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15, avenue de Ségur,
75007 Paris, France.
Tel (Fr) 01 45 51 26 07 - (Int.) +33 1 45 51 26 07
Fax (Fr) 01 45 51 26 32- (Int.) +33 1 45 51 26 32
E-mail: ijdst@europia.org
http://www.europia.org/ijdst

An innovative *comprehensive* knowledge model of architectural design process

Antonio Fioravanti,* **Gianluigi Loffreda**** and **Armando Trento*****
* Sapienza University of Rome, Italy. Email: antonio.fioravanti@uniroma1.it
** Sapienza University of Rome, Italy. Email: gianluigi.loffreda@uniroma1.it
** Sapienza University of Rome, Italy. Email: armando.trento@uniroma1.it

Contemporary architectural design emerges as a process characterized by a complex interplay between specialized jobs and multidisciplinary knowledge. Differences in the cultural and technical background of the actors involved are reflected in specialised representations of the design process entities they understand and treat. Pooling actors' intelligence by means of a real collaboration can improve the final results. To be effective, collaboration needs an innovative model aimed at a new comprehensive conception of the architectural design process/product together with the knowledge melting pot in which a project is developed. The proposed model is marked by four 'poles' of a symbolic knowledge tetrahedron that represents the different knowledge defining a project: product, context, actors and procedures. Each 'pole' is represented by formalized and agreed upon meta-knowledge structures and other semantic tools so that the knowledge exchanged between actors is easier to understand and use.

Keywords: knowledge modelling; design process; knowledge representation; architectural design; cross-disciplinary interaction

1 Challenges and problems in architectural design

In 2010 for the first time in the history of human kind most part of people in the world lives in cities and this trend seems to increasing up.[1] Now people live in a more and more anthropic world and are surrounded by artefacts (that implies to be designed) and by continuously changing physical places (*architecturally shaped*).[2] So architecture has a direct huge responsibility of world transformations (shaping the world) and an indirect one as it consumes the most part of energy (ecosystem sustainability).

Design and architecture are key-words to understand contemporary world as they are elective fields of meeting/clash of cultures and brains related also to other phenomena: globalization and migrations.

Governing all these phenomena can be done harmonizing different, but conflicting, trends and cultures as stated by Roma's Club in the ahead looking book "Limits to Growth" (Figure 1).[3]

Looking back to the microcosm, even if immense, that is architectural design we have to face same problems at a lower recursive level - in essence - how to integrate different cultures and reconcile (often) opposite objectives.

The interdisciplinary and dynamic nature of Architectural and Building Design clearly reveals the limits of conventional design in coping with the rapid changes taking place in this filed (in the broad sense) where various operators act.

A common answer to these problems is the 'Collaborative design' paradigm as witness by numerous literatures in this field.[4 5 6]

The AEC design process is peculiar one as "... the global goal being the good life. The rules for achieving this goal are certainly unclear; they vary for each

1 UN - United Nations (2009). World Urbanization Prospects, WUP 2009_Wallchart_Urban-Rural_Final.pdf [esa.un.org/unpd/wup/unup/p2k0data.asp]

2 Morris, W. (1881). The prospects of Architecture in Civilization Conference, London Institution, cited in On Art and Socialism, London 1947

3 Meadows, D.H. et al (1972). The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind, Report of Roma's Club, Potomac Book

4 Kvan, T. (2000). Collaborative design: what is it?, Martens, B. ed, Automation in Construction, 9:4, 409-415

5 Gero, J.S. & **Reffat, R.M.** (2001). Multiple representations as platform for situated learning

person, and, as in our *Alice in Wonderland* croquet game, they are ever changing. Furthermore, in this game there is no coup de grace or checkmate; the global goal has no "utility function", no cost-effectiveness, no parameters to optimize".[7] In AEC design process the "changing rules" are the cultural, technological, legislative, codes and economic context, also influenced by needs of clients and designers. Or it is like what recently Marcos Novak spoke: "... The synapses-brain and concepts are related each other like a swarm of bees instead of a graph".[8]
The project evolves like a 'narrative' romance as subject dependent on *humans* and *nature* each of them is a universe of believes... extremely difficult to formalize. At present, researches in this field can only take into account concepts from data to reasoning rules, believes are not formalizable in a homogeneous way, nor can be directly related to the immediate lower level concepts even if there are promising studies in Cognitive sciences.[9]
As reported in previous works,[10 11 12] the authors proposed new services that can assist and support "in a collaborative fashion" - almost like a professional available 'on tap' - supplying additional knowledge in order to enhance the entire design process and to reduce misunderstandings and code infringements by means of efficient, 'intelligent' and designer-friendly support systems.[13 14]
All the previous researches and tests show the core element for an effective cross-disciplinary design representation: to enhance collaboration and creativity among designers it is needed an innovative Design Knowledge-based Representation Model.[15]
This Knowledge – according to Hofstadter – is distributed among the actors in the process, both in terms of *conceptual entities* of design solutions - the *'product'* of design process and in terms of the *meanings* assigned to such entities.[16]
Moreover, in a more comprehensive model of architectural design process, the knowledge of context, actors and procedures should be considered.

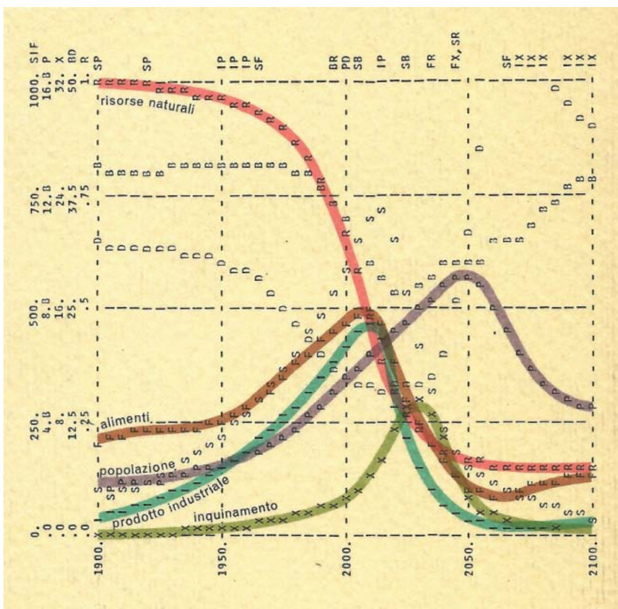


Figure 1 Society conflicting trends: R - natural resources, F - foods, P - population, I - industrial products, X - pollution, according to Roma's Club - 1972

systems. In: Designing, Knowledge-Based Systems, 14:7, 337-351
7 Negroponte, N. (1970). The Architecture Machine - Toward A More Human Environment, MIT Press, Cambridge, MA, p. 69
8 Novak, M. (2005). Conference in Rome, 15th April 2005 [www.neural.it/english/marcosnovak.htm]
9 Fioravanti, A. (2008). An eLearning Environment to Enhance Quality in Collaborative Design. How to Build Intelligent Assistants and 'Filters' Between Them, Architecture and Modern Information Technology 4:5
10 Fioravanti, A. & **Loffreda, G.** (2009). Formalizing and compu-ting Ontologies to Speed Up the Construction of Knowledge-based Colla-borative Systems, Three different approaches. In: Çağdaş, G. & Çolakoğlu, B. eds, Computation: the new Realm of Architectural Design, eCAADe 27, Istanbul, pp. 341-348
11 Carrara, G. et al (2009b). Knowledge-based Collaborative Archi-tectural Design, International Journal of Design Sciences and Technology, 16:1, pp 1-16
12 Carrara, G. & **Fioravanti, A.** (2002). 'Shared Space' and 'Private Space' Dialectics in Collaborative Architectural Design. In: Pohl, J. ed, Collaborative Decision-Support Systems. Baden-Baden, SAN LOUIS OBISPO, pp 27-44

