

30th eCAADe

CONFERENCE PRAGUE 2012

Czech Technical University in Prague, Czech Republic

vol. 1

DIGITAL PHYSICALITY

Edited by Henri Achten, Jiří Pavlíček, Jaroslav Hulín, Dana Matějovská

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1st Edition, September 2012

Digital Physicality – Proceedings of the 30th International Conference on Education and research in Computer Aided Architectural Design in Europe, Prague, Czech Republic, September 12-14, 2012, Volume 1. Edited by Henri Achten, Jiří Pavlíček, Jaroslav Hulín, Dana Matějovská. Brussels: Education in Computer Aided Architectural Design in Europe; Prague: České Vysoké Učení Technické v Praze.

ISBN 978-9-4912070-2-0 (eCAADe)

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Publisher: eCAADe (Education and research in Computer Aided Architectural Design in Europe) and ČVUT, Faculty of Architecture

www.ecaade.org

Cover design: Jakub Čaja

Printed at: Opus V.D.I., Prague

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Digital Physicality

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September 12-14 2012
Prague, Czech Republic
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<http://ecaade2012.molab.eu>

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Contents

5	Theme: Digital Physicality
7	Acknowledgements
9	Keynote speakers
11	List of reviewers
13	Contents
21	CAAD Curriculum
23	Impact of Digital Design Methods on Physical Performance Anetta Kępczyńska-Walczak
29	Strategic Thinking on the Redesign of a Foundational CAAD Course: Towards Comprehensive Training on Digital Design Antonieta Angulo, Joshua Vermillion
39	Two Approaches to Implementing BIM in Architectural Curricula Ning Gu, Bauke de Vries
49	Reforming Design Studios: Experiments in Integrating BIM, Parametric Design, Digital Fabrication, and Interactive Technology Tienyu Wu, Taysheng Jeng
55	An Innovative Approach to Technology Mediated Architectural Design Education: A Framework for a Web-Based Socio-Cognitive Eco-system Tuba Kocaturk, Riccardo Balbo, Benachir Medjdoub, Alejandro Veliz
67	Component-Based Design Approach Using BIM Andrzej Zarzycki
77	Educating New Generation of Architects Leman Figen Gül
87	4D Modeling and Simulation for the Teaching of Structures Principles and Construction Techniques: Towards Modeling and Visualization Guidelines for High-Rise Buildings Sylvain Kubicki, Annie Guerriero, Pierre Leclercq, Koenraad Nys, Gilles Halin
97	Building Performance Modeling in Non-Simplified Architectural Design: Procedural and cognitive challenges in Education Max Doelling, Farshad Nasrollahi
107	How to Deal With Novel Theories in Architectural Education: A Framework for Introducing Evolutionary Computation to Students Ethem Güner, Sema Alaçam, Gülen Çağdaş

- 115 Evaluation System for Content and Language Integrated Learning in Architecture Using Immersive Environments**
Matevz Juvancic, Tadeja Zupancic
- 125 Cybergogy as a Framework for Teaching Design Students in Virtual Worlds**
Scott Chase, Lesley Scopes
- 135 Developing Online Construction Technology Resources in Tectonic Design Education**
Jeremy J. Ham, Marc Aurel Schnabel, Sambit Datta
- 143 City Modelling**
- 145 Cities and Landscapes. How do They Merge in Visalisation: An Overview**
Emine Mine Thompson
- 157 A Parametric Approach to 3D Massing and Density Modelling**
Greg Pitts, Mark Luther
- 167 Parametric Urban Design: Joining Morphology and Urban Indicators in a Single Interactive Model**
José Beirão, Pedro Arrobas, José Duarte
- 177 Schizoanalytical Digital Modelling for Urban Design: Incorporating the Indexed Keys Methodology Into the Anthropological Analyses of Urban Structures**
Małgorzata Hanzl
- 187 Parametric Building Typologies for San Francisco Bay Area: A Conceptual Framework for the Implementation of Design Code Building Typologies Towards a Parametric Procedural City Model**
Antje Kunze, Julia Dyllong, Jan Halatsch, Paul Waddell, Gerhard Schmitt
- 195 Supporting Urban Design Learning With Collective Memory Enhanced Virtual City: The Virtual Jalan Malioboro Experiment**
Sushardjanti Felasari, Chengzhi Peng
- 203 Integrated Multi-Criteria Modeling and 3D Visualization for Informed Trade-Off Decision Making on Urban Development Options**
Noemi Neuenschwander, Ulrike Wissen Hayek, Adrienne Grêt-Regamey
- 213 Virtual City Models: Avoidance of Obsolescence**
Peter James Morton, Margaret Horne, Ruth Conroy Dalton, Emine Mine Thompson

