Human Behaviour Simulation to Enhance Workspace Wellbeing and Productivity

A BIM and Ontologies implementation path

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Three-quarters of the production value are generated during activities that involve thinking, conducting relational and brainstorming activities. Most of the European office buildings today have been designed on more than fifty year old architectural and psychosocial concepts. To improve wellbeing and productivity, design innovation focuses on human's use-process, evolving individual workspace to flexible and specialized ones, according to the users tasks - activity-based. BIM supports sophisticated behaviors simulation such as energy, acoustics, although the state of the art, this paradigm is not able to manage space use-processes. Compared to current research on simulation systems, the proposed method links spaces to user's Behavioral Knowledge including formalization of Personality Typologies and profiled behavioral patterns. A hybrid approach for computational technique has been identified, combining (big) data-driven algorithm with ontology-based context reasoning, in order to achieve both, the best performance from intensive data-driven methods, and the finest adaptation for ontological context awareness (including unexplored context capabilities and objects adaptations).

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WORKSPACES TO ENHANCE WELLBEING AND PRODUCTIVITY

In order to improve the quality of an architectural artefact, a central task for multidisciplinary design teams is to test the tentative design solutions and see how well they work 'in practice' before, during and after the construction: from digital model to real world.

The building quality does not involve only aesthetic and economical aspects but also wellbeing and productivity of employees.

Nowadays companies not only recognize the connection between employee productivity and mindfulness, but also they are looking at good data to support it.

The fact is, there is a major shift underway in the workspace from employee wellness to wellbeing. Almost all (96 %) of the 6,500 organizations surveyed by WorldatWork [1] offer elements of a wellbeing program, and three-quarters of them are increasing their offerings in the next two years with the main objectives of improving employee health, impacting healthcare costs and increasing productivity.

While the two terms "*wellness*" and "*wellbeing*" might sound much the same, in the workspace context they mean very different things.

Most of the European buildings, specifically facilities used as working places and offices, used by companies today are designed and built on more than fifty years old architectural and psychosocial concepts. This is reflected on the workspace use-process that does not respond to the needs and way of working required nowadays. The problem of human disengagement from the cultural and working context generates a loss of productivity and excessive operating costs that frequently are reflected on a reduction of competitiveness.

Given these premises, emerges the potential and strategic importance of rethinking the workplace, to be considered not only as an element of cost reduction related to unused spaces but above all as a lever to increase the percentage of workspace user engagement.

In fact, according to Gensler (2011), to be able to improve by 10% the productivity of human resources can be reflected on an economic advantage 20 times higher than the one obtained with the 10% reduction of the spaces.

Workspaces should be redesigned by focusing on the wellbeing of people and considering the value generated by activities carried out by the latter. According JLL global [2], three-quarters of the company production value are generated during activities that involve thinking, conducting relational and brainstorming activities. The urgent problem is that nowadays workspaces, for how they are structured, they are not designed to facilitate these activities, nor are they designed to increase the level of welfare and "*engagement*".

Design innovation, focused on considering the humans at the center of the use-process, is currently oriented to an evolution of the individual workspace to flexible and specialized workspaces according to the tasks that users must play - activity-based.

Productive workspace elicit collaboration, creativity and foster new work experience integrating processes, actors and products.

Involvement, open connections and peering, multidisciplinary sharing, interoperability starting from comfort and wellbeing for the most important assets of any companies: people.

In order to provide different spaces and suitable for the various activities, it is important to review the design process starting from the analysis of the occupants, the space use-process, employees and their prevalent psychological profiles.

To allow coexistence and availability to all workers of different types of environment it is necessary to define and adopt a smart and flexible working model-process so that everyone can benefit from the most suitable and comfortable space.

Design by means of simulations

A long debate has arisen, especially in Europe, from the possibility of re-using and giving new functions to existing buildings.

On one side, there is the necessity and the opportunity of giving new life to these environments while, on the other side, especially in big cities' historical centers, where still higher is the density of office facilities, several problems arise from the preservation of the built heritage artifact and its actual capabilities of hosting new functions, users and use scenarios.

At present, the task of predicting and assessing if and how an existing environment will effectively host new uses and/or users is still unsupported and completely left to designers' expertise and imagination.

To enhance the control on the final design product and use process quality is a key element for boosting work space users' wellbeing and productivity.

Property managers, architects, structural engineers, energy engineers and all the actors involved in companies' asset re-functionalization, know very well the importance of how the building and the activities are accurately modelled in order to better design and manage the use-process.