The multidisciplinary nature that characterizes the recent architectural design processes exactly matches this concept of knowledge distributed among the various specializations involved in a project.
By means of a suitable structure for representing and managing the technical knowledge distributed among the various (specialist) actors, the research aims at laying the foundations of a new generation of designer support tools that can enhance mutual understanding and consequently improves the entire design lifecycle, avoiding as far as possible any incoherence, incongruence and inconsistency of the proposed design solutions.

2 Design: complexities and collaboration

As a general rule, actors often deal with quantity of information that exceeds their capacity to master it and also specialists supplying it are prevented from having an overall and in-depth view of the design solution thus the majority of the specific problems of the other actors involved are left out. It is not possible, in these circumstances, to a-priori establish how a designer can consult and use this amount (or part) of information.
With dangerously expanding costs and timeframes, as can be measured by the waste of energy and its consequent effects on the environment, the current quality of building is declining, reason of oversimplified design solutions often being proposed to solve complex problems in which the first solution that succeeds in reconciling the actor's majority is judged the definitive one.[17]
The profound professional differences of each actor due to the wide variety of their educational and training experiences are reflected in the widely varying modes in which they understand and consider the entities (objects and processes, properties and relations, physical characteristics and spaces) involved in a building process. This gives rise to the so called "symmetry of ignorance", which often represents an high barrier to the reciprocal understanding among actors and which thus prevents a correct and profitable design interaction.[18]
Over times and at present many forms of interaction among actors in the design process have existed, any of which has advantages and drawbacks linked to their peculiarities. These forms do not depend on the number of actors collaborating but rather on other factors: the timing of the actions (the overall time required for the intervention and the presence or absence of different phases), overlapping responsibilities, the hierarchy of actors, knowledge of the operation context and asynchronous/ synchronous actions.
"Collaborative design" it is the highest form of interaction in design where actors are jointly responsible for work, they can help each other to integrate others' partial design solutions and they understand how their work is going to match with the others' ones. It requires that the actors involved in any stage of the process exchange information and knowledge activating mutual understanding.[19]
An efficient collaboration among the actors along the design process consists in the capability of any actor to propose potential solutions to other actors, to make others understand her/his and to together modify her/his own project solutions according to the suggestions received.
The "fundamental bases of collaboration reside on knowledge and on the way it is communicated among the actors", independently of the means and tools adopted in the design process.[20]

13 **Carrara, G.** & **Fioravanti, A.** (2007a). X-House - a Game to Improve Collaboration in Architectural Design. How to distill a CD-Based Model into an eLearning Tool. In: Kieferle, J.B. & Ehlers, K. eds, Predicting the Future, 24th eCAADe Conference, Frankfurt, pp 141-149

14 **Carrara, G.** & **Fioravanti, A.** (2007b). Collaboration – New Media – Design. An Integrated Environment for Supporting Collaboration in Building Design. In: Pawlak, A. et al eds, Coordination of Collaborative Engineering – State of the Art and Future Challenges, 5th Workshop on Challenges in Collaborative Engineering (CCE'07), Krakow, pp 125-142

15 **Carrara, G.** & **Fioravanti, A.** (2005). Creative architectural design boosted by ICT enhanced incubator. In: Gero, J.S. & Sosa, R. eds, Computational and Cognitive Models of Creative Design, 6th International Roundtable Conference, Heron Island, AUS, pp 275-300

16 **Hofstadter, D.R.** (1999). Gödel, Escher, Bach: an Eternal Golden Braid, Basic Book, New York

17 **Carrara, G.** et al (2009b). ibid

18 **Kalay, Y.E.** (2009). The impact of information technology on architectural design in the 21st century. In: Tidai, T. & Dorta, T. eds, Joining Languages, Cultures and Visions, CAAD Futures, Montreal, Les Presses de l'Université de Montréal, pp 21-34

19 **Gero, J.S.** & **Kannenglesser, U.** (2006). A

The assumption is that Collaborative design can contribute to the improvement of design methodologies together with advanced technologies, to the services of the design process and of project quality as seen in most advanced architecture engineering firms (Ove Arup, SOM, etc.)

3 A *Comprehensive* architectural and building knowledge model

Knowledge Modelling and Representation are the core of the problem as taking into account a real collaboration among all the actors involved in a design process implies formalization and exchange protocols and an agreement on concepts and on overall domains of Knowledge Representation Structures.

The present paper refers to an innovative *Comprehensive* Theory on AEC Knowledge Model developed by the authors. Till now researches have been concentrated on building representation from geometrical point of view (proprietary formats, IGES, neutral format, .dxf, PHIGS, etc.); then from more comprehensive format (proprietary BIMs or ISO standard; STEP,...); then from "object" point of view with more building description SfB, etc., then from 4D representations considering the time dimension;[21] then from the 'situated' actions[22] or 'condicio' environment (building + design phase + actors who design in that phase).[23] All these representations consider a growing number of different entity types, but other two elements should have to be explicitly considered: *actors* (physical persons and juridical persons, active - designers; passive - predefined users, patients, clerks, etc.) and *procedures* (design phase, bureaucratic course, public institution approvals) that discipline and guide the design process.

All these entities are considered by AEC Design Process point of view.

So the scenario in which a building project is delineated by means of the outlines and guidelines is marked by four 'poles' of a Knowledge symbolic Tetrahedron that represent the different kinds of knowledge: product, context, actors and procedures.

function-behaviour-structure ontology of processses. In: Gero, J.S. ed., Design Computing and Cognition, Springler, Netherlands, pp 407-422

20 Carrara, G. et al (2009a). An Ontology-Based Knowledge Representation Model for Cross-disciplinary Building Design - A General Template. In: Çağdaş, G. & Çolakoğlu, B. eds, Computation: the New Realm of Architectural Design. eCAADe Istanbul, pp 367-373

21 Kavakli, M. (2001). NoDes: kNOwledge-based modelling for detailed DESign process - from analysis to implementtation, Automation in Construction, 10:4, 399-416

