Toward Space Oriented BIM Practices

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When performing design tasks, architects think in terms of space, and act on physical elements. They often use various representation means to shape and to communicate the complex aspects of space. Architectural representation is often driven by visual perception whilst current BIM practices seem to be based on semantics associated with scheduling building items (element, position, quantity, etc.). The reduction of architectural sensitive approaches to merely technical ones, reveals only quantitative and restrictive information that does not reflect the architect's multi-sensorial experience. This paper examines some recent model proposals which include descriptions of architectural space concept, and tries to suggest a possible synthesis of this work. It focuses on cooperative practices necessary to unveil the sensitive dimension of the architectural design, and presents a state of existing BIM tools based on relevant tasks used in these practices in order to acquire more knowledge about the concepts which ensure a cooperative work taking into account the sensitive spatial aspects.

Keywords: *Cooperative design, Architectural space, BIM, Qualitative property, Topology*

INTRODUCTION

The overall sensation of a space cannot be understood by an analysis of its measurable properties. The overall ambiance of a space is given by all the interconnected computational factors of which it is composed (Drozd 2009). Shadow, light, transparency, depth, sound, smell, heat, airflow, materials, textures, etc., are all elements that simultaneously participate in discovering and perceiving a space (Bonnaud 2012). Referring to physical experience, it is observed that architecture engages and assembles a large number of sensory dimensions: lighting and thermal ambiance, openness and sunshine of a space, etc. Topology is also an important aspect to qualitatively describe a space. It plays a leading role in evoking feelings in space (ex. communicating spaces, space with exterior relation, etc.). The perception of ambiance induces a questioning about the representation of sensitive spatial aspects. According to Mark Crunelle, it is complex to translate through visual features all perceptions provided by our various senses (Crunelle 1996). That is why, architects always used representations evoking the observers' sensations to reveal the intended ambiance of designed spaces.

BIM models are defined as a consolidated base of parametric objects organized into multiple layers of information describing the physical and functional characteristics of a building (BIM handbook 2014). BIM modelling introduces a technical approach into digital cooperative practices. Such an approach is based on the use of measured standards and codifications, transforming all building information into quantitative data. Only constructive information is taking into account during the design phases. However, a sensitive space approach is not yet integrated. Visual representations used in BIM tools do not allow the user to recognize all elements properties existing in BIM models. BIM models provide information about spaces that not include the relationship between them (Brodeschi 2015). Current BIM practices cover limited points of view that cannot apprehend all the architectural knowledge (form and function) expressed in the philosophical discourse (Bhatt and Kutz 2012).

In this study, we discuss the sensitive space approach during architectural design phases. The first chapter focuses on recent research having addressed data modelling of architectural space concept. The second chapter looks at relevant tasks enabling collaborating on spaces, taking into account their sensitive aspect. Then, the third chapter explores the capability of current BIM tools to realize such tasks. Finally, we try in the last chapter to formalize in a first data model all core concepts allowing taking into account qualitative and topological information about spaces. Our long-term objective is to propose an alternative approach based on these types of sensitive information to assist cooperative work during the design phases.

BACKGROUND

Architectural space is often considered as a construction result. An empty element bounded physically or virtually, in which we can experience a feeling of enclosedness. The generally accepted perception of space within science today is as a relation between things (Ekholm 2000). A building is constructed to provide a set of interior and exterior spaces. It is designed on the basis of a specific program designating the properties of those spaces (shape, location, ambiance, openness, sunshine, relation and communication between, etc.). Most of existing space models treat only the intrinsic properties of a space (ex. geometric data, location, quantity, etc.) and abstract properties related to human experience. The IFC model supports, in part, this type of information. It contains data describing the quality of space including:

- Thermal requirements (required temperature, minimum and maximum values depending on the season, etc.).
- Lighting requirements (lighting values, whether the space requires artificial lighting (true or false), etc.).
- Occupancy requirements (activity type, headroom required for the activity assigned, number of users, areas rate by users, daily duration of the activity, whether an external view is desirable, etc.)
- Safety requirements (fire risk factor, whether the space is intended to serve as a storage of inflammable material, or as an exit, etc.)
- Space covering requirements (nature and thickness of floors, walls, ceilings, etc.).

