammars (Stiny, 1981). The second module, the generation module, uses discursive grammars (Duarte, 2001) replicating urban design moves for the production of design alternatives. A discursive grammar is composed of a programming grammar setting the specifications for some design move, a generation grammar to generate the design moves, and a set of heuristics to guide the generation rules into fulfilling the specifications defined by the programming grammar. Both the generation and the programming grammar are composed of a description grammar and a shape grammar (Stiny and Gips, 1972). The shape part in the programming grammar can be empty. An evaluation module tests the solutions against the requirements in order to validate the design options.

The CIM model supports the communication between the three modules using a common ontology with semantic descriptions of the components of urban patterns. The main purpose is to provide semantic and computer-readable descriptions of urban patterns as a repository of coded information, to suport the generation of urban programs and design alternatives by the participants of the urban design process. The CIM concept borrows some of its principles from the BIM one: "A Building Information Modelling (BIM) comprise a system that aims at incorporating all aspects of design from geographic information, to building geometry, to component relationships, and finally, to the quantities and properties of the building components." (Montenegro and Duarte, 2009) It utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a building and its related project/life-cycle information (Ashcraft, 2008). In the case of CIM the model, it refers to a city instead of a building. A City Information Modelling consists in the process of creating a computer readable model of knowledge and standard specifications regarding the urban environment and the process of its development.

PUBLIC SPACE PATTERNS

In the present paper, we focus on the descriptive structure of public space patterns (PSP). Descriptions in PSPs are used to characterize both the existing urban environment, the urban intervention programme, and the designed environment. Description rules in the formulation model generate the urban programme descriptions from the urban environment ones.

Public space patterns are here described as the outdoor living spaces of urban communities. Moughtin (2003) described them as "the most important elements of city design." These spaces are basically streets, squares, plazas, promenades, parks, crossroads, and so on. The paper will focus on squares and plazas and their description components that are needed to define the requirements in an urban programme.

In short, PSPs can be described according to:

1. Their operative structure (the way they emerge from the context until they take a definitive geometry);
2. Their five dimensions (see Figure 2);
3. The rules for placing them (selection and locating rules that answer the questions: which patterns shall we use and where shall we locate them?).

Public space patterns and their operative structure

The modelling of PSP patterns is supported by an algorithm that connects three components of urban design:

1. The urban context and its interpretation for devising the development vision which will structure the urban programme;
2. The urban programme which consists in the description of the patterns' goals guided by the development vision and aiming at providing semantic data to feed the generation of urban form; and
3. The generation of urban form which is the set of design rules used to generate urban designs from the specifications of the urban programme.

The integration of these three components permits one to select and locate adequate PSPs on the intervention site.

Figure 1shows the main components of PSPs. The urban design workflow encompasses three phases. Pre-design Phase 1, which is a context analysis phase aimed at defining a development vision expressed through conceptual patterns. These patterns correspond to generic representations of ideas for the development of a certain urban area at an early stage of the planning process. Pre-design Phase 2, in which description grammars are used to interpret the specifications set in the development vision and generate the urban programme from the context by manipulating formulation patterns. Formulating patterns are also encoded into description rules which read the description of the existing urban environment and generate appropriate specifications that make up the urban program. The

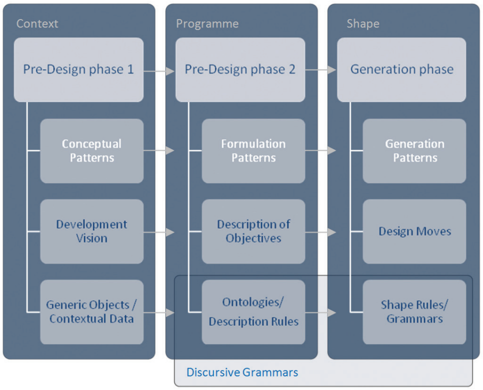


Figure 1.
Diagram showing the information flow between the formulation (context and programme) and the generation phases.

generation phase uses generation patterns which correspond to recurrent design moves. Designs are defined by the progressive application of generative design moves following the specifications of the urban programme. The generation patterns recognize occurrences in the context and specifications of the urban programme for which a design is generated through the application of a set of compound rules replicating an urban design move. Designs are obtained by composing multiple design moves.