22 Gero, J.S. & **Reffat, R.M.** (2001). ibid

23 Carrara, G. & **Fioravanti, A.** (2002). ibid

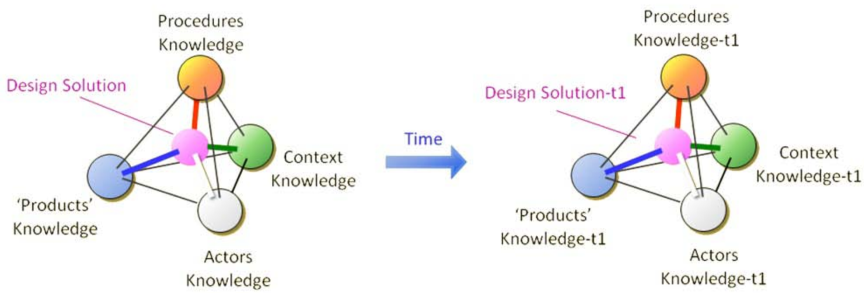


Figure 2 Comprehensive Model of Architectural Design process - symbolic knowledge tetrahedron during the design process. The four knowledge Realms 'shape' the Design Solution during t ÷ t1 time period

Each type of knowledge *in-forms* and *de-fines* the design solution - the building project - with different times, means and ways and for different purposes. The four 'poles' of knowledge shape what happens during the AEC design. Each 'pole' is constituted by knowledge-based system in its respective domain. In particular on the knowledge of the *product* (building - with its components and its multidisciplinary aspects), *context* (site - with reference to physical, legal, planning, ecological and climatological aspects), the *actors* involved (humans - professionals, contractors, customers and non-humans - agents, intelligent assis-

tants) and *procedures* that regulate this process (such as commitment, design phases, economic and financial aspects, administrative and organizational rules). All these 'poles' evolve in time but with different speed and scheduling. For instance, the procedure knowledge slowly changes as it depends on codes and laws that have an institutional and complex mechanism for approval, so during little period of time an actor carrying out specific tasks considers procedures (e.g. urban planning regulations) as fixed (Figure 2).
To realize such a collaboration actors have to share a restricted domain of their own knowledge on which all agree and that allows them to interact and understand each other.

4 Architectural Design Knowledge Realms

On the basis of *Comprehensive* Design Knowledge Model we define the following four 'poles' or *realms*. The entities of each realm have a general and powerful Knowledge-based Representation Structure (Section 6) developed by the authors not exhaustively but for some significant entities.

4.1 Product realm

This realm represents all the entities strictly part of the designed product. Referring to Building Products, the authors in previous works investigate this aspect defining two Macro-Classes: Physical Elements and Spaces. The first set includes all the components of the building and of the product in general, while the second one includes all the spaces bounded by or container of other components, product and spaces.
The overall product is a set of the entities of the Product Realm. It is related hierarchically to part of itself and structurally linked to others Realms - Context, Actors and Procedures - by means of attributes and relationships according to the Knowledge Representation Structure. For instance a sink is a sanitary fixture entity of the *Product* realms made up of a top, a cabinet, legs, screws and so on; it has a relationship with other product entities - floor, wall(s), hydraulic plant, etc.

4.2 Context realm

Context represents the set of entities that is not part of the product realm and that contributes to its definition by influencing the design process in terms of physical, morphological, orographical, social and urban constraints and in terms of design suggestions, references or, in general, cultural environments. For instance entities of this realm are the Site in which the building will take place with all its own attributes like height, lightness, neighbouring buildings and so on.
Referring to the sink example, entities of the context will be, for instance, the Cultural aspect for people to whom it is going to be designed and so on. All these entities with all their specific attributes and relationships, will contribute to define the Design Product.

4.3 Actors realm

This realm includes all the actors (human and not) that interact with the design solution during the design process like designers, testers of the 'product', clients, commitments, firms, public and private purchasers, etc.
Each entity is represented by means of attributes, relationships, etc. as better ex-

plained in sec. 4., and rules and each actor is able to interact with the ‘product’ influencing it and also modifying the design process and the design solution.
Referring to the Table example, actors-designers can be the architect who, influenced by her/his specific cultural background, by the above mentioned Context and by the Client and Use Requirements defines the geometrical shape of the product, the number and type of sink legs (which are product entities) and many other aspects.
Some aspects of the design solution will be verified, for instance by actors like a Structural Engineer or by another actor like an Industrial Designer that will propose their own specialist design solutions according (or not) with the architect’s one.
F.i. during the Design Process, in different phases iteratively, actors are able to interact with the Design Solution to check its specifications with her/his own requirements. The tests can be defined previously or can be more general to verify a design solution in non-predictable situations and rate its performances (for instance, many actors -users sit on the sink).

Figure 3 Design when Actor Realm prevails - Japanese Garden at Waikato New Zealand; Winton guest house, 1987 - F.O. Gehry

4.4 Procedures realm

As shown above, each actor will operate in a different way, in a different time and with different targets, requirements, design paths and goals, pre-determined or not. This aspect represents the Process realm: the set of rules (in a broad sense) that guide the overall Architectural and Building Design Process by managing some entities of other Realms. This Realm can freeze or start up or deactivate entities of components, spaces, designers, clients, firms, urban constraints, regulation planning permissions, codes, relationships, etc., macro-classes as well as particular attributes of entities; it can check procedure rules (in recursive way) or schedule product definition during Design Phases.

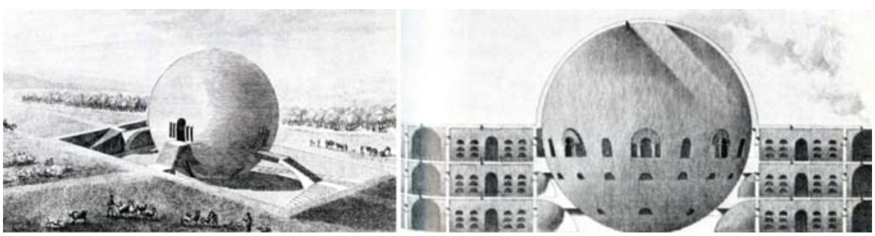


Figure 4 Design when Context Realm prevails - Enlightenment and revolutionary ideology may result in non-constructible buildings. Forest guards’ house, Mopertuis,by 1780 - Ledoux; , Cemetery, Chaux, by 1800 - Ledoux

Figure 5 Design when Product Realm prevails - WOBO - World Bottle, a new "brick" for developing countries, 1963 - Mr Heineken

Figure 6 Design when Procedure Realm prevails - New seismic codes forced to cut squared shaped wings in smaller parts so that unforeseen pillars had to be built to sustain them. MAXXI museum, Rome, 1999 - Z. Hadid

The complexity of the building design and its own peculiarity relies on being an 'always prototyping process'. Each context is unique, as well as each building, as well as each design process and, of course, as well as each human (or non-human) designer and user. All these 'uniqueness' creates another uniqueness that is the product of the design process in which all these component are involved: the final design solution, and, later, the building.

5 Realm perspectives of *Comprehensive* architectural design model

The above mentioned Design Knowledge Model is an innovative and more *comprehensive* way to analyse, define and manage the architectural and building design process.

As well as planets design their specific revolution around the Sky and each path can appear different if it is analysed from a different perspective (Sun-centric model, Earth-centric one, Moon-centric one, and so on), in an Actor-centric Design model, the entire design process seems to change according to specific Actor Realm perspective. But differently from the "Motion of heavy bodies", architectural and building design has a lot of different possible perspectives.

Just for instance, some decisions, some rules, some specific product aspects are Actor Realm-dependent (Figure 3), some of them are Context Realm-dependent (Figure 4), other ones are strictly Product Realm-dependent (Figure 5) and other ones are Procedure Realm-dependent (Figure 6).