Researchers are urgently called at developing methods and tools to support the decisions-making processes related to workplaces refurbishment, change of use, conservation and management.

On this basis, few current research projects (Tabak 2009; Zimmerman 2006; Shen 2012) have been involved in in the development of conceptual modeling approaches in order to enhance simulation of existing artifacts in relation with their potential re-uses.

Specifically, the problem addressed by the authors' research group since the last decads is the conceptual development and validation of a modeling and simulation platform to test different use scenarios in order to understand and evaluate the relationship between humans users and the designed workspace, namely if and how the re-designed environment will be able to host its intended new functions, users and use processes.

Actual research framework outlined in this paper starts from occupancy analysis (users profiling, context and reciprocal interaction) in order to collect Behavioral Knowledge. A suitable structure for formalizing project-process semantics and incrementally populate it have been studied.

The core of the modelling task is to ensure an efficient connection between building process, product, context and users, in order to support design and evaluation, by means of both static simulation (Data-driven and Ontology-based) of a specific artefact, and dynamic simulation of a contextualized use process (Agents+AI).

The environmental behaviour

According to Kurt Lewin's founder of the experimental Social and Environmental Psychology (1936), Topological psychology (or "Field Theory"), the field of social and environmental forces influences behaviour.

LEWIN'S BEHAVIOUR FORMULA: B = f (P, E)

His 'Reciprocal Determinism' theory, defines Behaviour as function of the Person and his/her (physical/social) Environment, where Person, Environment, and Behavior influence one another in a dynamic way (Figure 1). In this way, he started to develop a systemic view of environmental behavior.

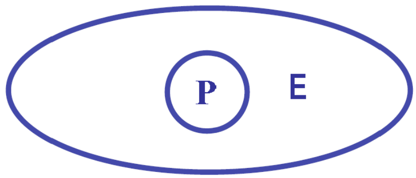

Figure 1
Behaviour as function of Personality, Environment and their relations.

The environment does not only cause behavior, but is also influenced by behavior:

Persons ---> MODIFY ---> *Environment*

Persons actively search for situations that fit their aims and personality:

Persons ---> SELECT ---> *Environments*

Personality, attitudes, expectancies, goals, and competencies are influenced by the social and natural environment.

Authors perspective starting from Lewin theory and extending the concepts of Persons and Environment, is that a reciprocal influence exist between users and context, where the first affects the latter, and viceversa (Gargaro 2015).

Users <---> MODIFY<---> *Context*

Users <---> SELECT<---> *Context*

Since Personality makes users unique and different from each other, starting from the late XIX century numerous structured psychological approaches have been proposed such as e.g. *Analytical and deep Psychology* (Freud), *Humanistic Psychology* (Rogers; Maslow), *Trait approaches towards personality* and *Personality Typologies*.

Anyway, in today practice, it can be observed a diffuse pragmatic classification approach adopted by commercial goods and services industry, based on opportunistically oriented and effective *Personality Typologies* definition.

'Consumer' typology and 'life-style' typology use psychological and other features to describe a group of persons: these are not personality theories or traits in the classical psychological sense, e.g. not stable over lifetime.

Such typologies often include *consumption pattern* and *behaviours* as a basis for classification. Of course it is required a clear distinction between characteristics used for classification, and related behavioral characteristics, e.g. different variables can be focused on the same or different typologies: demographics, environmental knowledge, environmental concern, norms, activism, shopping motivations, shopping behavior etc.

In order to collect formalized knowledge related to users' profiles, in order to model phenomenon and process simulations we classified two main methodological categories.

On one side, more traditionally, experts work on the defining space users Personality Typologies by means of structured surveys for outlining differences in the same classes of users approaching the same activities (preferences, value orientation, expectancies, attitudes, etc.).

On the other side, the knowledge source originates by a sort of reverse engineering process, capturing data, information and knowledge from real world monitoring, by means of different media technologies (temperature revelator, camera, RFID, Internet of Things, etc.) according to the following process: REALITY -> BIG DATA COLLECTION -> DATA DRIVEN PROCESSING -> ONTOLOGY RECOGNITION -> ONTOLOGY POPULATION

Expected capability, implemented action and oriented behaviour instances

Designers are used to define function as what could be done in every space, and the action as an actual instantiation of a function (i.e. a function that was put into effect).