However, this model does not take into account the rest of qualitative spatial requirements, like the openness of a space, its sunshine, its acoustic ambiance, etc.

Proposing a method for automatic updating of spatial requirements during the design phases, Kim specifies two types of space requirements: activity-based requirements and space-based requirements (Kim 2015). These requirements cover only spatial information supported by the IFC model and do not include requirements related to the topology of spaces. Topological requirements are usually requested by the future user of the building, focusing mainly on information about the boundary and the neighbourhood of spaces. E.g. The openness of a space to the outside, its sunshine, its orientation and its relationship with the rest of surrounding spaces (proximity, communication, container / content, etc.).

Based on an analysis of the conceptual model of spaces, space boundaries and enclosing structures advanced by Bjork (Bjork 1992), Ekholm and Fridqvist present a modelling for spaces including descriptions of their topology in a building (Ekholm and Fridqvist 2000). Using a spatial view, they introduce the concept of user organization to conceptually separate between the intrinsic properties of the built environment and the properties of human activities that are to be housed within. But there is no reflection in the two previous models that addresses the design requirements for the topology of spaces or for their qualitative properties related to the user activity. Among existing recent models, it is only the work of Bhatt who takes into account, implicitly, topological requirements (Bhatt 2011). It proposes a spatial modelling based on modular ontology, including both qualitative and topological requirements, to verify compliance of the spatial properties proposed during the design phases with regulatory requirements. E.g. the range space of a sensory device, the distance between emergency exits in public spaces, etc.

We have just shown that spaces are taken into account, in existing data models, particularly in the IFC model as a set of quantitative and topological properties. Quantitative properties can be guided by qualitative requirements. Currently addressed qualitative requirements cited above are related to designers' field of intervention. E.g. MEP engineer determines the thermal requirements, electrical engineer determines the lighting requirements, etc. However, the user requirements are given in terms of further qualitative properties (e.g. an open and sunny living room communicating with a large kitchen). Hence, information about qualitative and topological spatial requirements must be present in a useful model for design, checking and validation of spaces during the teamwork evolution. In our work, we specifically focus on qualitative and topological requirements expressed by the future user of the building (the owner). In continuity with the work of KIM, this study aims to integrate these types of requirements in current BIM practices and to suggest a decision support method allowing designers to control them.

RELEVANCE OF SPACE CONCEPT IN COOPERATIVE PRACTICES

According to Ireland, spatial problems are complex (Ireland 2015). He argues that to organize spaces, architectural practices tend to flatten spatial problems into something quantifiable so that they can be managed and planned. He states that *"Approaching the configuration of space in the standard way raises the question whether any richness is lost? There is often a qualitative disconnect between the articulation of spatiality in the built environment and the spatiality of being"*. To overcome this issue, we propose to integrate spatial logic in BIM practices. Indeed, the architectural space concept is a shared knowledge between all AEC actors, unlike physical structural or MEP elements, which define it in BIM models. This integration will enhance designers' cooperative work, and enables them to act on the container (building elements) taking into account the quality of the content (spaces) through sensitive dimension expression.

The architectural space; a design entity loaded with sense

Evoking the sensitive dimension of space raises the issue of its representation as a negative empty and immaterial entity: did the designer need BIM tools to translate the feeling of space and communicate it? How to represent what cannot be seen, but can be felt? How can we represent both physical and abstract information necessary to describe sensitive knowledge about a space? All this information seems very useful, especially during the design phases, when user requirements are given in terms of spatial qualities (e.g. the first intentions required by a house owner might be: a large kitchen, an open and sunny living room, etc.) and spatial topology (living room near the kitchen, bedroom upstairs, etc.). Current BIM practices must therefore translate this diversity of properties by moving towards new representative and cooperative methods (associating representation, description, relations, etc.). In addition to **adding** and **visualizing** spaces, BIM tools functionalities must allow designers to **enrich**, to **navigate** on and to **check** sensitive spatial data to express all owners' requirements. They must also allow them to **receive**, instantly, all information about changed spaces, responsible actors and resulting required tasks, according to each actor needs.