Public space patterns dimensions

A PSP is multidimensional. It contains data associated with five main concepts: 1. City Objects, 2. Function, 3. Material, 4. Morphology, and 5. Mobility. Each concept corresponds to a pattern's descriptive attribute.

Let us consider the example of a public square. This space can contain several elements such as a fountain, a sculpture or/and a kiosk. These are "City Objects" that are part of the spatial structure. The square can embed associated "Function(s)" (e.g. leisure / playground, etc.) and the surfaces and components associated with tem can be made of specific "Material(s)." Krier's (1979) and Moughtin (2003) morphological definitions can provide descriptions for the "Morphology" and "Mobility" concepts. For instance, a square can be a slightly twisted rectangle and have four corner entrances.

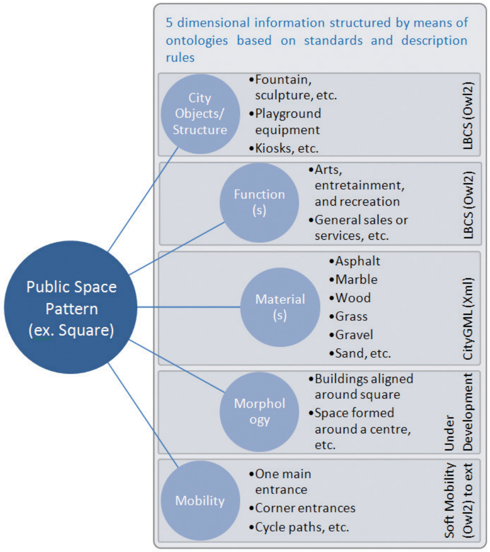
We used a number of different ontologies to express the dimensions of PSPs because an ontology is a knowledge models with very a clear hierarchy of classes, which facilitates the description of the pattern's components. In addition, an ontology allows one to add descriptive attributes of classes and their instances. A computational ontology editor like Protégé (Sintek et al, 2001) allows one to import ontologies developed for a specific model or shared by the Web community. This type of editor also permits one to merge several ontologies from different sources into a more complex ontology that structures the knowledge base. This feature allows one to replicate, very directly, the concept of integrating different dimensions into a single pattern.

In practical terms, each of the PSPs main concepts is modelled using the OWL 2.0 ontology editor. The advantage of using the OWL language lies in its specific hierarchical structure of concepts and classes, which permits the use of advanced inference mechanisms. (Montenegro et al, 2011) OWL 2.0 editors like Protégé makes use of reasoners to infer data from the hierarchical structure of classes of ontologies, making the underlying concepts explicit and allowing the emergence of new concepts. The reuse of shared ontologies based on the semantic web language facilitates the development of knowledge models.

Let us focus on the group of core ontologies that were used to model the descriptions of the public space patterns (Figure 2):

1. For the "City Objects" and "Functions" dimensions we used the LBCS, a land-use standard modelled as an ontology for 4CityPlan using OWL 2.0. More information on this subject can be found in Montenegro et al. (2011)
2. For the "Materials" dimension, we used the CityGML standard, (Kolbe et al., 2005) a land-

Figure 2
The different dimensions of public space patterns.



use standard concerning the representation of 3D city objects. This shared ontology also was modelled using OWL 2.0;

3. For the "Morphology" dimension, we used the PSP basic ontology which is under development (its taxonomic structure is shown in Figure 4);
4. For the "Mobility" dimension, we used the Soft Mobility ontology (Metral et al, 2010), albeit it was necessary to extend its domain concepts to fulfil specific aspects of the patterns.

Public space patterns location

PSPs are selected and located on the intervention site according to a set of rules. This selection/location problem is similar to the "Facility Location" problem [1]. This problem, also known as location analysis, has been the focus of a branch of operations research and computational geometry concerned with the mathematical modelling of finding the optimal placement of facilities, in order to minimise transportation costs, avoid placing hazardous materials near housing, outperform competitors' facilities, etc.

The PSP location problem type is as follows: given a set of public space patterns and a group of people who can be served from such patterns then identify:

1. which public space patterns should be used; and
2. which groups of people should be served from which public space patterns in order to minimise the total cost of serving all people and to maximize their quality of living.