A design process could be analyzed and managed by different perspectives by "freezing" a specific Realm and then driving changes in the other ones.

Procedures (Figure 7) usually evolve slowly whereas Product, Actor and Context rapidly change, so that from an actor-designer point of view, with fixed procedures, the design process is a continuous specification of building requirements (creation of sub-classes) into a more and more specific building project (their instances) that is compared to previous building requirements. Then in turn a specific building project (the design solution and/or its part) can be generalized to become a new class (Figure 8). So, the design can be conceived as a continuous Specification/Generalization process.

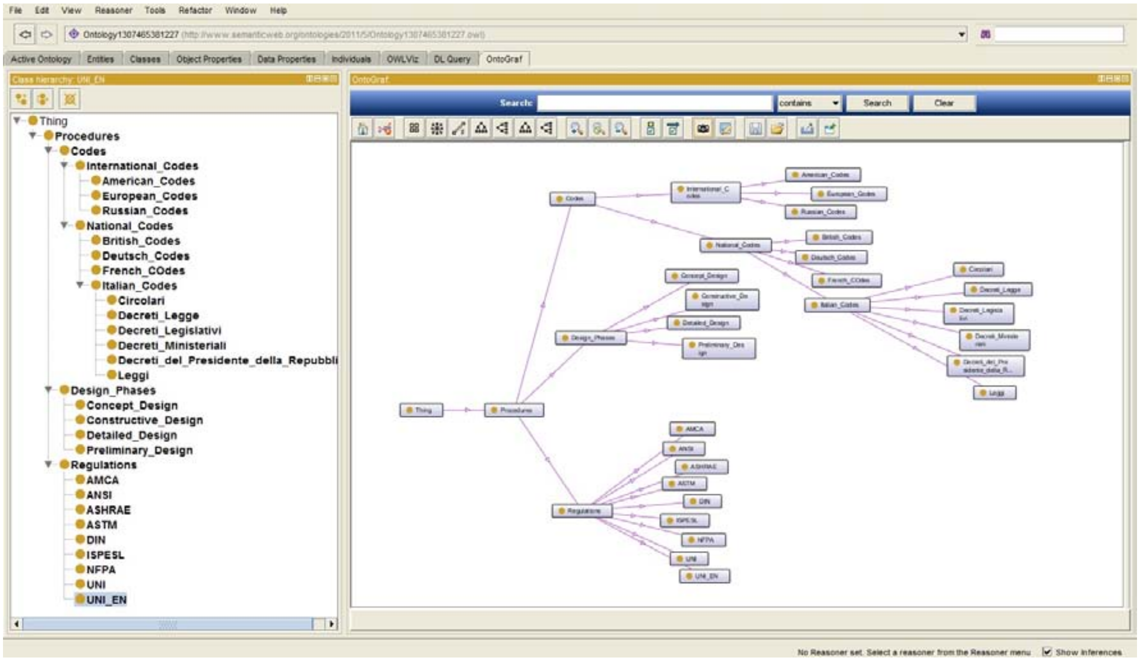
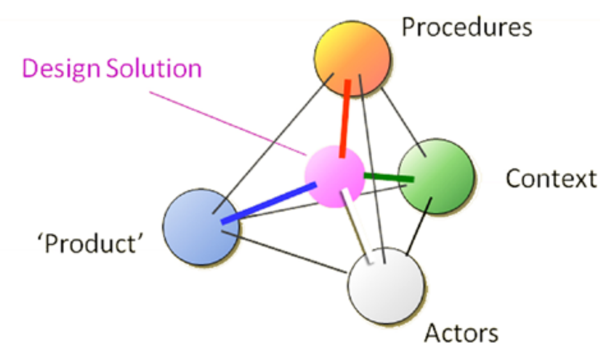


Figure 7 A screenshot of Procedure Realm: Codes, design phases, Regulations



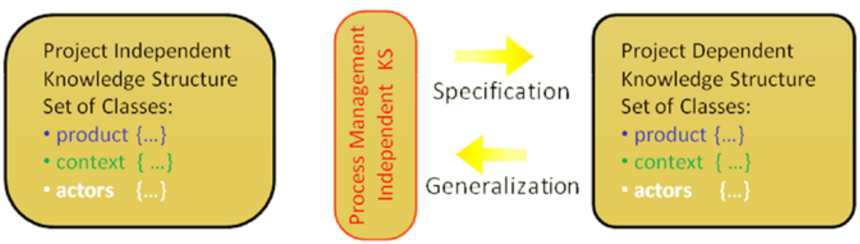


Figure 8 When Procedures are fixed only Product, Context and Actors Realms change. The design activity is a continuous process of specification (sub-Classes and instances) / generalization (super-Classes and Clas-ses)

The proposed Knowledge Model allows this more comprehensive and accurate definition of design process and increases the control of the product. Every time Product, Context, Actors and Procedures Realms 'shape' a unique overall Design Solution.

6 The knowledge entity representation

A fundamental role is thus assigned to the Knowledge-based Structures - KS. If there were no Knowledge-based Structures or other significant semantic tools, information exchanged between actors would occur at a low semantic level, difficult to understand. Another difficulty is that to highlight the differences between specific design solutions, every actor should directly compare, "vis-à-vis", different ones in order to identify differences and / or contradictions.[24 25]

On the contrary, in this new Model all the entities of a design product/process are identified and made "explicit" by means of: a set of elements; a set of attributes associated with elements; a set of relationships between elements.

A "set of elements" is made by entities each actor uses in her/his design solutions, as well as those that can be recognized but do not fall within her/his particular field of expertise. Each entity will be part of an ontology that allows an unambiguous definition and relative semantic and behaviour as well as the definition of its properties (physical, geometrical, etc.) and relationships with other entities to which it is connected.[26]

This structure of knowledge has been investigated by the authors together with the definition of a "*general* structure type" for any entity - a "template".[27 28]

Each entity of the design process is represented by three aspects: Meanings, Properties, and Rules. This general entity representation by means of three folded faceted ontologies can effectively represent the actual concepts involved in a design process.

6.1 Meanings

The facet "Meanings" in relation to the ontology considered includes all aspects associated with the stated meaning of the entities represented, including those associated with significant symbols used to represent the entity, the name of the class, definition(s) shared by all actors involved in the ontology (Common Ontology, and / or Specialist Ontologies).

The Model formalization is structured into a flexible, dynamic and so-called "rule-dependent" manner, so that, with reference to the context, constraints, objectives and the needs of end users, the meanings associated with entities may change. As meanings are explicitly expressed, it is easier to detect inconsistencies and/or constraint violations by actors.

Both the common meaning and the specialized ones are influenced by the context in which the entities associated with them is placed, following the activation of systems to monitor and control consistency, regularity and coherence. The entity will thus become more "appropriate" to its context.