In order to clearly state a basic taxonomy of Behavioral Knowledge, authors, according to Wurzer (2009) state two notions:

- Capability: the ability to perform a certain action in a space (e.g. capability can sit and can park bed in a hospital's waiting area).
- Action: the implementation of a capability in space and time (e.g. action wait in the same waiting area that either uses can sit for patients that can walk or can park bed for reclined patients).

A substantial part of present scientific research is focused on developing techniques to model, learn, recognize, and predict what users are doing in the environment, so that the system is able to make decisions about how to assist them and designers.

Usually, the literature calls what users are doing human behavior or human activity interchangeably (Remagnino et al. 2005; Ros et al. 2013).

These terms usually mean a sequence of human actions that can be tagged with a label, that is, the corresponding activity/behavior. These authors agree to define human action as the simplest unit in the human activity, and it is usually associated with a sensor event.

From the authors' point of view, as long as new semantic approaches are being developed (Chen and Nugent 2009), new abstraction levels appear in the system.

For this reason, from the authors' perspective, a difference should be made between the terms human activity and human behavior to separate the concepts of what the user is really doing in the environment (activity, intended as the implementation of space functional capability), which is inferred from sensor data and machine-learning techniques, and the purpose or meaning it could have (behavior, intended as a contextualized and oriented system of users' actions).

Despite the great advances produced in the last decade, the complexity and the quantity of possible complex activities, the temporal interdependences among actions (Ros et al. 2013), the relevance of the semantics associated with a behavior (Chen and Nugent 2009), and the existence and interaction of several actors in the same environment/context, make learning and recognition of human behavior relevant and bring up clear challenges in present research.

DESIGN TOOLS

The advent of BIM technologies and their pervasive diffusion in the professional design studios is introducing an interesting modification of designer habits, extending their capacity to foresee building-related problems and conflict managements, which are typical of the subsequence phases: construction, maintenance, re-use or demolition.

This happened because the multidisciplinary decision making process, complex and, for some aspects highly recursive, relies on the way product-related knowledge is modelled in the actual CAAD design tool.

BIM and Users

Studying the most common standard in the BIM field, such as Industry Foundation Classes (IFC) [3], we can observe that CAAD tools have been developed by means of a space-components product approach, successful in terms of data exchange and information interoperability between programs. Notwithstanding that, these tools lack of semantics that in turn is reflected in the modelled buildings, especially when required to simulate its behaviour in terms of usage, safety and comfort.

More specifically, predicting human behaviour in a building during its usage, by means of the current standards, tools and technologies is an urgent open problem, which has challenged knowledge engineers and building designers for long time. It also involves a lot of resources in terms of industrial research and development in the fields of military and videogames.

BIM paradigm supports sophisticated design approaches to simulate complex behaviors such as energy, acoustics, lighting, although at the state of the art, it is not able to manage both user's activities and space use-process.

On the other side, in recent decades, companies typically centered wellness programs only on the physical aspects of health, such as blood pressure, blood sugar and so on.

By contrast, the actual trend is oriented to well-being, a more holistic concept - focused on 'being' - acknowledging the connection between the body and mind, as well as the workplace environment and experience itself [4].

In order to evaluate wellbeing in workspaces, simulation models need to manage complex semantics, including both, BIM based environmental physical parameters, and formalized user's personal aspects, like personality typologies, traits profiling and expected behavioral patterns.

As new approaches for task modeling include semantics to simulate human activity, *context awareness techniques in terms of space and time* become a more central part of next future systems.

BIM models must be integrated with more abstract sematic levels, e.g. characterizing Spaces not only by physical parameters related to environmental comfort but also with space-time functional aspects, including, in terms of Capabilities the effective distinction introduced by Tabak (2004) between two different classes of Activities: Skeleton Activities, referred to companies planned functional processes and Intermediate Activities, intended as recurrent occurences, only partially predictable in term of process.

Once collected and formalized, Knowledge can be computed to process simulations.

Use-process simulation tools

As agreed by the most scientific literature in the field, a simulative model is based on two main components:

- A static component, representing a specific and unique system status based on all formalized entities, including all the instances present in the instant T0,
- A dynamic component, able to perform the changing of the entities state from the system status T0 to T1.

In the last years, agent-based modeling approaches have been introduced in this research field, aiming at simulating users' behavior in built environments by developing a series of autonomous entities - the agents - each of which interacts in an autonomous way with the other users and with the environment surrounding it.

This kind of simulation approaches, such as "narrative approach" doesn't allow a prediction but the pre-defined scenario visualization.

According to Kalay (2013), agent-based models has shown to be highly requiring in terms of computational resources and not enough expressive in the simulation of events in which the users-agents have to make context dependent decisions and behave in an interleaved way.