- 225 Digital Aids to Design Creativity**
- 227 Interpretation Method for Software Support of the Conceptual Redesign Process: Emergence of New Concepts in the Interpretation Process**
Jakub Jura, Jiří Bíla
- 235 Design Optimization in a Hotel and Office Tower Through Intuitive Design Procedures and Advanced Computational Design Methodologies: Façade Design Optimization by Computational Methods**
Subhajit Das, Florina Dutt
- 245 On Creativity And Parametric Design: A Preliminary Study of Designer's Behaviour When Employing Parametric Design Tools**
Sheng-Fen Chien, Yee-Tai Yeh
- 255 Scripting Shadows: Weaving Digital and Physical Environments Through Design and Fabrication**
Eva Sopeoglou
- 259 Visual Narratives of Parametric Design History: Aha! Now I See How You Did It!**
Halil I. Erhan, Rodolfo Sanchez, Robert F. Woodbury, Volker Mueller, Makai Smith
- 269 "Divide Et Impera" to Dramatically and Consciously Simplify Design: The Mental/Instance Path - How Reasoning Among Spaces, Components and Goals**
Antonio Fioravanti, Gianluigi Loffreda, Davide Simeone, Armando Trento
- 279 Parametric Tools for Conceptual Design Support at the Pedestrian Urban Scale: Towards Inverse Urban Design**
Anastasia Koltsova, Bige Tuncer, Sofia Georgakopoulou, Gerhard Schmitt
- 289 The Disassembly of a Musical Piece and Its Conversion to an "Architectural" Pathway: An Algorithmic Approach**
Stamatis Psarras and Katherine A. Liapi
- 299 Generative Design**
- 301 Swarm Materiality: A Multi-Agent Approach to Stress Driven Material Organization**
Marios Tsiliakos
- 311 Decoupling Grid and Volume: A Generative Approach to Architectural Design**
Hao Hua
- 319 Creativity With the Help of Evolutionary Design Tool**
Philippe Marin, Xavier Marsault, Renato Saleri, Gilles Duchanois

- 329 Emergent Reefs**
Alessandro Zomparelli, Alessio Erioli
- 339 Behavioural Surfaces: Project for the Architecture Faculty Library in Florence**
Tommaso Casucci, Alessio Erioli
- 347 Acoustic Environments: Applying Evolutionary Algorithms for Sound Based Morphogenesis**
Isak Worre Foged, Anke Pasold, Mads Brath Jensen, Esben Skouboe Poulsen
- 355 Exploring the Generative Potential of Isovist Fields: The Evolutionary Generation of Urban Layouts Based on Isovist Field Properties**
Sven Schneider, Reinhard König
- 365 Speculative Structures: Reanimating Latent Structural Intelligence in Agent-Based Continuum Structures**
Joshua M. Taron
- 375 Modeling of RL- Cities**
Aant van der Zee, Bauke de Vries
- 381 User Participation in Design**
- 383 Digital System of Tools for Public Participation and Education in Urban Design: Exploring 3D ICC**
Anja Jutraz, Tadeja Zupancic
- 393 Crowdsourcing: Theoretical Framework, Computational Environments and Design Scenarios**
Rivka Oxman, Ning Gu
- 403 Visual Support for Interpretation of Spatial Complexities in Urban Environments**
Spela Verovsek, Tadeja Zupancic
- 413 Affordable Web-Based Collaborative Mapping Environments for the Analysis and Planning of the Green Networks of Brussels**
Burak Pak, Johan Verbeke
- 423 Shape Studies**
- 425 Fuzzy Approach to the Analysis of Architectural Composition: As Applied to Villa Design by Adolf Loos**
Zuzana Talašová