For example, a "shear wall" is represented by an entity - a class, which has a label - class name, several definitions - the meanings - dependent on the specialist discipline where it is considered. For instance, a shear wall in a Structural Engineering domain is a load "bearing wall" with very different moment resistant capacities on the two main axis ways, in an Architectural domain can be seen like a

24 Beetz, J. et al (2006). Towards a topological reasoning service for IFC-based building information models in a semantic web context. In: Prtoceedings Joint International Conference on Computing and Decision Making in Civil and Building Engineering, Montréal, Canada

25 Fioravanti, A. & **Lof-freda, G.** (2009). ibid

26 Gero, J.S. & **Kan-nenglesser, U.** (2006). ibid

27 Carrara, G. et al (2009a). ibid

28 Fioravanti, A. & **Lof-freda, G.** (2009). ibid

29 ibid

30 **Trento, A.** et al (2010). Ontologies for Cities of Future - The quest of formalizing interaction rules of urban phenomena. *In*: Schmitt, G. et al, eds, Future Cities, Zurich, vdf Hochschulverlag AG an der ETH Zurich, pp 797-804

simple “partition” that separates two rooms or from an Energy Engineering point of view could usefully used as a “Trombe’s wall”, and so on.

6.2 Properties

This category includes all related descriptive/behavioural aspects of an entity considered including: geometric properties (shape, size, position, etc.), physical properties (materiality and related attributes), behavioural properties (with respect to structural issues, energy, noise, lighting, etc.) defined by specific values associated with properties of the entity itself and/or of the other entities.
Properties can be computed through the use of methods, algorithms and/or procedures and/or external software. Such properties will be defined by default value and /or by input values of its own or other entities.

6.3 Rules

Represent the “connection synapses” between an entity and others, multiple and distinct that are inside a knowledge structure and between them.
This type of “complex network” and “many to many” relationship consists basically of two main types of connections: relational rules (Relationships) and rules of thinking (Reasoning).
Relational rules between the entities can be:

- links between lower level and other entities, characterized by increasing complexity as a result of “assemblage” or combination of multiple entities, or vice versa (Part-Of, Whole-of); hierarchical relationships that govern the general stratification of the entities (Father / Son); type of entity, class or individual entity (Is-A, instance-of)
- rules of reasoning, characterized by: algorithms and codes in formal language for analysis, monitoring and evaluation of concepts associated with specific entities with procedures of type inference “If-Then”;
- context-dependent rules, with reference to current regulations, which thus become binding constraints for the entities with which these rules are associated;
- consistency of rules composed of algorithms aimed at verifying the consistency of values, parameters, attributes, instances
- rules of thumb, so-called “best practice” design, formalized as a concrete language code

7 Ontology developed implementations

The representation took into consideration different tools like Lisp and Protégé to formalize the model of a Systemic Knowledge of Building and its entities (components, building parts, characteristics, constraints, relationships).
These formalizations speed up the implementation of well formed knowledge that in turn makes knowledge-based system content rich. After testing a few simple design problems it was evident that to develop an effective ontology for specialist actors of architectural design process it should be used a mix of these representation tools. Protégé may fulfil the exigency of Lower-Ontology Level and an open frame structure fits Upper-Ontology Level.[29]
To investigate the Comprehensive Knowledge Design Model in a different Realm than Product, it has been implemented a set of entity representative of the Context Realm in Urban Planning field - Urban Domain Ontology Street System using Protégé ontology editor.[30]

The implemented Context representation with its entities (Street Components, Street Nomenclature, Street Descriptions, Axial Network, Transportation Network, etc.) provides a real-time explanation of the meanings associated with the design solutions (Figure 9). This investigation also pointed out the need of a more accurate cross-disciplinary definition of rules, concepts representation and "common meanings" to support real and effective collaboration and design consciousness.

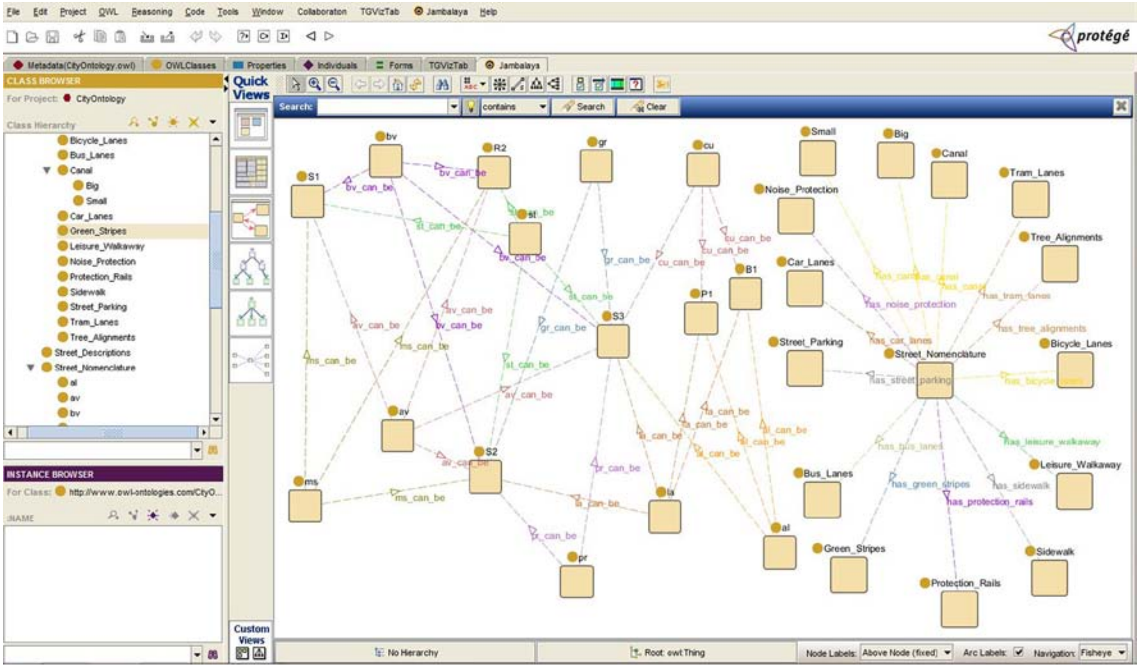


Figure 9 A screenshot of implemented ontology of Urban Domain Ontology Street System in Context Realm

8 Design activity

As stated above, the expertise of the various actors involved, is different in each case. The challenge is to develop a platform that makes mutual understanding among all of them possible and that can be an effective and true support to which we claim: *The design activity can be defined as the ability to choose among hypotheses.*

Therefore, we need on one hand to use innovative methods and technologies that can help in design choices (control, monitoring and modelling) and on the other hand an easy way to share new hypotheses. In this way, step by step, each actor can learn more about his/her own project objectives and may propose new solutions that are compatible with those of other actors.

The difficulty at this point shifts towards the discovery of a method for the evaluation of the *appropriate* solution, not necessarily the optimal one: the so-called evaluating and assessment procedures.