Figure 3 shows a graphical representation of the problem (left) and one possible solution (right).

The PSP placement problem may be complicated by other factors like people being served by more than one PSP. For instance, some people might use different PSPs depending on the way PSPs are combined with certain public facilities. For some people, it may be more interesting to use a slightly more distant square in combination with a needed facility than the closest square alone.

These factors may have a smaller impact in the case of facility placement like a school or a health centre. Squares and other types of public outdoor space enclose additional placement problems. Since such spaces are an integrate part of the territory, they reflect not just the population's needs (resident or/and transient) but also other factors, like their geographical location or historical value, which may transform them into focal points or landmarks and, therefore, into urban attractors. This means that PSPs location data depend on population density as much as on certain features of the territory like specific topographical features, the presence of historical buildings, and other site features.

The solution to the PSPs location problem can be informed by Alexander's pattern concept (1977), namely, the feature described in Section 8, which concerns the relations among patterns of different scales and types. Following Alexander's pattern definition, public space patterns have the following characteristics: 1) all patterns have the same format, 2) patterns are illustrated with an archetypical example of the problem, 3) each pattern has an introductory section that specifies the context in which it may occur or be applied, 4) patterns are defined by one or two sentences describing the essence of the problem that they address and solve, 5) the problem is described in a longer section explaining the pattern's context, its validity, and the ranges of its variation, 6) the solution, the core of the pattern is given by a set of precise instructions that specify how to instantiate it, 7) the description of the solution in a diagram with its main components, and 8) the set of smaller and bigger scale patterns that are related with the pattern, which helps to complete its description and identify its affordances.

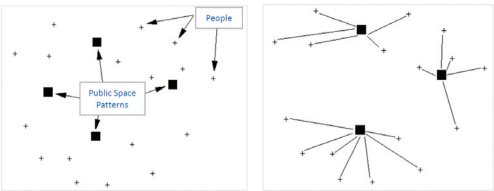


Figure 3
Diagrammatic representation of a PSP location problem (left) and solution (right).

METHODOLOGY

To identify patterns in public space that may be reused in design, four basic methodological approaches are being used:

1. Identification of patterns in a wide range of cities supported by a literature review (e.g.: Moughtin, 2003) – 'universal' high level patterns. The outcome will be a set of patterns that encode 'ideal' principles for the design of cities.
2. Identification of patterns according to sustainability criteria – sustainable patterns. The outcome will be a pattern language to provide diverse levels of quality at the public space level. (Montenegro, 2010)
3. Identification of patterns from several case-studies using traditional analytic techniques (manual and visual). The result will be a repository of patterns used in practice to share and reuse – essentially these are morphological patterns. (Beirão et al, 2011)
4. Identification of patterns extracted from several case-studies using data mining techniques. This approach allows the identification of local cultural patterns, as well as the characterization of the parameters of morphological patterns (Gil et al, accepted 2011).

Our use of the term pattern follows the concepts of Alexander et al (1977) and Gamma et al. (1994). Our goal is to identify the description components of patterns that are needed to generate adequate urban design programs and solutions. The four approaches mentioned above permit the systematic identification of the high level description of an urban environment, which defines the generic type of public space; the qualitative parameters that affect sustainability; the morphological descriptors of public space patterns, which are essentially geometric parameters; and the semantic properties of such parameters, which permit to relate their values with morphological qualities of the public space. These objectives are encapsulated in the five dimensions of PSPs and represented in the overall ontology, which helps to make explicit to the designer the relations among these dimensions.

On the morphological level six types of public squares have been identified so far and were used to model the corresponding pattern for reuse in design. Five types result mainly from planned processes and the remaining results from non-planned ones. The six types are Sq1- a main plaza, a structuring square specifically designed with this purpose and which can have different but well-defined shapes, such as circle, a square or distortions of these shapes as highlighted in Krier (1979); Sq2 - a square that results from the subtraction of a block in a grid (e.g.: the Rossio square in the Manuel da Maia's plan for the reconstruction of Lisbon): Sq3 - a square that results from the subtraction of part of a block in a grid (e.g.: public space in front of the Seagram Building in New York); Sq4 – a square that results from subtracting shapes from the corners of city blocks in a crossroad (e.g.: the Barcelona Cerdá´s plan squares); Sq5 – a square that results from the opening of an inner courtyard in a block (e.g.: the Spanish Seville patios; Sq6 - a public space formed out of a remnant space in an irregular grid (e.g.: typically the mediaeval square).

