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Gerhard Schmitt, Ludger Hovestadt, Luc Van Gool, Frédéric Bosché, Remo Burkhard, Suzanne Coleman, Jan Halatsch, Michael Hansmeyer, Silke Konsorski-Lang, Antje Kunze and Martina Sehmi-Luck

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We hope that the first eCAADe conference in Zurich, the theme of Future Cities, the presentations and the interactions will initiate a new debate on computer aided urban design and planning and thank all participants for coming to Zurich.

Contents

Ontologies for Cities of the Future

The quest of formalizing interaction rules of urban phenomena

Armando Trento[1], Antonio Fioravanti[2], Gianluigi Loffreda[3].
[1,2,3]Sapienza University of Rome - Italy
[1,2,3]http://dau.uniroma1.it
[1]armando.trento@uniroma1.it, [2]antonio.fioravanti@uniroma1.it, [3]gianluigi.loffreda@uniroma1.it

Abstract. *"A city can not be designed" Watanabe [1]: our ambition can be at the maximum to guide someway and in some part its growth. So as planners need tools to aid an open design with uncertain goals. This research group begin to develop such a tool at high level of abstraction (Fioravanti 2008), with the aim of investigating the potentiality of a collaboration among complementary research domains.*
The present work reports about early implementation results of an innovative approach developed by the authors, for representation of design knowledge. It has been identified in the Urban Design Ontology (Montenegro and Duarte 2009) some design entities and their internal relationships that have been formalized and visualized by means of an intuitive interface. As a matter of fact, this approach, by means of inference engines allows coherence's check and constraint verification, pointing out incompatibility between initial design program and each partial specialist design solution and/or the overall shared one.
Keywords. *Knowledge formalization; urban design ontology; knowledge structure; collaborative design; open design.*

Complexity and inessentials of city design

In the last decades, "material changes in our lives are almost irrelevant. The important changes are demographic, in health care and education. Today, the majority of people around the world live in cities. Urbanization changes your worldview. So, the real change is in meaning, not in goods." (Drucker 2007).

The actual activity of design and planning extends increasingly into all sectors involving the final product: our lives.

To develop such scenarios on possible long-term changes in cities and their territorial contexts, some existing researches base their approach on the analysis of demographic, economic, technological, environmental, etc... phenomena which interact with the spatial organization of urban and territorial systems.

As it is necessary to try and foresee the often unpredictable city changes resulting from new inventions and advances in technology, tools, methods and social customs, a huge amount of multi-disciplinary knowledge needs to be managed along the planning and the design practice. But the design is often an inappropriate term to describe what architects do about cities. We agree with Watanabe [1] "a city can not be designed". As a matter of fact a city, from a designer point of view, is a project without a beginning nor an end: an "open design". Our ambition can be at the maximum to guide someway and in some part its growth.

So as we need tools to aid an 'open design' with uncertain goals.

We begin to develop such a tool at high level of abstraction (Fioravanti 2008) to collaboratively design buildings. This system is conceived as a general tool that has also the capability to be used in several specialist domains. The knowledge both Specialist ones and Common one (Carrara et al. 2009) has been implemented with its inferential engine that allows to discover contradictions and incoherencies among different design solutions. The system has not a predefined design path, but is data driven, so it can be applied to a flexible "open design". This paper does not concern with a specific inference engine for city planning but it is focalized on a first implementation of content of knowledge related to city planning.

This knowledge to be computed and shared, has to be machine and designer's use oriented, formalized and managed: referring to the present situation, the research of new effective ways for representing multidisciplinary design knowledge is needed.

More, and heterogeneous, data are more demanding is its representation so it is needed an higher abstraction layer of knowledge to be related and computed. We think that the system model we succeeded applied in building and architectural design, owing to a 'general template' representation model (Carrara et al. 2009), can be usefully applied to urban planning (Fig. 1). But the system conceived for architecture is quite different for planning one, so the overall research has been split up into two steps:

- the first one deals with entity representations, where the 'general template' representation is applied by analogies to another domain knowledge;
- the second one refers to rules of inference engine, where it is observed a more deep difference with 'design' in the strict sense.

The present work reports about early results of an explorative phase of collaboration founded on a shared innovative approach among complementary studies developed by the authors. The general framework of the parallel ongoing researches faces the problem of multidisciplinary knowledge representation and it is mainly aimed at its collaborative management.