The simulation model here presented integrates two main modules:

- Use Process Knowledge which structure has been presented in previous papers (Trento 2013), linking, in a homogeneous computational environment, BIM to higher level semantics;
- - Simulation engines to perform and visualize the effects of the model status change.

Based on this kind of model, a hybrid Agents based simulation model is investigated.

Agent are associated to AI resources, that reside not only in the Actors' Knowledge Bases, but opportunistically in other entities (Context, Product, Process), reducing computational loads and enabling inference engines to process rules-based reasoning.

Techniques for representing Human Behaviour

Current trends show that tracking and monitoring people is becoming an integral part of everyday life so that user behaviours can be captured and stored.

This way we have the user actual actions performed with their specific movements, characteristics, peculiarities. We can distinguish an activity, the planned action for every space; the undertaken action that starts in a space; the concrete action performed that depends on the personality of each person. An activity can be planned for certain spaces for instance -checking passport, but the subsequent actions are determined by circumstances and each person has his/her own habit to do his/her job.

Data-based approaches (i.d. Bayesian networks, decision trees, etc.) appear to stand out while knowledge-based techniques are back. The latter include, among others, information indexing and retrieval, hierarchical knowledge sources (i.d. taxonomies, ontologies, encyclopedias, dictionaries), representation languages, distributed knowledge, and especially logical tools.

According to Villalon et al. (2010), the broader the ontology is, the more situations are possible to be modelled, in order to assist the users in their daily activities; and the less usable the ontology is in order to achieve a specific goal. However, the more specific the ontology is, the fewer possibilities exist to be reused, and the more efficient the ontology is for that field.

The size of the problem, specific domain, and concrete task are key elements when selecting an ontology. However, what can be appreciated from the Rodriguez (2015) survey is that most of the works require a data-intensive-driven first approach to robustly identify the most basic-level actions or activities.

Context Awareness

Context consists of not only physical space like environment, but also cultural, psychological, technical, etc. (Gargaro 2013) or any information that can be used to characterize the state of an entity (Dey and Abowd 2000). Entities can include a person, an object, an environment, an application, or a device that interacts between them and the user.

Proposals to model context can be integrated with human activity models provided with semantics.

According to Rodriguez (2015), as time is not a feature inherently treated in knowledge-driven approaches such as logic-based systems, having hybrid methods with a first data-driven preprocessing stage appears to be the right direction to benefit from both data- and knowledge-driven computing paradigms. As ontological reasoning can be computationally expensive, this type of combination would achieve the best performance and efficiency from (time-dependent) data-driven methods (that can be more efficiently computed) and obtain the best adaptation for context awareness in each case.

It is important to note that Web Ontology Language 2 (OWL2) is powerful for expressing knowledge entities, context entities and relations among entities. However, OWL2 is insufficient to model context relations and rules with the form of cyclic relations

Therefore, the ontologies discussed require an integration with a rule language - such as Semantic Web Rule Language (SWRL) [5] or SPARQL Inference Notation (SPIN) [6] - in order to express more complex and real-life ontext rules.

The combination of Data language with Rule-based language improves the reasoning capabilities.

Rule-based languages enable definition of consistency rules, reducing ambiguity in the context information and thus maintaining and improving the information quality. For instance, SWRL extends the semantics of OWL and defines antecedent-consequent rules and built-in operators (math, comparisons, string and time).

As a concluding remark, we can clearly point out that the integration of different methodologies (i.e. data-driven and knowledge-based ones) could help overcome current limitations in scenarios with several actors, providing semantics to social activities, user identification (according to behavior semantics), and so forth.

Current hybrid approaches such as Gomez-Romero et al. (2011) have shown that these types of combinations can enhance the response of data-driven approaches as the environment complexity and the context awareness needs increase.

A FRAMEWORK TO FORMALIZE SPACES AND HUMAN BEHAVIOUR

The model for simulation of the interaction between humans and environment presented here outlines an implementation pattern for integrating BIM space and physical characteristics by behavioural knowledge, intended as a semantic structure capable of representing the entities and their relationships between activities-actors-context and places (Fioravanti 2010)

Compared to current research in the field, the present approach to represent Behavioural Knowledge includes among others formalization of user personal aspects, like Personality Typologies, classes profiling and expected behavioural patterns.

A hybrid approach for computational technique has been preferred, combining (big) data-driven algorithm with ontology-based context reasoning, in order to obtain both, the best performance and efficiency from intensive data-driven methods, and the best adaptation for ontological context awareness (including unexplored context capabilities and objects adaptations).