"The intelligence of a system is not measurable in terms of research capacity, but of the ability to use knowledge about the problem to eliminate combinatorial explosion of warnings. If the system had any control on the order in which possible solutions are generated, then it would be useful to know this order so that the so-

31 Simon, H.A. (1996). The Sciences of the Artificial, MIT Press, Cambridge, MA
32 Hofstadter, D.R. (1999). ibid
33 ibid

lutions had a high real opportunity to appear before. Intelligence, for a system with limited processing capability is the wise choice of what to do next...”.[31]
This does not mean that you want it to be the computer to decide the optimal design, but it just underlines how useful a more effective mutual understanding among different actors involved in the same design process would be.
The building design as a final product has a set of data. These data until a few years ago were almost exclusively made up of paper documents (drawings, documents, calculations). Even then, much of the data were comprehensible only to operators with similar roles and responsibilities (and sometimes even among similar specialists) and, at least to make them readable by the other players involved the documents were often accompanied by explanatory text documents.
The set of data produced by the generic operator is not simply the result of a mindset that allowed the designer himself to issue such data. The problem is that each operator has separate available specialized tools, resources and above all has extensive in-depth knowledge, but limited to a very narrow specialist field.
Today the transition from paper to digital has further complicated the situation: there are formal written documents and data as manuals, but in fact, the knowledge is undergoing a process of formalization in the form of increasingly complex and specialized digital software; referring to the mutual understanding of what is produced by the other parties involved, we still use text documents explaining that, although masked under the guise of modernity of files or email, nevertheless remain ineffective.
Collaboration, defined as the ability to discuss a topic “on an equal footing”, requires a level of communication that allows an actor to understand what another actor has expressed in design solution.
The *Comprehensive* Model let any actor to extend her/his own Knowledge-based Structure - KS - modifying facet of Her/his entities and/or including others’ meanings.
“Every aspect of the general underlying structure is recognizable only to certain levels of observation.”.[32] The *Comprehensive* Model ensures that all actors are able to deal with objects created with the same “level of observation” realizing what Hofstadter’ wishes.[33]

9 Prototype implementation approaches

The innovative model for the proposed structure of knowledge representation, thanks to its extreme sharpness, provides clarity in the formalization of the data modelled and promotes mutual understanding of the information exchanged between the actors that are part of the design process.
The first implementation was done using pure Lisp. Thus it was possible to manipulate the instances and the inference engine directly and change the properties of entities in a free and accurate way, but at the cost of a relatively small-scale implementation.
The main feature of the entity is linked to the “type” of the entity: the “Super-Class”.
This was formalized in accordance with a custom “frame” structure, similar to the one studied by McCarthy, through an ISA slot (Is-A, a). The advantage of being able to manipulate even this level of the structure of an entity is not only the ability to manage its inheritance, but to be able to combine separate entities con-

stituting the so-called “assemblies”.
Currently, technologies like the logical point of view can be recognized in the Web Ontology Language OWL, which allows the formalization of formal Entity-Relationship structures.
A second approach to modelling entities was carried out using an open-source tool: Protégé. The entities model was formalized according to the Knowledge structure “Meaning - Properties -Rules”.
Protégé2000 has been developed by Stanford University for the acquisition of information and the formalization of domain knowledge.
The above-mentioned ontology editor not only allows names, extended meanings associated with them (descriptions) and properties (the functions and their values) to be assigned to classes, but also defines a set of associated rules to determine the relationships among them.
In this case, the difference between “meaning” of the entity (name and description), properties (slots and associated attributes) and relationships are clear and well defined.
The rules, in particular, are formalized by means of a proper software development kit (SDK), PAL - Protégé Axiome Language.
Constraint verification and control and the consistency check, separate from the entity definition, is not in real time with the instantiation of the entities involved.
The plug-in PAL allows users to add constraints on the data for which the formalism of the frame itself is not expressive enough.

10 A closer look at Protégé implementation

The expressive potential, and descriptive representation of the Meanings-Properties-Rules representation, lies primarily in the clear division of knowledge “atoms” that make up the different concepts and their “manipulation” by the use of multiple types of rules. *Rules represent the “synaptic links” among entities.*
The complete definition of an instance (at least in relation to the specified attributes and relationships) allowed checks by creating rules according to the proposed model of knowledge representation; these rules in the Protégé environment are called Constraints.
Constraints, designed and formalized by means of the proprietary language PAL, were compiled into the software Protégé; they have been checked for formal correctness and operation (ie compliance with the specified constraint) within the same software and then exported to OWL (Web Ontology Language) to be associated to the classes and instances implemented.
Each constraint is characterized by a set of propositions derived from predicate logic, respecting the formal language rules to check formal coherence and most of all a series of universal or special quantifiers (related to all the elements of a given class, or at least one element of a specified class) in order to explain properly the rule as a logical proposition to associate to the involved class/es.
In this way it was possible to explain the following simple rules of topological character like that. The constraint “Communication between room and corridor door” make explicit the need: “For each instance of the class Hospital_Room exists at least one instance of the Class Corridor and an instance of the Class Door such that the specific “door” belongs simultaneously to the two checked rooms (Corridor and Hospital_Room)” (Figure 10).

In a much easier way it is stated that every hospital room must have at least one door that opens onto a corridor.

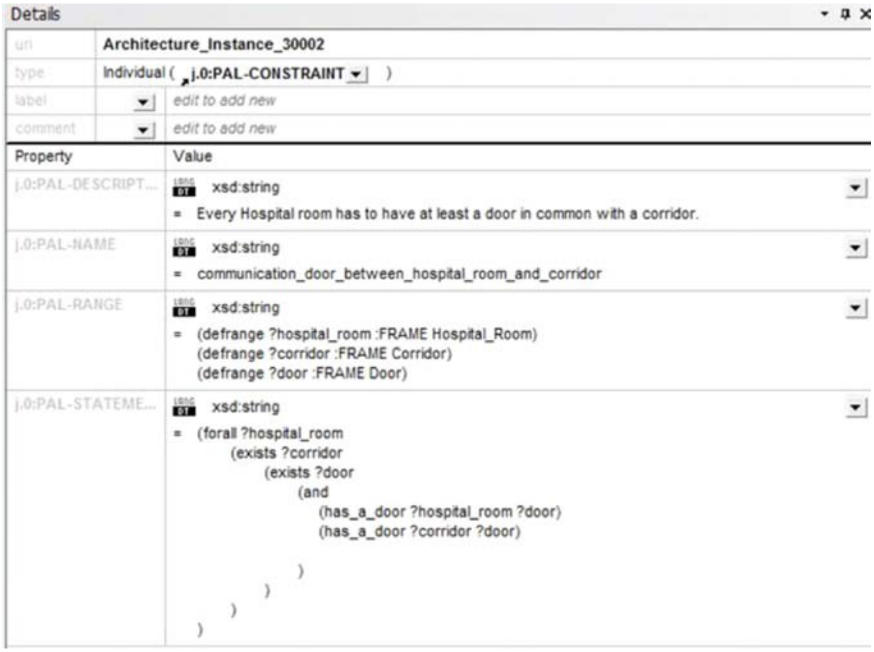


Figure 10 The constraint 'Communication between room and corridor' makes explicit the need that every hospital room must have at least one door that opens into a corridor