The idea is related to a new way for representing technical knowledge - referring to cities and their complex territorial contexts - and for exchange

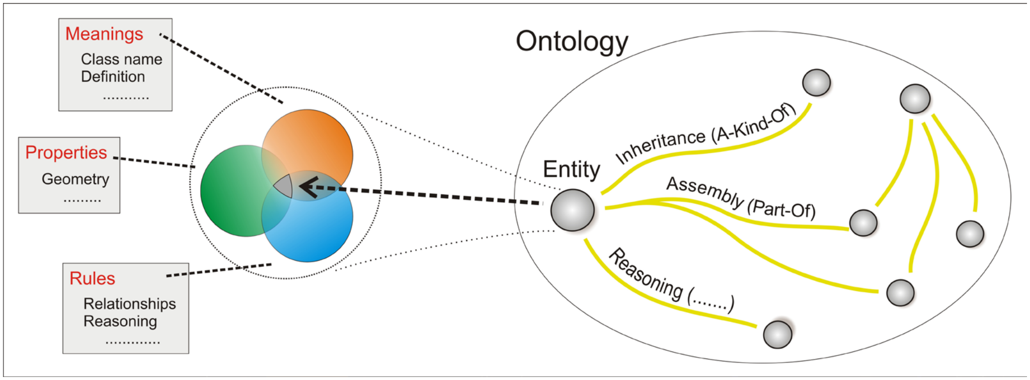

Figure 1
General representation of entities and their features by the triplet - Meaning, Properties and Rules.

it in the design process at the site planning scale including formulation, generation, and evaluation modules.

Knowledge representation model: The quest of planning

One fact seems to be clear: There are several models of urban programs used in the creation of urban plans. It seems also clear that some have failed tremendously; and others have lacked implementation, remaining as theoretical guides. Still, its common flaw appears to be the lack of crucial urban matters like sustainability factors. This has resulted, systematically, in the creation of inappropriate plans that are far from satisfying urban populations needs, and far from making an appropriate use of site features.

The task of creating a good plan in order to increase the quality of urban life seems to be relatively easy at a first glance, by simply producing a full and resourceful program, built according to urban codes, regulations, and standard parameters. However the problem is more complex. Other urban programs have taken upon that task and have failed in the implementation of the plan.

Creating a plan seems to be similar to the task of creating a language (Deacon 1998), or even to use a new language, requiring an additional effort to understand its new rules. In classical language (linguistics) there is an interaction between two crucial components: the semantics (the ideas), and the syntax (the form according to which ideas are organized) (Chomsky 2002). Connecting the two, in order to create logic, is an enormous task, partially because the urban language (or the planning language) and its structure is surely a natural language of human beings, but it is hidden in a seeming unconscious use of "things" (stones, glass, concrete, void, enlargement, route, path, etc.) that create an artificial landscape. Understanding and clarify it is the core of research efforts.

Ontologies for representing design knowledge

Although based on basic principles, the mission of planning is complex. Urban planning deals with extended variables (Mabert et al. 2003), becoming difficult to establish the right ingredients to develop urban programs (Jabareen 2006). One way to solve the amount of information is to clarify it by creating a knowledge model called ontology (Gruber 1995).

Referring to design, an ontology provides an accurate mechanism to explicit, increase and exchange the knowledge about a specific subject matter common to some actors.

The first step needed to represent relevant concepts in design consists in a well defined, homogeneous entities' sets by means of task oriented formalized ontologies. Each actor in the design process has to be able to (re-) model the entities and rules assumed in his own ontological domain, in order to be supported in the evaluation and suggestion of design solutions.

The ontologies universe comprises several systems depending on the main target of the specific design process: a specific research task, developed by City Induction Group (Beirão et al. 2009), concerns the selection of core features foreseeing the Urban Design Ontology - UDO.

"Such a selection requires a disclosure of the crucial components of the urban planning process, that is, the nature of urban space (the field of its application), the nature of design actions (the field of its proposals), and the interoperability of those within a supporting computational system (the field of its administration)".

Aware of the impossible completeness of any formal representation system of reality (Hofstadter 1988), the proposed model arises as a goal the concepts modelling, characteristics and in general, of the knowledge processes involved in building and urban design.