This section reports on a theoretical framework and some early implementation patterns developed in the general framework of an on-going research aimed at the definition of a new approach to support assistive systems for management and performance simulations.

To model and test knowledge related to the user behaviour in a building environment we need:

1. Spaces that are characterized by physical parameters related to environmental comfort but also with space-time Functional aspects, Potentialities or Behaviours, Capability or Action (Wurzer 2010);
2. A Use Process Knowledge structure (Trento 2013) that includes Skeleton Activities and Intermediate Activities (Tabak 2004);
3. An Agent-based simulation, enhanced by associating agents with AI resources (upper ontology level), that reside not only in the Actors' Knowledge-based systems, but also in other

systems (Context, Product, Process).

Planner traditional approach conceives at the beginning of planned processes expertise, technical regulations, best practices, etc. in an architectural schema (Wurzer 2009; Wurzer 2010). However, those processes are correctly performed only if the planner can rightly anticipate and inform the usage of the building by different building users.

Evidently this is a risky task, relying on designers limited and implicit knowledge, since the human behaviour in a building is highly non-deterministic and not a-priori definable.

To support this kind of operation, we rely on a general structure of knowledge representation known in the scientific community developed by DaaD group that works to extend its application fields (Fioravanti et al. 2011; Fioravanti et al. 2012).

As a starting point we used the already defined "Meaning-Properties-Rules" (M-P-R) knowledge structure (Carrara et al. 2009) able to describe the product entities and their relations by means of a general template (freezing the control on the other knowledge realms, as context, actor and process).

Behavioural simulation innovative approach. How to afford the mismatching "squared peg in a round hole problem"

The innovation is to take into account misused spaces or inappropriate user's behaviour to modify one of them or both to reach the activity goal.

The human history - especially the science one - is plenty of overcoming (apparently) impossible goal. The "trial and error" paradigm both in technology and in theory, very often intertwined, as a means to adapt circumstances, tools and goals has been the normality not an exception at different abstraction layers with different granularity.

The key concept to resolve deadlocks has frequently been the "adaptation" mechanism.

For instance, the classical problem of "squared peg in a round hole problem" - extending this concept to human satisfaction of workspace - can be solved by cutting the peg, or enlarging the hole, or both.

Going back to the peg: How can it fit in the hole?

Can it be cut? What is the stiffness of material? Are there tools to modify it in a right manner? What is the cost? How much time should be spent for modifying the initial planned work? What phase is it, the design or the construction one?

Situational and contextual factors need to be taken into account for understanding human behaviour.

Apart from personality traits, further interpersonal differences are important for explaining and predicting environmental behaviour, e.g. competencies and knowledge, expectancies, value orientations, (environmental) attitudes, personal norms, psychological states (e.g. tiredness, stress, state-anxiety).

Explaining environmental behaviour contemporarily relies, to very large extent, on different concepts than clinical and personality psychology. As value-orientations, attitudes, knowledge and competencies are usually understood as less stable (less deeply rooted in personality) as compared to personality traits, considering these factors opens up possibilities for changing environmental behaviours.

The new approach we present here, differently from (Trento 2013) does not completely renounces at the task of modelling the actor's *personality profile*, and focuses on defining a set of occurrences, that dynamically happen in the workspace and, organized in a proper way, represents a scenario of experience of the building use.

An 'event' represents a set of activities, performed by a determined group of actors in a determined space of the building.

If we use simulations in a virtual world to simulate future events of the real world, we have to reliably represent it, but not be limited by the real world rules. So, while in the real world only people have the capabilities to think, evaluate the environment and control their behaviour, in the virtual world this task can be assigned to entities, both representing physical or abstract objects.

This is helpful for our approach because it offers the possibility to build event- agents and give them the task of controlling other 'passive' objects (actors, furniture, building components, facilities), their behaviours and their interactions.

In this modelling approach a scenario of building usage can be represented as an organized, time-depended and context-depended structure of events by means of a suitable formalism.