To provide a useful conceptual framework in order to lead a collaborative situation functional analysis, Ellis and Wainer established a functional clover, which defines three cooperative areas: coproduction, coordination, and communication (Ellis and Wainer 1994). Based on this functional clover, we highlight in the next sections the relevance of space concept in cooperative activity.

Space as a co-production aid

Spatial logic in BIM practices facilitates co-production of spaces. Actors manipulate space as a generic entity including a set of building elements (walls, ceilings, floors, doors, windows, etc.). This practice is helpful, especially, when the project program is governed by regulatory requirements on space (quantitative, qualitative and topological requirements). Some specific public projects (museums, hospitals, courthouses, airports, etc.) or projects having graphical charters (banks, stores, etc.) have this kind of requirements. For example, French hospital operating theater design is governed by regulatory spatial requirements, e.g. 1. *"A relaxation room can be internal or external to the operating room. It must have a natural lighting."*; 2. *"The pre-anesthetic room must be next the operating theater. It is desirable to provide mood lighting and / or specialized lighting."*; 3. *"A doctors' cloakroom is compulsory, it ensures changing theater dress... It should connect common circulation areas to the operating theater."*; 4. *"The recovery room is a part of an operating theater. It is considered a buffer zone between the theater and the common area of the hospital."* (Translated by the authors from: French circular DH / FH / 2000/264 on 19 May 2000 on the establishment of operating theater boards in public health institutions).

Such spatial requirements are only known implicitly by architects and designers, who are continually trying to satisfy during the advancement of the design. Thus, a checking process is indispensable. BIM practices should enable designers to **enrich qualitative and topological properties of space** in order to take into account requirements during the design process (Siala et al. 2016). These qualitative and topological aspects of a space should be generalizable to all spaces of the same type. For example, in requirement 1) above: *"natural lighting"* must be generalized on all *"relaxation rooms"* of the hospital. Also, in requirement 3) each *"operating theatre"* in the hospital must be separated from the common circulation by a *"cloakroom"*.

During the conceptual design phases, traditional communication means, like minutes of meetings, show certain limits, especially when coordination involves certain particular structural or MEP elements (a dropout beam, a pipe reservation in a slab, etc.). Indeed, the localization of observations in the designed building is difficult, particularly when actor has not attended the coordination meeting. That is why, often the architect must annotate the observations on building plans in order to localize and then communicate them to the interested actors. Thus, allow actors **enriching spaces with meeting observations** facilitates the reuse of information by all actors and the identification of actors' actions. To structure all the information about spaces, it will also be of interest to enable designers to **enrich spatial data associating notes** (to report an issue, point out a remark, etc.), **documents and links** (mood lighting data sheet, specific lighting website, etc.).

At the operation and maintenance phase, the integration of the building user in BIM practices will provide the possibility to take into account the changes he brought to his private spaces. Indeed, the decomposition of BIM models into individual "space-objects" (a detached and shared part of the whole model) allows the building user to **enrich spatial in-**

formation adding his changes and thus give asset managers a clear vision of the real state of the entire building at a time t.

Space as a coordination aid

During architectural design process, coordination activities cover, in most cases, changing the state of some building elements (add a wall, enlarge a window, move a column, etc.). Existing BIM practices enable the structuring of information concerning various building elements, classifying them by type. Thus, to coordinate on a specific element implies consulting all lists of elements (walls, columns, beams, etc.). In this context, a **spatial logic navigation** will provide not only a space-oriented coordination (by zone, floor, space type, etc.), but also the identification of the actors who are concerned by a specific activity. For example, to coordinate about a 'kitchen design' needs all element layers forming this space: enclosing walls, ceilings, openings, equipment, etc. Based on selected layers, it could be easy to determine the necessary actors to coordinate this activity (e.g. in this case: architect, designer, electrical engineer, MEP engineer, kitchen designer, etc.). To ensure a spatial logic navigation through the project, a definition of relating enclosing elements, openings and even eventual sub-spaces, is necessary. So that selecting a space involves the selection of all building objects belonging to it. With this feature spatial logic navigation becomes a reality. The integration of qualitative and topological spatial information in current BIM practices would make it possible **to check whether designed models satisfy required constraints**, during updating models. This will aid the co-production of spaces by orienting designer's vision towards the desired spatial quality. This checking will highlight problematic changes which do not respect the requirements previously enriched by the architect. For example, in requirement 3) of the previous section: *"A doctors' cloak-*

Table 1
Relevant tasks for collaborating taking into account sensitive spatial dimensions.