Thinking about building design, urban planning and future cities organization, this research group has specified three different main areas:

- Building: Spaces, Components, Equipments, MEP;
- Settlement: Buildings, Infrastructures, Context, Environment, Urban spaces;
- Humans: Users (different kinds), Designers, Clients, Social Communities;

The specific objective is reflected in the specificity of the model, therefore, affected by the main domain interested, this model is framed accordingly and fits into modules conceptually homogeneous and typical scope-oriented (Carrara et al. 2009).

Starting by creating a mechanism for a purpose whatever, without understanding its wide contextual framework induces often, the creation of "efficient" laboratory prototypes. This happens mainly because such prototypes are developed within a very limited context, with rules that are only efficient in such limited laboratory environments (Pickering 1992). Unfortunately, such prototypes are in general inefficient when dealing with real world problems.

To improve prototypes - How can it be done?

An ontology editor seems to be one of the planning model's preferable platforms, because it can easily build up a structured bridge between elements (abstract or physical) and rules of the model. In fact, some of the ontology software editors possess today a procedural framework to develop rules, and also flexible protocols for design solutions (Trento 2009).

The straight linking process between data-taxonomic-structure (to be formalized by means of ontology class editor) and data-description-rules (by ontology rules editor) allows agents (humans or software) to eliminate part of the hard task of translation that usually occurs when it's necessary to transfer information among different platforms.

The planning process requires also the establishment of an adequate communication with stakeholders, to share ideas within a planning team, or to present a shared strategy by a community. The planning process requires thus a method to select and organize data that describes the urban context, to generate a description of the solution for that context, and to share and communicate the solutions to the stakeholders.

One of the main objectives of this research is precisely to capture the rules of interaction of urban phenomena in a boarder context. The best way to trail such an objective is by start digging in the planning framework in order to describe its basic structure.

A new knowledge modelling representation

An innovative level for knowledge representation and management is the subject of an in progress research by the authors.

Specifically, 'rules' can be classified in:

- Reasoning Rules and Algorithms: formal codes for analysis, checking, evaluation and control of concepts associated to specific entities with inferential procedures of 'If-Then' type.
- Codes, Laws and in force Rules: context dependant rules referred to the in force law that will become constraints for the entities which they are related to;
- Consistency Rules: algorithms to check the consistency of values, parameters, attributes, instances, relationships and properties referring to the specific meanings associated to each entity in the specific context on which it is used;
- Good Practice Rules: non-formalized rules, rules of thumb, practices and concepts that represent part of the reasoning process of each actor on his own specific disciplinary domain during the design process.

By means of Inference Engines able to match rules among the ontologies - all of which formalized into a self-sufficient syntactically coherent IT structure - a deductive layer allows the designers to use in a coherent manner different levels of abstraction, or to exploit a conceptual interoperability.

The dynamic and semantically-specific representation detecting incoherent/favourable situations by means of a constraint rule mechanism can allow them to be highlighted and managed in real time. At the same time it allows actors to make alternatives, more consciously reflecting on the consequences of their intents.

In this way the impact of a networked ontology-based system can make actors more aware of overall design problems, helping them in operating more participative and shared choices.

UDO Implementation

In this paper it is presented the early implementation result (according to the Semantic Web standards) of some contents of Urban Design Ontology - UDO - recently published by the City Induction Group (Beirão et al. 2009).

Three are the steps the implementation path can be methodologically subdivided:

- technical knowledge identification (in terms of domain ontology contents: classes of entities and relationships among them)
- technical knowledge formalization (in terms of ontology structured meanings/properties/rules)
- technical knowledge management (in terms of design constraints checking, design generative algorithms, ontology interoperability and reasoning).

In this case study, oriented to plan operative objectives, contents are provided by the work of City Induction Group: the early definition of "Urban Design Ontology was developed to encode the features within a designing system, that is, they are supposed to encode urban structures for designing and not to describe the urban environment which can sometimes be inconsistent with the embedded qualitative definitions".

The UDO "defines and organizes the significant relations among the various types of objects and features found in urban space to be used in the urban design process. In order to understand the city and its complex system of relationships", this ontology "is divided into sub-ontologies or systems, each one containing features from a specific domain of the city structure, namely 'Networks', 'Blocks', 'Zones', 'Landscapes' and 'Focal Points' (Fig. 2).