- 433 Leaving Flatland Behind: Algebraic Surfaces and the Chimaera of Pure Horizontality in Architecture**
Günter Barczik
- 443 Recursive Embedding of Gestalt Laws and Shape Grammar in the Weaving Design Process**
Rizal Muslimin
- 451 Shape Grammars for analyzing Social Housing: The Case of Jardim São Francisco Low-Income Housing Development**
Max Andrade, Leticia Mendes, Giovana Godoi, Gabriela Celani
- 459 Generation of Energy-Efficient Patio Houses With GENE_ARCH: Combining an Evolutionary Generative Design System With a Shape Grammar**
Luísa G. Caldas, Luís Santos
- 471 Transformation Grammar for Housing Rehabilitation: From a Specific to a General Grammar**
Sara Eloy, José Pinto Duarte
- 479 On Shape Grammars, Color Grammars and *Sortal* Grammars: A Sortal Grammar Interpreter for Varying Shape Grammar Formalisms**
Rudi Stouffs
- 489 GRAMATICA: A General 3D Shape Grammar Interpreter Targeting the Mass Customization Of Housing**
Rodrigo Correia, José Duarte, António Leitão
- 497 Bio-Origami: Form Finding and Evaluation of Origami Structures**
Daniel Baerlecken, Matthew Swarts, Russell Gentry, Nixon Wonoto
- 505 Estimating the Fractal Dimension of Architecture: Using Two Measurement Methods Implemented in AutoCAD by VBA**
Wolfgang E. Lorenz
- 515 Simulation, Prediction, and Evaluation**
- 517 Study on an Architect-Oriented Workflow for Freeform Surface Design Tools**
Chengyu Sun, Junchao Lu, Qi Zhao
- 525 An Event-Based Model to Simulate Human Behaviour in Built Environments**
Davide Simeone, Yehuda E. Kalay
- 533 Real-Time Electric Mobility Simulation in Metropolitan Areas: A Case Study: Newcastle-Gateshead**
Eiman Elbanhawey, Ruth C Dalton, Emine Mine Thompson, Richard Kottor

- 547 Architectural Software Tool for Structural Analysis (Atsa) Intended for Intuitive Form-Finding Process**
Lukáš Kurilla, Marek Růžička, Miloš Florián
- 555 Iterative Refinement Through Simulation: Exploring Trade-Offs Between Speed and Accuracy**
Patrick Janssen, Vignesh Kaushik
- 565 Physics-Based Modeling as an Alternative Approach to Geometrical Constrain-Modeling for the Design of Elastically-Deformable Material Systems**
Moritz Fleischmann, Achim Menges
- 577 Acoustic Consequences of Performative Structures: Modelling Dependencies Between Spatial Formation and Acoustic Behaviour**
Dagmar Reinhardt, William Martens, Luis Miranda
- 587 Urban Acoustic Simulation: Analysis of Urban Public Spaces Through Auditory Senses**
Merate Barakat
- 593 Explauralisation: The Experience of Exploring Architecture Made Audible**
Thomas Krijnen, Jakob Beetz, Jacob Voorthuis, Bauke de Vries
- 599 Emergence as a Design Strategy in Urban Development: Using Agent-Oriented Modelling in Simulation of Reconfiguration of the Urban Structure**
Peter Buš
- 607 Equalizing Daylight Distribution: Digital Simulation and Fabrication of Optimized Inner Reflectors and Bottom Extractors for a Light-Duct**
Shinya Okuda, Xiaoming Yang, Stephen K Wittkopf
- 613 Meeting Simulation Needs of Early-Stage Design Through Agent-Based Simulation**
Gabriel Wurzer, Nikolay Popov, Wolfgang E. Lorenz
- 621 Parallel Analysis of Urban Aerodynamic Phenomena Using High and Low-tech tools**
Flora Salim, Rafael Moya
- 631 Virtual building Construction Laboratory in Undergraduate Engineering Education**
Maciej Andrzej Orzechowski, Agata Włóka

- 637 Design Tool Development**
- 639 ar:searchbox: Knowledge Management for Architecture Students**
Christoph Langenhan, Arne Seifert, Astrid Teichert, Frank Petzold
- 647 Visualizing Post-Occupancy Evaluation Data: Rationale, Methodology and Potential of Enviz, a Visualization Software Prototype**
Panagiotis Patlakas, Hasim Altan
- 655 Lawnmower - Designing a Web-Based Visual Programming Environment That Generates Code to Help Students Learn Textual Programming**
Gabriel Wurzer, Burak Pak
- 665 System Design Proposal for an Urban Information Platform: A Systems Proposal**
Gideon Aschwanden, Chen Zhong, Maria Papadopoulou, Didier Gabriel Vernay, Stefan Müller Arisona, Gerhard Schmitt
- 675 Open Graphic Evaluative Frameworks: A Climate Analysis Tool Based on an Open Web-Based Weather Data Visualization Platform**
Kyle Steinfeld, Stefano Schiavon, Dustin Moon
- 683 Building-Use Knowledge Representation for Architectural Design: An Ontology-Based Implementation**
Armando Trento, Antonio Fioravanti, Davide Simeone
- 691 Design Guidance for Low-Energy Dwellings in Early Design Phases: Development of a Simple Design Support Tool in SketchUp**
Vincent Macris, Lieve Weytjens, Kenny Geyskens, Marc Knapen, Griet Verbeeck
- 701 Parametric Urban Patterns: Exploring and Integrating Graph-Based Spatial Properties in Parametric Urban Modelling**
Martin Bielik, Sven Schneider, Reinhard König
- 709 Application of Fuzzy Logic for Optimizing Foldable Freeform Geometries: An Example of a Practical Application – A Foldable Window Shade**
Madalina Wierzbicki-Neagu, Clarence Wilfred de Silva
- 719 Volume Rendering in Architecture: Overlapping and Combining 3D Voxel Volume Data with 3D Building Models**
Christian Tonn, René Tatarin