	Tasks	Data	Support
Co-production	**Add/ modify/ delate**	Space	BIM model
	Visualize/ navigate	Space	BIM model
	Enrich	Qualitative requirements	Space
		Topological requirements	Space
		Design notes*	Space
		Operation notes**	Space
Coordination	**Navigate**	Spaces	BIM model
	Check	Requirements	Space
		Updating changes	Space
	Detect	Actor's actions	Spaces
Communication	**Receive /emit**	Changes***	Spaces
		Required tasks	Spaces

* Notes enriched by designers (notes that report issues, meetings observations, remarks, etc.).
** Notes enriched by the building user (describing changes he brought or needs to bring to his private space)
*** Includes updating changes and changes added by the building user

room is compulsory, it ensures changing theatre dress... It should connect common circulation areas to the operating theatre." A method must enable BIM tools to verify if proposed design solutions satisfy this topological requirements (for example by focusing on the location of those three spaces: operating theatre, cloakroom, common circulation areas).

During the evolution of design, models are exchanged between actors, so that each one introduces adjustments according to his related competence and field of intervention. In this context, current BIM practices should allow **checking automatically changes that have been carried out on spaces during updating models**. This will help to determine the impact of changes on the quality of spaces, and then to communicate relevant updating changes to interested actors. For example, once an architect has expanded a space, the MEP engineer should have the notification allowing him to revise heating and cooling requirements. Checking updating changes also enables BIM tools to associate changes with the responsible actor. This will facilitate **the detection of all actors' actions** and ensure a more detailed tracking of the design progress.

Space as a communication aid

Respectively to the previously intended two **checking process**, current BIM practices must ensure the distribution of the resulting information flow, according to each actor's needs. So that **each actor receives only relevant information relating to his filed of intervention**, and then acts quickly. E.g. 1. An architect has changed the function of a space from "staff office" to "conference room". The acoustic engineer should have the notification to act on the acoustic treatments of enclosing walls, according to the new function; 2. During the operation of a residential building, a user has changed the spatial arrangement of a bathroom. The plumbing enterprise should have the notification to verify the piping connection. Likewise, the asset manager should have the notification allowing him to actualize the BIM model taking into account the latest changes. Based on the conveyed information, the BIM manager can **emit various suggested tasks** on spaces for each concerned actor, in order to structure the coordination activity.

In this chapter we explained how BIM practices can offer new opportunities to collaborate on sensitive spatial information. Table 1 summarizes required tasks of this approach. In the following chapter we will highlight limitations of current BIM tools to provide such tasks.

STATE OF CURRENT BIM PRACTICES

In order to establish the need for a new vision of spaces in current BIM practices, existing BIM tools are first investigated.

Methodology

According to Table 1, we have first defined a set of simple modelling tasks. These tasks have been established to highlight fundamental limits of the various BIM tools with regard to tasks described in the previous chapter (allowing the cooperation on sensitive spatial data). Then, sets of qualitative and topological information were associated with a set of spaces modelled by a CAD tool, then registered under IFC instance to be tested. Regarding topological information, several kinds of link relations have been used in this model, in order to make connection between spaces (e.g. adjacency, intersection, content of subspaces, etc.).Qualitative data concern spatial requirements supported by the IFC model.

Finally, handling these types of data by different BIM tools enabled the detection of the limits of each tested tool to represent and manage initially enriched semantics, to continue enriching them and finally to cooperate throughout. The observation work was carried out on a set of CAD tools (ArchiCAD, Revit, Allplan, and Tekla) and groupware (BIMsync , A360 , BimTRACK , Tekla BIMsight and dRofus). The results of this study are illustrated in Figure 1.