'Networks', for instance, describe the domain

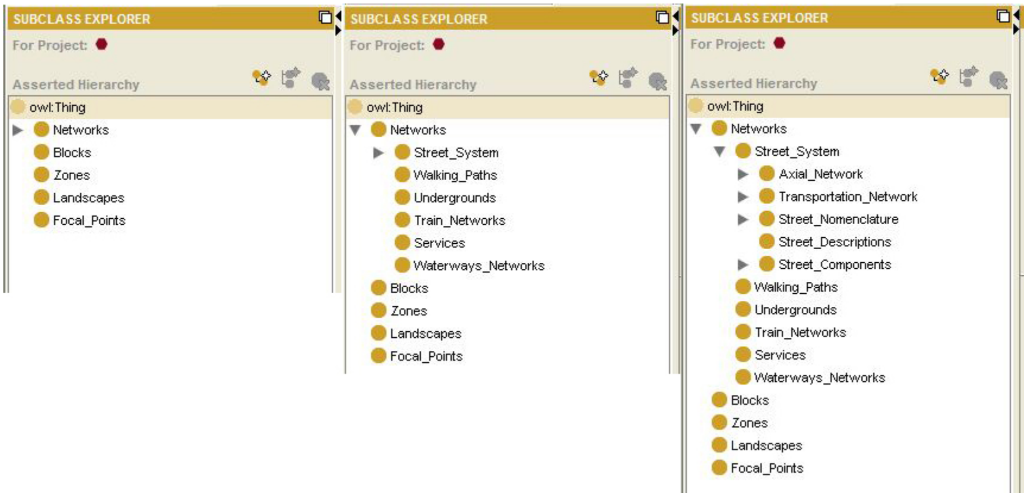

Figure 2
Blow up of hierarchy in Urban Design Ontology Classes.

of connectivity and city morphology in which they identify the street system (Montenegro and Duarte, 2009)".

Assumed the theoretical model, this proceeded to formalize and implement some segments of it.

Operatively we used for the implementation phase an Ontology Editor, a tool which allows various approaches to knowledge representation. Very often, meanings as well as properties and/or rules among different design entities, are implicit into the "visual" representation shared among the actors involved in the design process.

Design solutions usually are suggested and presented by architects or urban planners referring to a small section of a more complex city portion. Without any tag, it could be really difficult to distinguish each entity and to make a qualitative use of its quantitative computational values. Even assigning a name (and consequently, a multiplicity of operative meanings) to each object (building, block, street and more widely "functions"), most of the implicit relationships, links and constraint will remain hidden.

By using Protégé ontology editor the group implemented a set of entity representative of the UDO Street System to check the theories above mentioned (Fig. 3).
This representation and management model of the project entities (Street Components, Street Nomenclature, Street Descriptions, Axial Network, Transportation Network) can provide a real-time explanation of the meanings associated with the design solutions, as long as exists a dynamic connection between the ontological representation and the usual one of each stakeholder.

This kind of concepts representation allows a quick check of constraints even to "non specialist" actors: the use of different definition layers associated to different kind of links or constraints, easily point out inconsistencies or incoherencies.

By using only an implicit representation, many kinds of constraint will not become recognizable by all the actors. In a traditional design process, this