727	Virtual Architecture
729	A Case Study of Using BIM in Historical Reconstruction: The Vinohrady Synagogue in Prague Stefan Boeykens, Caroline Himpe, Bob Martens
739	Virtual Worlds and Architectural Education: A Typological Framework Burak Pak, Caroline Newton, Johan Verbeke
747	Physical and Digital Models for Electronic Spaces: The 3D Virtual Re-Building of the Philips Pavilion by Le Corbusier Alberto Sdegno
755	Urban Games: Inhabiting Real and Virtual Cities Andrzej Zarzycki
765	Index of authors

Building-Use Knowledge Representation for Architectural Design

An ontology-based implementation

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Abstract. *During building design processes, designers have to predict and evaluate future building performances oriented to its intended use and users. Current BIM and IFC technologies support designers allowing data exchange and information interoperability but, since their lack in semantics, they don't provide any knowledge implementation about how the designed building will be actually used and how people will interact with it. The research described in this paper aims to overcome this shortcoming by developing a new modelling approach, oriented to representation and management of knowledge related to future building use and users. The proposed representation model is based on an already accepted ontology-based structure and will make this large amount of knowledge accessible and usable by designers during architectural design processes, in order to enhance the final quality of the design product.*

Keywords. *Design Knowledge Representation and Management; Ontology-based Systems; Building Use Process; Building Performances prediction and evaluation.*

INTRODUCTION

Quality, according to Pirsig's (1981) universal statements, does not belong to the object itself, nor to the subject itself, but to both and to their interactions. In architecture it is terribly true as we have a Building Object and Man/Women that interacts with it (Fioravanti et al., 2011 p. 185).

In a Building Object even if it were very well "formed" in its spaces and technology elements and it were correctly addressed by Relation Structure towards goals, its success would depend on its concrete use. Just for instance the Marcello's Theatre in Rome was (and it still is) actually used as a residential building or the Musée national d'art moderne - Centre Georges Pompidou in Paris is used by visitors

and district inhabitants - just for exhibition -, as the public square under the building was never opened because of terrorist attack fear.

How people "live" a building, their holistic sensation passing through and around its spaces and the perceived quality, relies on two aspects:

- Functional ones – anthropometric movements and perceptions –, f.i. can be represented by Relation Structure and Inference Engines;
- Soul ones - personal believes and social and cultural habits, f.i. can be represented by agent-based models simulating single human behaviours.

The present paper mainly refers to the first aspect of human user behaviour in living buildings and the corresponding knowledge modelling it for a better architectural design process.

In order to improve the quality of a design product, a central task for a multidisciplinary team is to test the proposed design solution, predicting its future performances before, during and after its passage from digital model to real world and vice versa: Digital Physicality | Physical Digitality.

Designers know very well the importance of how the building is modelled in order to manage the design process and to enhance their control on the final product quality.

The advent of BIM technologies and their pervasive diffusion in the professional design studios are introducing an interesting modification of designer habits, extending their capacity to deal with problems and manage conflicts during the building process (feasibility, design, construction, maintenance, use, demolition or re-use phases).

At base of this “designers’ thinking change” is the fact that the decision making process – multidisciplinary, complex and for some aspects highly recursive – relies on the way product/process related knowledge is modelled in the usual CAD design tools.

Studying the most common standards in this field (IFC), we can observe that these classes have

been developed by means of a **space-components product approach**, successful in terms of data exchange and information interoperability between programs, but not intended for human understanding.

This lack of semantics mainly affects the modelled buildings efficacy when it is required to represent and predict its behaviour in terms of usage, safety and comfort.

At the same time, it’s important to consider that, beside the product knowledge representation and its aforementioned deficiencies, what is missing is the representation of **design process knowledge** and how to capitalise such a knowledge.

More specifically, the prediction of future building use by means of the actual standards, tools and technologies is still an open problem, that challenges knowledge engineers and building designers since long time.

Is a matter of fact that human behaviour representation, and its related knowledge management, is a problem that has been faced with more efforts in other research fields such as military operational management or videogames industry.