Events and Relations among them are extremely influenced by the status of the built environment and by what is happening in it, so we can consider the event-environment system as a stochastic system in which there is a high level of uncertainty and variation. While in the real world events emerge from people behaviour, in the proposed model events are predefined in order to build a usage scenario but this doesn't mean that the structure is fixed. In fact, to build a reliable structure of events, the model deals with two different components during the simulation: narrative events sequence and events structure adaptation. The first is necessary because, to build a scenario, it's necessary to build a general plot of the occurrences that are going to happen in environment; this can be derived by the pattern of activities related to the functional aims of the designed building and by the initial building program. But this is not sufficient to reliably represent the usage scenario because we need to adapt this plot to the status of the on-going built and activity context to simulate the effective sequence of events. It is not a one-way system comparing initial event structure of the model with event actual status, but a bidirectional one because at each instant the system has to look at the actual event status - the behaviour, evaluate it and adapt the events structure on the basis of this status.

Use and Behaviour Knowledge

'Use Process Knowledge' is represented by means of Use Process Ontology, a structure based on Use Process Entities, qualified by a system of Use Process Rules (Trento 2013). On one hand these process rules govern activities planning and on the other hand they control the relationship with the rest of knowledge realms: who does what, where, when and how.

Use Process Knowledge can be described by means of process classes, at different levels of aggregation:

- Use Process Actions: elementary class entities structuring the Use Process Ontology. They represent the process based on user's minimum ergonomic function.
- Use Process Activities: a set of Use Process Actions structured in time and space, oriented by the functional programme. They qualify the relation between users and building (spaces, components, facilities, equipment, etc.).
- Use Process Rationale: aggregation of Use Process Activities. The importance of representation for use rationale has been recognized but it is a more complex issue that extends beyond artefact function. It is function of social-economical-environmental sustainability.
- Events: particular process entities, "milestones" that occur in the dynamics of the activities. Emergencies necessary to structure the causal and dependency relationship between Use Process entities".

IMPLEMENTATION PROCESS AND EXPECTED RESULTS

The research project is going on, according to the following steps:

1. Study of the knowledge domain related to the re-use of built heritage and identification of the knowledge to be modelled for the purpose of the platform;
2. Definition of a knowledge-based model for the formalization of the knowledge related to the heritage artifact and its intended use and users;
3. Formalization of this knowledge;

4. Selection and definition of simulative approaches and models for the predictions of the use processes and of the related building performances (space functionality, energy behavior, structural behavior, fire egress, etc.);
5. Integration of the Knowledge modelling environment and the Simulations environment within the platform;
6. Selection of some case studies and experimental application of the platform (to be performed recursively for the platform calibration);
7. Verification, validation and critical analysis of the platform and its functioning.

For implementing this theoretical model, we are using ontologies plus agents (upper ontology level) in order to model, the design use events entities, physical or abstract, and their space-time relationships structured by means of M-P-R (Carrara et al. 2009) meanings, properties (defining their state) and rules (relations, reasoning rules, consistency, best practices).

The new challenge now is to represent by means of the same knowledge structure M-P-R, the right entities and their relations, in order to manage in a CAAD environment, human behaviour simulation needs to be taken into account including psychological aspects.

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

A system of engines 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.

The implementation steps are:

1. Represent Design Knowledge of Event Ontology (e.g. expressed in OWL language);
2. Connect Event Ontology with actual BIM, or IFC (by means of API, or using Beetz (2009) transcription of IFC in OWL);
3. Connect BIM+ Ontologies with a Narrative environment (e.g. BPM, Virtools, etc.)
4. Find out in the Semantic Web community or build an inference engine to perform the user's behaviour.

The dynamic and semantically-specific representation together with Inference and Simulation Engines are able to predict human behaviour, so coherent/-favourable situations will be evaluated by means of a set of constraints, and will be highlighted and managed in real time.

At the same time, this model allows actors to assess alternatives, more consciously reflecting on the consequences of their intents.

By this way the impact of a networked ontology makes actors more aware of overall design problems and allows them to operate more participative and shared choices.

CONCLUSIONS

This paper reports on theoretical contents and some early implementation patterns developed in the general framework of an on-going research aimed at the definition of a new approach for modelling and testing knowledge related to the users behaviour in a building environment, oriented to support assistive systems for management and performance simulations.

The research agrees on introducing hybrid approaches to take advantage of each technique's best strengths. Combining ontology-based context reasoning with data-driven algorithms has shown to be a promising path to be explored.

This paper proposes how - in a very general case study - data-driven techniques, ontology taxonomy and reasoning agents can be an efficient resource for assisting designers in decision making processes 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 defined a framework implementation that can count on a limited 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 tools.

The specific field of application will be the design of building renovations - such as the ones belonging to Italian real estate public assets "Agenzia del Demanio" - in accordance with a predefined Use Functional Program and/or modifying it, by rescheduling activities and behaviours.

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