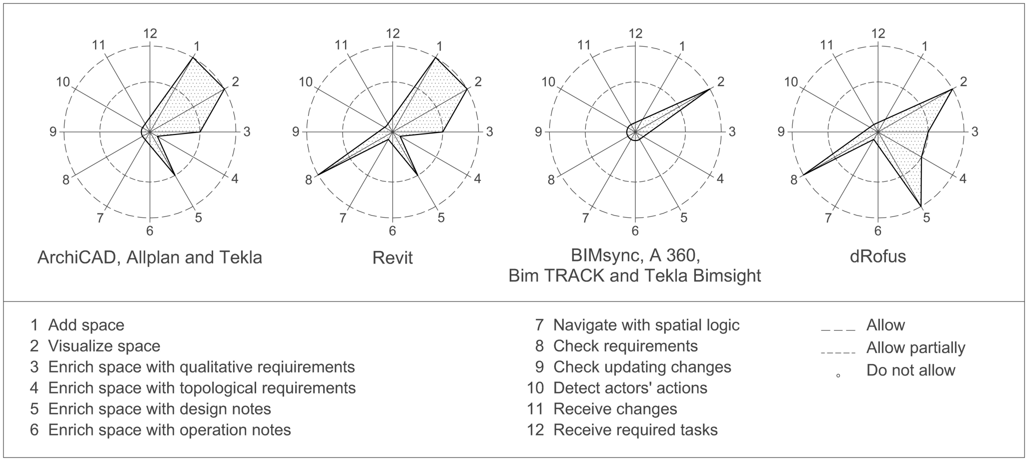


Figure 1
Ability of tested BIM tools to support defined tasks.

CAD tools

Creating space involves the automatic setting of its quantitative properties. Tested tools are limited to spatial requirements supported by the IFC model and do not consider the rest of the qualitative spatial requirements such as those concerning the openness of a space, its sunshine, etc. Likewise, they do not offer the opportunity to add the topological constraints explained in the previous chapter. In most of the investigated tools, a control approach allowing verifying the compliance of design solutions with related specified requirements is missing. CAD tools serve, among others, to organize spaces during the architectural design. However, they do not understand the connection between spaces and even the relation linking them to the enclosing elements. Tested CAD tools allow designers adding notes to a space (name, function, area, headroom, etc.), but do not permit further enriching it with associated documents, links and other personalized remarks like notes that report issues, meetings' observations, etc. Reporting issues is made possible by several integrated modules into CAD tools like A360 and Bim Track. Such modules provide the possibility to illustrate and share screen shots or recoverable views of a design situation, but they do not link remarks to corresponding spaces. With tested tools, it was possible to navigate on designed spaces within 2D or 3D visualization. However, given that all of these tools do not understand the topology of architectural objects, they do not provide navigation with a spatial logic.

Most of tested tools allow team-working on the same model. They enable designers to select and borrow desired building objects from the BIM model, working on and then synchronizing data. Using the same approach, we can imagine integration of the building user in the collaborative environment, in order to facilitate communication during asset management phase. Feature which is not provided at present by existing BIM tools and which requires that "space-objects" should be defined and loaned by asset managers to the building users. Although CAD tools offer advanced collaboration features, they show some limits when it comes to architectural space and specifically to spatial quality of the designed building. To facilitate collaboration, most of these tools can detect changes made to the building objects whilst updating models. A simple comparison between two versions serves to identify all building elements that have changed. Information about changes brought to spaces remains, however, unaddressed by all tested tools.

Thus, considering spaces in such cooperative practices represents a relevant alternative guiding collective activity to manage and validate the spatial quality of the building throughout the design phases.