The aim of this research is the development of a new approach for modelling process knowledge, specifically about building use and user’s behaviour in order to make it accessible and able to support performances simulation.

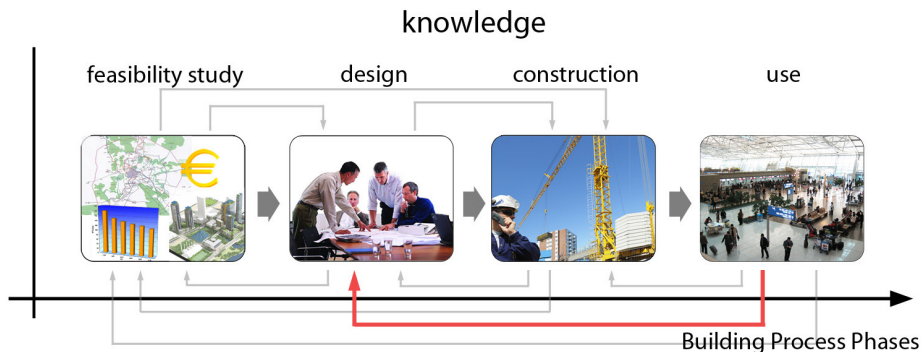


Figure 1
Capitalizing Knowledge
- Forward and Feed-back
knowledge in the building
process. In red the present
paper subject: building use
and architectural design.

Final goal has two main beneficiaries:

- Building designer, whose awareness can be enhanced, since s/he can learn from formalised user's behaviour;
- Building user, that can obtain a better comprehension of her/his interaction with building spaces, and learn how to correctly use them.

This paper reports on advancements achieved in such a direction in terms of theoretical contents and some early implementations developed in the general framework of an on-going, funded International Research.

REPRESENTING USERS-RELATED KNOWLEDGE BY MEANS OF ONTOLOGY

Planners traditional approach conceives in the overlapping of planned processes, usually based on general and consolidated knowledge, to an architectural schema (Wurzer, 2009, 2010). Technical norms and regulations, best practices and, most of all, personal level of expertise, have partially supported designers in evaluating the impact of their design choices on life and 'experience' of building users. Despite that, the increasing complexity of building design in both product and process, the rapid change of how people act in a built environment and their activities because of the introduction of new tools and technologies, and the birth of new design paradigms – the sustainability just to mention maybe the main one – have shown all the limitations of these ways to implement knowledge about users. In addition, the non-deterministic and not a-priori definable na-

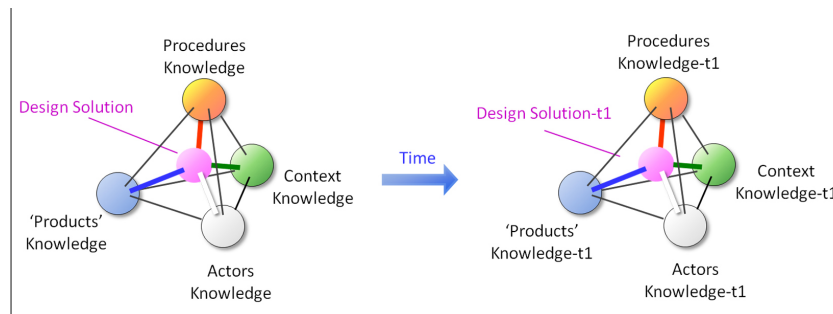
ture of human behaviour, its context dependence and its general complexity make the prediction task very daunting for designers, leaving them just the possibility to count on their own, often limited and biased, understanding of use phenomenon.

To provide a reliable, comprehensive and up-to-date knowledge base on human-building interaction, we thought of relying on a general structure for knowledge representation already presented and discussed among the scientific community by this research group (Carrara et al., 2009) and work to extend its application field to our purpose.

This comprehensive model of architectural design process (Fioravanti et al., 2011) is illustrated by means of a symbolic "knowledge tetrahedron" during the design process (Fig. 2). It makes explicit the "Time" feature: the four knowledge Realms, namely Product, Actor, Context and Process 'shape' the Design Solution during $t \div t1$ time period, representing the states of the system and its dynamic variations of state during the design process.

As of its high abstraction level and its comprehensive universal approach, the same model can be easily extended from the design process to all the following phases of building life cycle: feasibility study, design, construction, use. In fact, representing the knowledge related to building during its use, the realms proposed are still fully valid, while the part of knowledge considered for each of them is different from the design process phase. In this case the Actors Realm comprises knowledge about the future users, their profiles, their attributes; the Procedures

Figure 2
A comprehensive model of architectural design process: knowledge tetrahedron.