Our research is focused on the site planning level. Design in this research is defined as a particular arrangement of patterns which correspond to recurrent design moves where patterns can be customized according to contextual inputs.

DESCRIPTION GRAMMARS FOR URBAN DESIGN FORMULATION

The intended design support tool uses patterns for formulating programs and designing solutions. There are three different kinds of patterns: conceptual patterns, formulation patterns, and generation patterns.

Friedman (1997) sees urban design as a sequence of decisions that starts at large scale with the definition of a development vision and continues to lower scales (neighbourhood) with the specification of detailed design requirements, which can then be developed into specific designs. In our research, this model was captured, using Alexander's pattern structure as described in the previous section, into three different levels of patterns called conceptual, formulation, and generation patterns, as shown in Figure 1, and which address the definition of the development vision, the formulation of the urban programme, and the generation of design solutions, respectively.

In order to become operative, patterns have the structure of a design machine. (Stiny and March, 1981) A receptor describes the objects and events in a context by extracting the properties and measurements that permit their description in terms of some fixed set of categories used to describe urban environment. This means that the receptor recognizes the occurrence of the pattern. An effector produces design solutions defined by shapes and/or symbols that result from the recursive application of rules to the set of contextual descriptions to obtain the urban program and then the design solution. Each phase indicated in Figure 1 corresponds to a design machine which output respectively, development vision, urban program and urban designs. In Pre-design Phase 1 a design machine processes conceptual patterns; in Pre-design Phase 2 a linked design machine processes formulation patterns; and in the generation phase another machine processes generation patterns. Typically, conceptual patterns produce the specifications of a development vision, a set of generic concepts or concept goals to achieve in the development of a specific site. Formulation patterns start from descriptions of the design context at the current scale and a set of generic goal descriptions set at a larger scale (part of the development vision) and then produce a set of detailed descriptions of design solutions that are adequate to the context using description grammars. For instance, descriptions might associate the need of a park with the existence of a certain number of people which also is associated with a certain amount of built floor area within a specific cultural context. The rules edited in the ontology may specify also the weights or probability of a certain pattern to occur, as well as preferable relationships with other patterns. The obtained descriptions correspond to the urban program requirements. Generation patterns start from the description of programmatic requirements and generate a solution using discursive grammar rules (description and shape grammars).

The generation of public squares requires two kinds of decisions: (1) the distribution of squares (and square types) in a grid and (2) which types of squares to generate, that is, which square pattern to instantiate. Structural main plazas are located before the grid is generated. Other squares are applied after a grid is generated. The cells in a grid, regular or non-regular, can be transformed into blocks or squares. The distribution of squares is essentially a semantic issue which is related with contextual features and sustainable planning criteria. (Barton et al., 2003) Generation is, therefore, based on the description of the context for which a theory provides the criteria to produce descriptions of adequate design goals, that is, the design. Rules of the first kind (1) establish the relations between existing situations, locations, and needs of particular types of public spaces; and rules of the second kind (2) establish the internal descriptions of designs for particular types of public spaces. A PSP is instantiated by a shape grammar which provides a language of designs to generate a particular square type. The construction of design languages for urban design is a matter of concern of the research being developed within the context of the generation module in the City Induction project. More information on this subject can be found in Beirão et al. (2011).

CONCLUSIONS

Urban programs can be inferred from contextual data using public space patterns (PSP). These patterns enclose a number of complex concepts describing public spaces and relationships among them. The PSP ontology is capable of finding new implicit relationships which are difficult to describe otherwise. The use of a wide range of implicit and explicit rules, concerning by five different dimensions and drawn from existing standards and spatial studies, can reduce the ambiguity of the selection and location of patterns. It is the exploration of explicit and implicit relationships that allows the formulation of the urban program.

The model described in this paper is already being developed and implemented. This paper describes the foundations of the model and future research will continue developing detailing the model and the implementation. In practical terms, PSPs are being applied using a series of case studies to test the semantic information contained in the pattern location rules. Case studies provide a basis for the verification of the relationships among patterns. This will help to refine the description rules for each pattern in a given context, thereby facilitating the development of the rules underlying the conceptual model.