Groupware

Created with CAD tools, building objects can only be visualized and managed by groupware. Most of tested groupware interpret space semantics automatically assigned by the CAD tool (quantitative intrinsic properties), and ignore properties enriched by the designer (Qualitative and topological requirements). DRofus has the most advanced features allowing the management of spatial information. It enables the introduction of spatial requirements including equipment, some personalized qualitative requirements and even proximity requirements between spaces. A possibility for checking models pursuant to specified requirements is made possible by integrating dRofus module to a CAD tool (Revit). DRofus and Tekla BIMsight offer the ability to enrich information about a space associating notes and documents. In A360, the information about spaces was not taken into account neither in the 3D visualization, nor in the list of hierarchical objects. This last tool interprets BIM models only as a set of building elements (walls, columns, beams, doors, windows, etc.), spaces are thus completely ignored. Furthermore, no tested groupware permits navigation within the designed building with spatial logic, nor allows, likewise, the assembly of meeting observations by space. Groupware seem to be more appropriate than CAD tools for manipulation by building users. Therefore, providing a possible decomposition of models on groupware presents a pertinent approach, making possible for users to annotate spaces with changes made during the operation of the building.

Most of the investigated groupware allow the identification and management of compliance issues during updating models, by sharing views, annotation, and conflict detection (this last feature is supported only by Telka BIMsight and BimTRACK). However, they do not cover in any case incompatibility related to the spatial quality of the designed building, and even related to the form of spaces due to changes in enclosing elements. For example, shifting a wall position may generate the expansion of a space and the reduction of another. Consequently, those spaces needs in terms of lighting, cooling, heating, etc. also change.

So, foresee the checking of updating changes in space, in current groupware, helps to orient the designer's interest to improving the spatial quality of the designed building.

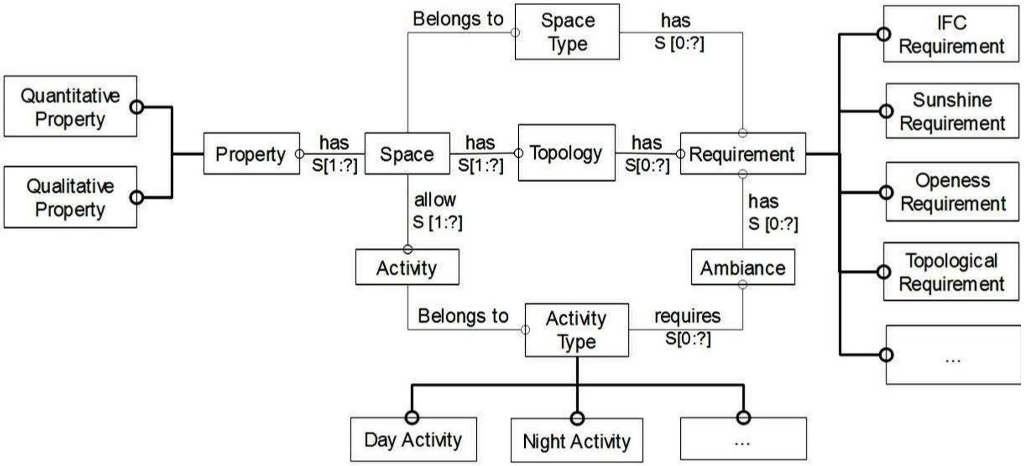
TAKING INTO ACCOUNT QUALITATIVE AND TOPOLOGICAL SPATIAL INFORMATION

Our purpose in this chapter is to define a first data model describing the sensitive aspects of spaces. Based on the observations illustrated in our analysis work on the state of the architectural space concept as addressed in the recent data models and in the current BIM practices.We define below the core concepts of our space model.Brodeschi states that the built environment may assume different functions depending on the physical configuration or the activities to be exercised in (Brodeschi 2015). In our model, architectural <Space> has two types of properties classified as follows:

- <Quantitative Property> which refers to the intrinsic space data. E.g. geometric data, location, quantity, etc.), and
- <Qualitative Property> which refers to extrinsic space data and depends on the interpretation of a human observer (e.g. the cooling or heating mood of a space, its openness to the outside, etc.).

A <Space> may allow the unfolding of one or more activities. E.g. a bedroom must allow the following activities: rest, play, read, sleep, etc. Each <Activity> belongs to a given <Activity Type> that requires a specific ambiance. E.g. <Day Activity>, <Night Activity>, etc. Thus, designing a space involves first to define the user activities that will be housed in and

Figure 2
Space model including qualitative and topological information.



then to determine ambiance fostering the unfolding of each <Activity Type>. Each <Ambiance> has specific requirements (see Figure 2).