Realm is where is formalized the knowledge about the actual process of use of the building, in terms of structured systems of activities, their requirements, their last and so on; in the Context Realm are represented data on how the process of use will be affected by context status (meant in a broad sense involving social, cultural and economic aspects) – for instance if the same product is conceived to be built in different parts of the world, inevitably it will be used in a different way and perceived in different customs–; the Product Realm will contain knowledge about building response to use, as whole and in all its entities (spaces, components, etc. and their use modalities and specifications).

This general representation model is linked to a specific knowledge structure oriented to formalization and description of single entities composing the design product (spaces, building components, furniture, equipment, etc.) freezing the control on the other knowledge realms, context, actor and process. Each entity is represented in its main features and in its relations with other entities by means of the ‘knowledge template (Carrara et al., 2009) based on the already discussed “Meaning-Properties-Rules” structure.

Starting from this representation model, already applied to represent a building design solution, but not studied to support the testing of its performances while-in-use, the new challenge is to extend it to representation of human behaviour in building in order to manage such information in a CAD environment. An implementation of such knowledge domains will give designers the possibility to count, during the analysis, synthesis and evaluation phases of design process, on:

1. a reliable, specific and up-to-date knowledge about how the building will be used;
2. a strong system of data as hypotheses for dynamic simulation of behavioural phenomenon happening in the building-in-use process.

THE PROPOSED APPROACH

Use process in the ontology-based model

Several researches have shown the capability of ontology-based representation systems in supporting collaboration among different specialists during the design process (references). The template for knowledge modelling previously proposed by our research group is able to represent the design solution

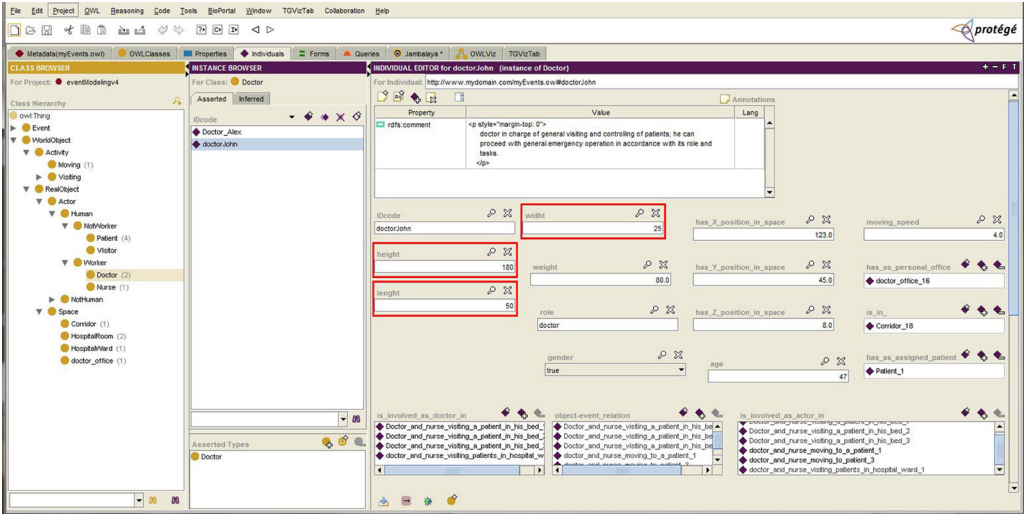


Figure 3
Representation of a user's profile by means of ontologies, in protégé environment.

as a whole by means of formalization of knowledge related to all its entities (spaces and components). At present, this approach provides just a static representation of the building, without providing necessary information about how the future building will interact with its process of use, in terms of actors involved and activities performed.

On other hand, the accepted “Meaning-Properties-Rules” structure, with its ability to model both real objects and abstract concepts, is applicable to the representation not only of product-related entities, but also of all those entities involved in the definition of the building use process (users with their profiles, activities, other resources involved, etc.). Furthermore, process-related entities and product-related entities cannot easily be structured and linked each other because of their heterogeneity; the ontology-based approach (and in particular the Meaning-Properties-Rules structure) can address this problem offering a common, homogeneous way of representation of such entities (Fig.3).

The result of such approach is a ‘knowledge structure’ composed by a set of entities representing both the design product in its space-component elements, and the process of use, in terms of users involved and activities performed in a standard use scenario. While BIM and IFC have a strong capability in representing geometrical values of product entities, they are “semantically poor”, and don’t allow the implementation of knowledge related to building use processes. The ontology-based system proposed can overcome this lack in representation providing a semantic network in which all the entities involved in the definition of the design product and of the building functioning can be integrated and connected.