The integration of patterns descriptions in ontologies already tested in the 4CityPlan interface (Montenegro et al, 2011) should constitute a basis for further development of the urban patterns model that constitute part of the core of the urban design model proposed within the context of the CityInduction project. The solution of the location problem will likely require the use of search algorithms. Future work will be concerned with the identification of the adequate algorithm among heuristic, optimization, and reactive-agents methods.

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REFERENCES

Alexander, C et al. 1977, *A Pattern Language: Towns, Buildings*, Construction, Oxford University Press, New York.

Ashcraft, HW 2008, B*uilding Information Modelling: A Framework for Collaboration*, The Construction Lawyer, 28 (3), pp. 5-19.

Barton, H, Grant, M, Guise, R 2003, *Shaping Neighbourhoods: a guide for health, sustainable and vitality,* Spon Press, London.

Beirão, JN, Duarte, JP, Stouffs R 2011, *Creating Specific Grammars with Generic Grammars*: Towards Flexible Urban Design, Nexus Network Journal 13 (1) 73-111.

Duarte, JP, Beirão, JN, Montenegro, N, Gil, J forthcoming 2011, *City Induction: formulating, generating, and evaluating urban plans*, in S.M. Arisona; Aschwanden, G.: Halatsch, J.; Wonka (eds.) Digital Urban Modelling and Simulation, CCIS Series Communications in Computer and Information Science Series, Springer-Verlag.

Gamma, E, Helm, R, Johnson, R, Vlissides, J 1995, *Design Patterns: Elements of Reusable Object-Oriented Software,* Addison-Wesley, Reading, MA.

Gil, J, Beirão, JN, Montenegro, N, Duarte, JP accepted 2011, *On the discovery of urban typologies: Data mining the multi-dimensional morphology of urban areas*, Accepted for publication in Urban Morphology. Published by International Seminar on Urban Form, France.

Kolbe, T, Gröger, G, Plümer, L 2005, CityGML: *Interoperable access to 3D city models, Geo-information for disaster management*, p.883–899.

Krier, R 1979, *Urban Space*, Rizzoli.

Metral, C et al. 2010, *Ontology-based approaches for improving the interoperability between 3D urban models*, Journal of Information Technology in Construction, 15.

Moughtin, C 2003, Urban design: street and square, 3rd Ed., Architectural Press, Oxford.

Montenegro, N and Duarte, JP 2009, *Computational Ontology of Urban Design: Towards a City Information Model, Computation*: The New Realm of Architectural Design [27th eCAADe Conference Proceedings / ISBN 978-0-9541183-8-9] Istanbul (Turkey) 16-19 September 2009, pp. 253-260

Montenegro, N 2010, *Building a Pre-Design Ontology: Towards a model for urban programs*, MSc. Dissertation, Faculty of Architecture, Technical University of Lisbon, Lisbon.

Montenegro, N, Gomes, J, Urbano, P, Duarte, J 2011, *An OWL2 Land Use Ontology: LBCS*, Accepted for publication in Cities, Technologies and Planning" (CTP 11) in conjunction with the 2011 International Conference on Computational Science and its Applications (ICCSA 2011)

Sintek, M et al. with Noy, NF 2001, *Creating semantic web contents with protege-2000*. IEEE Intelligent Systems, 16(2), p.60–71.

Stiny, G and Gips, J 1972, S*hape Grammars and the Generative Specification of Painting and Sculpture, Information Processing*, 71, pp. 1460-1465.

Stiny, G and March, L 1981, *Design Machines*, Environment and Planning B: Planning and Design, 8, pp. 245-255.

Stiny, G 1981, *A note on the description of designs*, Environment and Planning B: Planning and Design, 8, pp. 257-267.

Teller, J, Lee, JR, Roussey, C 2007, *Ontologies for urban development*. Springer Publishing Company, Incorporated, p.212.

URL:

[1] people.brunel.ac.uk/~mastjjb/jeb/or/facloc.html [Accessed June 1, 2011].

[2] webloria.loria.fr/~simoniol/OSimonin/travaux/ATT06MoujahedSimonin.pdf [Accessed June 1, 2011]