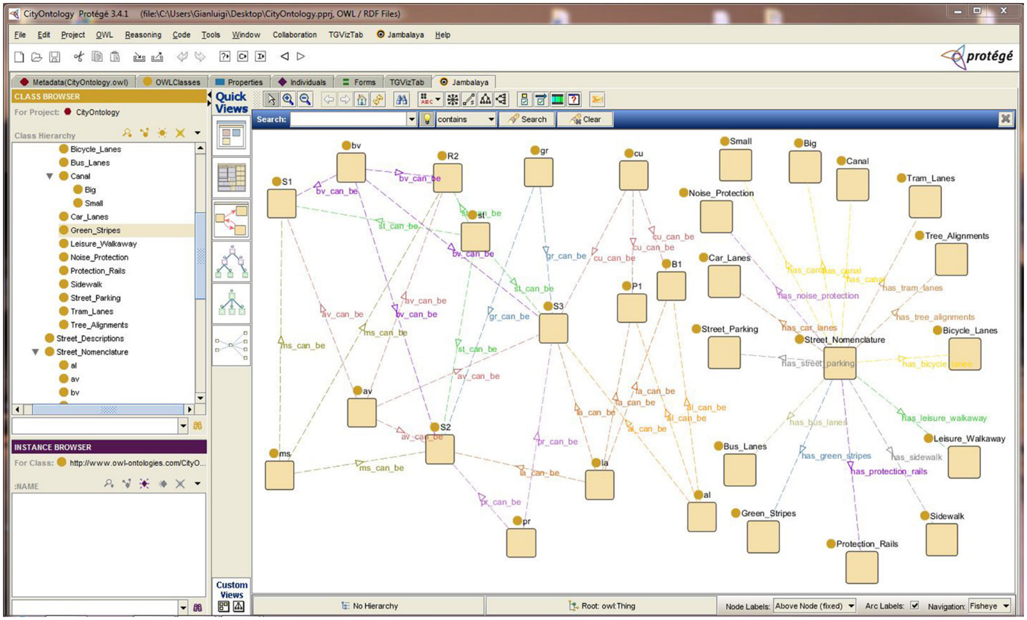

Figure 3
Visualization of some internal relations among the Urban Design Ontology Classes.

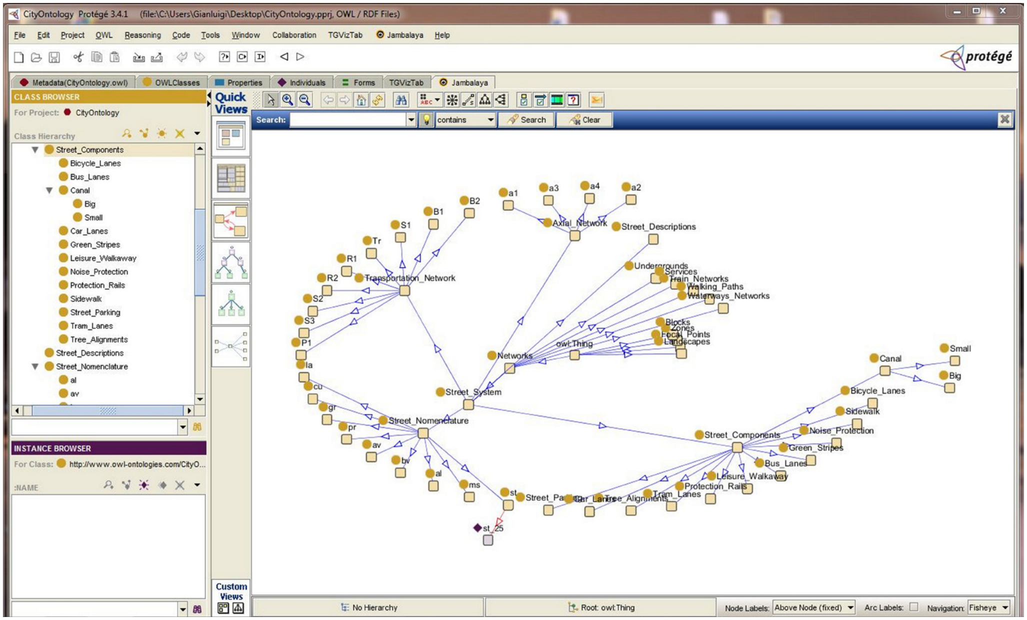

Figure 4
Visualization of some internal relations among the Urban Design Ontology Classes.

kind of problems will easily change into "time consuming" process made of continuous data exchange to explain rules and codes hidden behind specific design solutions.

Conclusions

With the aim of investigating the potentiality of a collaboration among complementary studies, the present work reports about early implementation results of an innovative approach developed by the authors, for representation of urban planning knowledge.

It has been identified in the Urban Design Ontology - recently defined by City Induction Group (Beirão et al. 2009) - a sub-domain of the "Networks" top-level class, the Street System. Subsequently some design entities and some of their internal relationships have been formalized and visualized by means of an intuitive interface (Fig. 4).

A clear and explicit concept representation including links, relationships, rules and constraints has been developed by the authors using Protégé ontology editor, the TGViz plug-in and the Jambalaya plug-in to show the modelled links and constraints.

As a matter of fact, this approach, although did not bring to exciting results from a qualitative relational perspective, it allows coherence's check and constraint verification at different levels of abstraction, pointing out each incompatibility between initial design program and each partial specialist design solution and/or the overall shared one.

The final objective of this research path is to represent in a intuitive manner the real complexity of cities by means of ontologies, exploring methods for capturing interaction rules of urban phenomena, without conflicting with their internal logic.

Future work is aimed at verifying the validity of this kind of knowledge formalization through a case study: an application of planning rules to the formalized ontology entities will be a representative example of its operative support in urban planning.

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