Ontologies model and simulation

The above proposed model can support designers during the phase of definition of a partial or final design solution; nevertheless, this is not sufficient to guarantee that the design solution will really interact as expected with users during its functioning. As matter of fact, human behaviour in building is a

hardly predictable phenomenon because of its dynamic features, and the strong influence of users’ *libero arbitrio*, context (in a broad sense) status, stochastic components, etc. Narrative and simulative approaches have been developed in the last years to dynamically represent specific aspects of the process of building use (Yan,2004; Koutamanis,1996; Cenani, 2008), but their results normally consisted in a simulation of very specific aspects of users’ behaviour (such as fire egress, pedestrian movement), based on a limited set of initial hypotheses.

At central core of this research is the idea to use the ontology-based model to provide all the hypotheses needed for the effective testing and simulation of the process of use. It provides a formalized, well-defined system of knowledge representing:

1. the built environment in all its parts (spaces, building components, furniture, equipment, etc.;
2. the system of users, their profiles, their attributes;
3. the system of activities to be performed, both taken as single entities, and as structure sequences and network of them to represent the developing of the process of use.

The whole model representing these elements is the result of the design process: the product obtained in the synthesis phase and ready to be evaluated in its effective use features.

Integration between a semantic model representing both environment and its intended use and users, and a dynamic calculator able to simulate how this will overlap, match and affect each other, will be able to provide a more reliable and comprehensive prediction of building future use during a certain span of time. The results of this simulation will be a virtual, general phenomenon that designers could measure, threat and evaluate in accordance with their specific objectives. As results, designers will be able to intervene on the design solution in order to solve critical points, inconsistency, unexpected functioning without really stepping into the construction process.

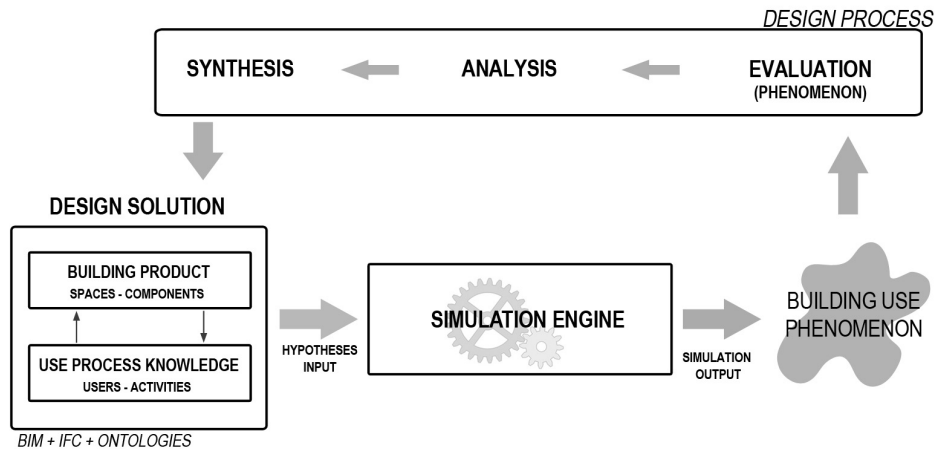


Figure 4
The design process supported
by building use simulation.

IMPLEMENTATION PROCESS AND EXPECTED RESULTS

For implementing this theoretical model, we are using the ontology technologies in order to model the product and use process entities, physical or abstract, and their space-time relationships structured by means of meanings, properties (defining their state) and rules (relations, reasoning rules, consistency, best practices).

Analysis, checking, evaluation and control of concepts associated to specific entities is performed by means of inferential engines, with deductive 'If-Then' type procedures.

A system of engines – matching rules among the ontologies – will work on a deductive layer overlapped at the actual BIM level, allowing the designers to use in a coherent manner different levels of abstraction, or to exploit a conceptual interoperability.

The implementation steps are namely:

1. represent Design Knowledge of Use Process Ontologies (e.g. expressed in OWL language by means of ontology editors, e.g. Protégé);
2. connect Ontologies with actual BIM, or IFC (by means of API, or using Beetz (2009) transcrip-

tion of IFC in OWL language);

3. connect BIM + Ontologies with a Narrative management environment (e.g. Virtools, etc.);
4. explore and find out in the semantic web community or build inference engine to perform the user's behaviour in the building.

The dynamic and semantically-specific representation performing human behaviour simulation will detect coherent/favourable situations by means of a constraint rule mechanism, allowing be highlighting and managing in real time.

At the same time it allows actors to make alternatives, more consciously reflecting on the consequences of their intents. By this way the impact of a networked ontology-based system makes actors more aware of overall design problems and allows them to operate more participative and to share choices and experiences.