A space is governed by a set of design requirements depending on the <Space Type> in which it belongs, following a topological preference or according to ambiance required by the <Activity> that will be housed in. Qualitative requirements may also be associated with a <Space Type>. Thus each <Space> must obey the common requirements for its <Space Type>. Requirements related to the space <Topology> define its relations with the remaining building spaces. E.g. Communication relation or closeness relation between two spaces, openness relation or extension relation with the outside, etc. All these requirements are variable, unlike regulatory requirements. They may vary from a project to another according to the climatic and geographical conditions of the project, etc. and especially according to the future user preferences.Our first space model is illustrated in Figure 2 using Express-G diagram symbols. In this model, we tried to take into account sensitive spatial data highlighted in this paper. Based on defines core concepts, a control protocol is possible to detect the spatial quality issues over qualitative and topological requirements previously set by the designer based on the requested program.

CONCLUSION AND FUTURE WORK

This study presents a review of architectural space as a key concept to reveal a sensitive dimension of architecture in current BIM practices during design phases. Observing recent research having dealt with space data modelling has allowed identifying the limits of these models to integrate sensitive spatial data. Exploring existing BIM tools has enabled this study to determine missing tasks allowing designers to design and co-produce spaces, to coordinate and also to communicate about spaces. In particular, about spaces sensitive aspects. As shown in Figure 1, only a small number of tasks are supported, even partially, by tested tools. We noticed that tasks 6, 7, 9, 10, 11 and 12 are not addressed by all of existing BIM tools. Visibly, dRofus has the greatest ability to enable remaining tasks.

A future work will include improving this first model. The final global model will be used to implement a decision support method allowing designers to control the spatial quality of the designed building, during cooperative work. DRofus seems to constitute an interesting support for this future work, including the integration of all identified missing tasks discussed in the third chapter. The overall goal is to achieve an efficient space-oriented prototype allowing the unveiling of the sensitive dimension of architecture, hidden currently in BIM practices.

REFERENCES

Bhatt, M and Kutz, O 2012, 'Ontological modelling of form and function in architectural design', *Applied ontology*, 7, pp. 1-32

Bjork, Bo-Christer 1992, 'A conceptual model of spaces, space boundaries and enclosing structures', *Automation In Construction*, 1(3), pp. 193-214

Bonnaud, Xavier and Chris, Younès 2012, 'L'actualité sensorielle de l'architecture contemporaine', in Gallimard, Coll (eds) 2012, *Architecture et perception*, La découverte

Branz, Building and construction (eds) 2014, *New Zealand BIM Handbook*, BIM Acceleration Committee, New Zealand

Brodeschi, Michal, Putievsky Pilosof, Nirit and E. Kalay, Yehuda 2015 'The definition of semantic of spaces in virtual built environments oriented to BIM implementation', *16th International Conference CAAD Futures*, Sao Paulo, Brazil., pp. 331-346

Crunelle, Marc (eds) 1996, *L'architecture et nos sens*, ULB, Bruxelles

Drozd, Celine, Meunier, Virginie, Simonnot, Nathalie and Hegron, Gerard 2009 'What Tools and Modes of Representation to Reflect an Architectural Atmosphere?', *In, 9th European Architectural Endoscopy Association Conference*, Cottbus, Germany, pp. 77-88

Ekholm, Anders and Fridqvist, Sverker 2000, 'A concept of space for building classification, product modelling and design', *Automation In Construction*, 9, pp. 315-328

Ellis, Clarence and Wainer, Jacques 1994 'A Conceptual Model of Groupware', *CSCW 94, ACM Conference on Computer Supported Cooperative Work*, North Carolina, USA, pp. 79-88

Ireland, Tim 2015 'An artificial life approach to configuring architectural space', *33rd eCAADe Conference*, Vienna, Austria, pp. 581-590

Siala, Aida, Allani, Najla, Halin, Gilles and Bouattour, Mohamed 2016 'Donner du sens à l'espace architectural. Vers une intégration de la dimension sensible de l'architecture dans les pratiques BIM', *Séminaire de Conception Architecturale Numérique SCAN'16*