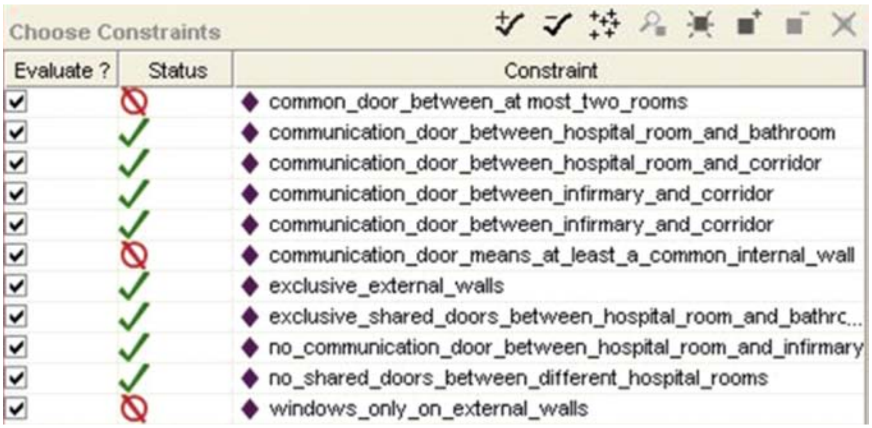


Figure 11 The results of the previously defined constraint check 'Communication between room and corridor' of hospital_rooms in a hospital case study prototype

Launching the verification of this constraint into the software Protégé, in accordance with the specific values associated with the different properties you will get a positive result if there are instances of Door, Hospital_Room and Corridor classes that simultaneously meet the specified proposition, negative otherwise (Figure 11).

Referring to the image above also other types of constraints have been created to test the robustness of this structure and especially to determine the ability to explain different types of propositions.

The main difficulty lies in define optimized propositions even for simple (and banal) concepts: in order not to burden the data load and then create many new classes or attributes, it is necessary to “get around” the obstacle by combining the effects of two or more simple constraints and thus learn to know the results, then better understand how to interpret the output and so correct the input design data.
For example, a common concept of two adjoining rooms which, in our mind immediately triggers a series of inferences, for a correct formalization requires multiple levels of regulation for the check and control: first, you must specify the domain you imagine to apply this type of rule in fact, wanting to maintain the division of logical domains, each rule used for the correct representation of the Entity in question should cover as much as possible homogeneous entity of the same domain.
Considering a greater complexity level of control, the preparation of a design solution, will for sure be able to verify the congruence between (for instance) two solutions designed in different domains.
This peculiarity which introduces the concepts of Heterogeneous Domains Rules (in the sense that contain links to entities belonging to two different considered domains) allows the verification of consistency, but as negative effect (in terms of implementation difficulty), introduces an additional burden of analysis and verification of design solutions to the system.

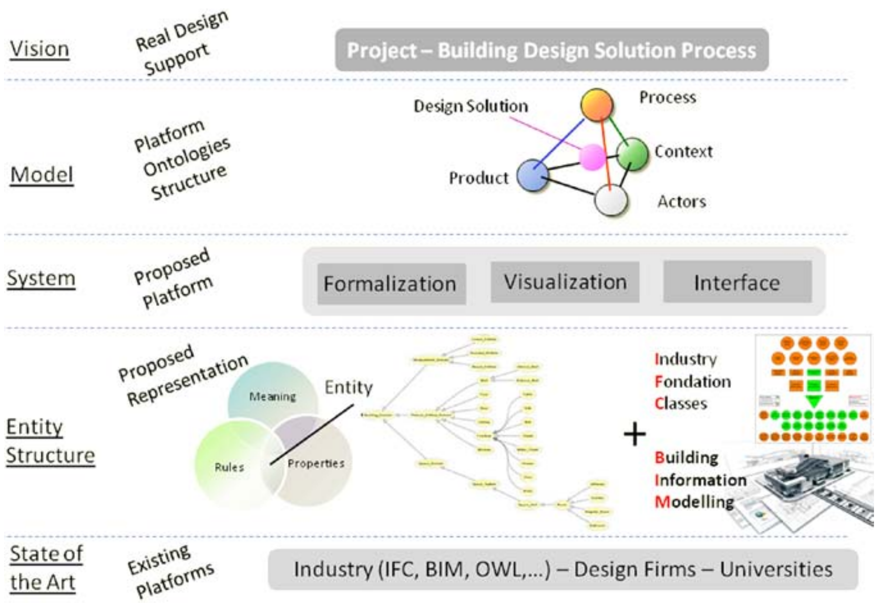


Figure 12 The overall schema of Architectural Design Process/ Product aided tool - present paper focused layers of Comprehensive Knowledge Model and Entity Structure

11 Conclusions

In the present paper it has been presented an innovative *Comprehensive* Design Knowledge Model part of an aid tool applied to an inclusive product/process aimed at Architectural and Building Design in both aspects of process and product (Figure 12).

Referring to the powerful Knowledge-based Structure representation developed by the authors (Meanings-Properties-Rules) and to previous researches on Collaborative Design, it has been investigated the set of entities that contribute to the architectural and building product definition.
A sub-set of involved entities have been analysed and structured into a *Comprehensive* Design Knowledge Model by means of four *poles* that represents four different realms involved in Building Design Definition: Product, Context, Actors and Procedures. That allows the Model to better simulate the real life environment in which design solutions are carried out.
Turning our attention to the future, it is possible to trace the potential of the tool described starting from its innovative elements, in particular with reference to the model that defines an inclusive and intuitive knowledge structure more expressive and user friendly than IFC standards and integrated with it. From the management standpoint, this result opens up to the potential offered by the ontological argument which represents an efficient automatic resource to help the actors (humans or software agents) in the recursive decision-making process of design.

11.1 Discussions on potentials and limitations

The innovative application of the emerging technologies described above gives rise to two experimental observations that enliven the discussion of this research: the first is that the technologies based on ontologies do not belong to the current generation of commercial tools for building design. At the same time, what this work has managed to demonstrate through the implementation related to several case studies is that today it may be taken for granted that the ease with which an actor lacking a specific information science background can approach the (re)modelling of a formal ontology for building and architectural design and to personalize it to suit his own needs.

11.2 Future research and potential applications

The Comprehensive Model developed has as its working horizon the upgrading of the links between the representation of the concepts used and their processability and management by an information platform.
The implementation of these links opens up to the potential of software agents for the support of specific design tasks: in this way the platform can attain a level of reasoning consistent with the working methodology of the designer, thus supporting an ‘intelligent’ management of the operating data.
In particular, by developing these information platforms, it will be possible to simulate the collaborative design of project themes referring to infrastructures having a high degree of complexity.
More generally, the potential of this research refers to manifold final results the spinoff effects may be classified in the following environments:

- *Cultural*: working in a collaborative fashion with shared knowledge will yield a generalizing method for a fresh organization of technical knowledge in building. Indeed, the identification of a structure for the representation of design entities simplifies the processes of mutual comprehension between complementary domains. In this way it is possible, with a greater economy of resources, to map the ontologies tasked with the same design aim, translating the different meanings linked to the shared entities.

- *Technical*: the formal definition of the ICT model will facilitate information exchange between the productive and the design organizations and will allow a more immediately operative approach to the construction of prototypes. The endemic difficulties encountered in the construction sector in its progress towards emancipation from consolidated techniques and technologies (often from non virtuous traditions and habits) will necessarily be reduced as systems capable of enhancing the rich heritage of multidisciplinary knowledge spread.
- *Technological*: an efficient formalization of the specialist contents linked to the project entities, opened up to the automation of the project activity and consequently to the rationalization of the productive process. The spinoff ranges from the definition of the components starting from the basic materials, their installation, and from the management of the building system to its demolition and disposal.
- *Didactic*: innovative forms of teaching collaboration in the multidisciplinary architectural project. The opportunities offered by an on-line platform of the type proposed reduce the critical organizational points of the multidisciplinary didactic workshops, affording the actors (students and teachers) a quantum leap in the quality of e-learning tools by experiencing in a more concrete fashion the difficulties and potential of collaboration on the basis of a shared design theme.