CONCLUSIONS

Ontology technologies do not belong to the present generation of commercial building design tool. At the same time it's a fact how easily today we can model a structured domain ontology.

This paper proposes how – in a very general case study – ontology reasoning can be an efficient automatic resource for assisting actors (human or software agents) in decision making process along recursive building design sessions, performing event based simulation of human behaviour in a defined building environment.

At present the proposed general framework has been only partially implemented: it can count on a limited but sufficiently representative number of building entities formalized by means of current ontology editing systems in order to be used for design reasoning, using the large family of ready-built inference engines and information extraction, checking and verification facilities developed in the last few years by a growing international community.

Research work is planned to develop various software agents, in particular prototypes to simulate integrated collaborative hospital design.

ACKNOWLEDGEMENTS

The research was partially funded by Italian MAE (Ministry of Foreign Offices) 2012 Research Project: “BKM - Building Knowledge Modelling: structuring A/E/C knowledge for a new generation of design tools”.

REFERENCES

- Beetz, J, van Leeuwen JP, and de Vries, B 2005, ‘An ontology web language notation of the industry foundation classes’, in *22nd CIB W78 Conference on Information Technology in Construction, CIB-W78*, Dresden, Germany, pp. 193-198.
- Carrara, G, Fioravanti, A, Loffreda, G and Trento, A 2009, ‘An Ontology based Knowledge Representation Model for Cross Disciplinary Building Design. A general Template’, in G. Çağdaş, and B. Colakoglu, (eds). *Computation: the new Realm of Architectural Design*, Istanbul, pp. 367-373.
- Cenani, Ş and Çağdaş, G 2008, ‘Agent-Based System for Modeling User Behavior in Shopping Malls MallSim’, in M. Muylle (ed.), *Architecture ‘in computro’*, Antwerp, pp: 635- 641.

- Fioravanti, A, Loffreda, G and Trento, A 2011, ‘An innovative comprehensive knowledge model of architectural design process’, *International Journal of Design Sciences & Technology*, 18(1), pp. 1-16.
- Kalay, YE 1992, (ed.), *Evaluating and Predicting Design Performance*, John Wiley & Sons, New York.
- Koutamanis, A and Mitossi, V 1996, ‘Simulation for Analysis: Requirements from Architectural Design’, *Proceedings 6th EFA - European Full-scale modeling Association - Conference*, Vienna, pp. 96-101.
- Pirsig, RM 1990, *Lo Zen e l'arte della manutenzione della motocicletta*, Adelphi Edizioni S.p.a., Milan, Italian edition of Zen and Art of Motorcycle Maintenance, Bantam Books, New York, 1974.
- Trento, A, Fioravanti, A, Loffreda, G and Carrara, G 2010. ‘Managing formalised knowledge to support collaborative design - A research approach for integrating and reasoning on different ontological levels’, in *Proceedings 10th Design & Decision Support Systems in Architecture and Urban Planning*, Eindhoven, 19-22/07/2010, Eindhoven: Technische Universiteit Eindhoven, p.19.1-19.17.
- Wurzer, G 2009, ‘Systems: Constraining Functions Through Processes (and Vice Versa)’, in G. Çağdaş, and B. Colakoglu (eds), *Computation: the new Realm of Architectural Design*, Istanbul, pp. 659-664.
- Wurzer, G, Fioravanti, A, Loffreda, G and Trento, A 2010, ‘Function & Action: Verifying a functional program in a game-oriented environment’, in G. Schmitt et al. (eds), *FUTURE CITIES*, Zurich, pp. 389-394.
- Yan, W and Kalay, YE 2004, ‘Simulating the Behavior of Users in Built Environments’, *Journal of Architectural and Planning Research (JAPR)* 21:4, Locke Science Publishing Company, Inc.

DIGITAL PHYSICALITY

vol. 1

Digital Physicality is the first volume of the conference proceedings of the 30th eCAADe conference, held from 12–14 September 2012 in Prague at the Faculty of Architecture of Czech Technical University in Prague. Physicality means that digital models increasingly incorporate information and knowledge of the world. This extends beyond material and component databases of building materials, but involves time, construction knowledge, material properties, space logic, people behaviour, and so on. Digital models therefore, are as much about our understanding of the world as they are about design support. Physical is no longer the opposite part of digital models. Models and reality are partly digital and partly physical. The implication of this condition is not clear however, and it is necessary to investigate its potential. New strategies are necessary that acknowledge the synergetic qualities of the physical and the digital. This is not limited to our designs but it also influences the process, methods, and what or how we teach.

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ISBN: 978-9-4912070-2-0