Knowledge Tetrahedron is a symbolic expression for a conceptually new kind of Design model and representation allowing building analysis as an integrated knowledge universe: interaction among actors can be made on entities at higher semantic levels instead of just data sharing at low semantic level.

Such an approach has been implemented in different situations and it shows to be congruent and effective.

It represents the basis of the on-progress research on Building Design Collaboration and it will also be the input of an innovative learning methodology for Architecture and Building Multidisciplinary Design Collaboration, to create a new generation of designers more aware of the increasing complexity of the design processes.

Bibliography

Beetz, J., **Leeuwen, J.P. van** and **Vries, B. de** (2006). Towards a topological reasoning service for IFC-based building information models in a semantic web context. In: Prtoceedings Joint International Conference on Computing and Decision Making in Civil and Building Engineering, Montréal, Canada

Carrara, G. and **Fioravanti, A.** (2007a). X-House - a Game to Improve Collaboration in Architectural Design. How to distill a CD-Based Model into an eLearning Tool. In: Kieferle, J.B. and Ehlers, K. eds, Predicting the Future, 24th eCAADe Conference, Frankfurt, pp 141-149

Carrara, G. and **Fioravanti, A.** (2007b). Collaboration – New Media – Design. An Integrated Environment for Supporting Collaboration in Building Design. In: Pawlak, A., Sandkuhl, K., Cholewa, W. and Indrusiak, L.S. eds, Coordination of Collaborative Engineering – State of the Art and Future Challenges, 5th Workshop on Challenges in Collaborative Engineering (CCE'07), Krakow, pp 125-142 (GI-Edition, Lecture Notes in Informatics, Kollen Druck + Verlag, Bonn)

Carrara, G. and **Fioravanti, A.** (2005). Creative architectural design boosted by ICT enhanced incubator. In: Gero, J.S. and Sosa, R. eds, Computational and Cognitive Models of Creative Design, 6th International Roundtable Conference, Heron Island, AUS, pp 275-300

Carrara, G. and **Fioravanti, A.** (2002). 'Shared Space' and 'Private Space' Dialectics in Collaborative Architectural Design. In: Pohl, J. ed, Collaborative Decision-Support Systems. Baden-Baden, SAN LOUIS OBISPO, pp 27-44

Carrara, G., Fioravanti, A., Loffreda, G. and **Trento, A.** (2009a). An Ontology-Based Knowledge Representation Model for Cross-disciplinary Building Design - A General Template. In: Çağdaş, G.

and Çolakoğlu, B. eds, Computation: the New Realm of Architectural Design. eCAADe Istanbul, pp 367-373

Carrara, G., Fioravanti, A. and **Nanni U.** (2009b). Knowledge-based Collaborative Architectural Design, International Journal of Design Sciences and Technology, 16:1, pp 1-16

Carrara, G., Fioravanti, A. and **Novembri, G.** (1997). 'An Intelligent Assistant for architectural design studio', eCAADe 1997 Conference, Wien [info.tuwien.ac.at/ecaade/proc/carrara/carrara.htm]

Fioravanti, A. (2008). An eLearning Environment to Enhance Quality in Collaborative Design. How to Build Intelligent Assistants and 'Filters' Between Them, Architecture and Modern Information Technology 4:5 [www.marhi.ru/AMIT/2008/4kvart08/Fioravanti/Article.php] Extended edition of this paper is published in Muylle, M. ed, Architecture 'in computro' - integrating methods and techniques, 26th eCAADe Conference, Antwerp, pp 829-836

Fioravanti, A. and **Loffreda, G.** (2009). Formalizing and computing Ontologies to Speed Up the Construction of Knowledge-based Collaborative Systems, Three different approaches. In: Çağdaş, G. and Çolakoğlu, B. eds, Computation: the new Realm of Architectural Design, eCAADe 27, Istanbul, pp 341-348

Gero, J.S. and **Kannenglesser, U.** (2006). A function-behaviour-structure ontology of processes. In: Gero, J.S. ed., Design Computing and Cognition, Springler, Netherlands, pp 407-422

Gero, J.S. and **Reffat, R.M.** (2001). Multiple representations as platform for situated learning systems. In: Designing, Knowledge-Based Systems, 14:7, 337-351

Hofstadter, D.R. (1999). Gödel, Escher, Bach: an Eternal Golden Braid, Basic Book, New York

Kalay, Y.E. (2009). The impact of information technology on architectural design in the 21st century. In: Tidai, T. and Dorta, T. eds, Joining Languages, Cultures and Visions, CAAD Futures, Montreal, Les Presses de l'Université de Montréal, pp 21-34

Kavakli, M. (2001). NoDes: kNOwledge-based modelling for detailed DESign process - from analysis to implementation, Automation in Construction, 10:4, 399-416

Kvan, T. (2000). Collaborative design: what is it?, Martens, B. ed, Automation in Construction, 9:4, 409-415

Meadows, D.H., Meadows, D.L., Randers, J. and **Behrens, W.W.** (1972). The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind, Report of Roma's Club, Potomac Book

Morris, W. (1881). The prospects of Architecture in Civilization Conference, London Institution, cited in On Art and Socialism, London 1947

Negroponte, N. (1970). The Architecture Machine - Toward A More Human Environment, MIT Press, Cambridge, MA

Novak, M. (2005). Conference in Rome, 15th April 2005 [www.neural.it/english/marcosnovak.htm]

Simon, H.A. (1996). The Sciences of the Artificial, MIT Press, Cambridge, MA

Trento, A., Fioravanti, A. and **Loffreda, G.** (2010). Ontologies for Cities of Future - The quest of formalizing interaction rules of urban phenomena. *In*: Schmitt G. et al, eds, Future Cities, Zurich, vdf Hochschulverlag AG an der ETH Zurich, pp 797-804

UN - United Nations (2009). 'World Urbanization Prospects', WUP2009_Wallchart_Urban-Rural_Final.pdf [esa.un.org/unpd/wup/unup/p2k0data.asp]

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> **Beckett K.L.** and **Shaffer D.W.** (2004). Augmented by Reality: The Pedagogical Praxis of Urban Planning as a Pathway to Ecological Thinking, University of Wisconsin, Madison
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> **Gorard, S.** and **Selwynn, N.** (1999). Switching on to the learning society? Questioning the role of technology in widening participation in lifelong learning, Journal of Education Policy, 14:5, 523-534
> **Blackman, D.A.** (2001). Does a Learning Organisation Facilitate Knowledge Acquisition and Transfer? Electronic Journal of Radical Organization Theory, 7:2 [www.mngt.waikato.ac.nz/Research/ ejrot/Vol7_1/Vol7_1articles/blackman.asp]
> **World Bank** (2002). Social assessment as a method for social analysis, World Bank Group [www.worldbank.org/gender/resources/assessment/samethod.htm]

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