Spatial Typology for BIM

Preassembling for Synthetic Architectural Design

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Contemporary Building Information Modeling (BIM) software provides basic component types such as bathtubs, desks, windows and walls that are available in many varieties of kinds and ready for drag-and-drop into a design project. However, the software is unlikely to provide higher level constructs such as bathrooms or offices as types, and these spatial concepts are largely unframed in the ontology of the building system. This paper looks at these spatial concepts left unframed in BIM as important fabric in the design process, examines how they are represented typologically in conventional design resources such as Neufert Architects' Data, and discusses strategies for embedding them in BIM. Together with abundant published cases of architectural designs, the examples of spatial forms in these resources play a role of Big Data. The paper then demonstrates a prototype of parametric office building typology embedded in BIM and illustrates how such a tool helps an architect to study volumetric layout on a given site. The approach tested leads to an idea of BIM imbued with a massive taxonomic library of preassembled spatial types and takes us a step closer to a symbiotic or synthetic architectural design process.

Keywords: Building Information Modeling, Architectural Typology, Design Representation, Big Data, Synthetic Design

INTRODUCTION

What is BIM? This question continues to be answered in many ways by people who find different stakes in it. In the preface of the BIM Handbook (Eastman et al. 2008), Laiserin gives a historical account and shows that many ideas such as simulation, database, and automation play important roles in forming BIM. The present study looks at architectural design as a composition of types and specifically focuses on the symbol system as a critical ingredient of BIM.

Geometric modeling applications such as Rhino provide primitives such as cylinders and boxes along with tools to manipulate them. An array of cylinders can simply be positioned on a thin rectangle box. In a typical BIM application, the same step can be carried out by placing an array of columns on a floor that they attach to. A column is a symbol for a type of architectural part, whereas a cylinder is a symbol for a geometric primitive. A column has parametric properties such as height and material and can be associated
with specific geometry such as a cylinder, rectangular extrusion, or H-section, which can be interchanged. One piece of column that is inserted in the drawing is said to be an instance of the column type. A column also knows how its instance relates to instances of other symbols, such that a column attaches to a floor at its bottom and intersects with a beam.

In this way, a BIM application provides an environment where an architect drags and drops various types of architectural parts such as columns and walls, edits them, and assembles them into a building. A huge number of instances of these types are included in the design, and the spatial relationships between them are simultaneously recorded as the design develops. The resulting model is a giant web of building information.

The foundation enabling this process is its symbol system of architectural parts. A typical BIM application today comes with the basic tectonic vocabulary necessary to document a building, including wall, window, floor, column and others. The application also embeds floor level, grid, room name, section line and other elements as special symbols, each with its own properties and embedded ways to relate itself to other symbols. A window is hosted in a wall. The floor level can be used to set the relative vertical position to a floor instance, and a column instance may be located with reference to a grid intersection.

All of these features are important concepts for any architectural design process. To build intelligent software for a shared domain of discourse, the specification of its representational vocabulary as an ontology is a known strategy (Gruber 1993). However, not all familiar spatial concepts are readily available in a typical BIM application. For example, it likely provides no bathroom or office building as built-in types. Instead, an architect is expected to assemble basic components such as bathtub, sink, wall and floor one by one and create a bathroom or office building design. These spatial concepts are largely left unframed in the ontology of the building system. The present study aims to fill this gap by using existing design resources as a “Big Data” of credible examples and by mining a useful body of disciplinary knowledge that has already been compiled.

**PRECEDENT AND METHOD**

The idea of types in architectural design is deeply tied with that of composition throughout history. The classical order, for example, is described by many books, from the Four Books of Architecture (Palladio 1570) to A History of Architecture on the Comparative Method (Fletcher 1905). Figure 2 shows William Mitchell’s coding scheme of classical order (Mitchell 1977). In this case, the lines between named elements represent two different essential relationships between types in a somewhat confusing fashion. The line between Order and Doric represents type and subtype relationship, often referred to as “kind-of”
in computer science. Tuscan, Doric, Ionic, Corinthian and Composite are sibling types that belong to Order, their parent type. The line between Doric and Architrave represents the composition and component relationship, often referred to as “part-of.” Cornice, Frieze, Architrave, Column and Pedestal are all component parts that belong to the Doric order composition. Spatial relationship between components can be more specifically described. For instance, a column shaft attaches to its base, and a wall hosts its windows in a facade.

These relationships can be nested in a hierarchy. The Doric subtype may further be classified down by Greek and Roman subtypes and makes a tree-like taxonomy of types. Mitchell’s illustration also shows compositional hierarchy with Doric at the highest level, Column and Shaft at the next two levels, and Neck at the lowest level of this breakdown. His team proposed and demonstrated Topdown (Figure 3), a software toolkit that allows encoding of such taxonomy and composition of types and provides visual navigation through their hierarchy (Mitchell et al. 1990).
In a scheme with the entire building regarded as the top level of compositional hierarchy, a typical BIM application provides elemental types near the bottom of the hierarchy, such as wall, window and floor. The wall taxonomy is rich with tectonic subtypes such as brick, stud and curtain walls and describes each subtype as a composition of finish, substrate, insulation, sweep, etc. The vocabulary still lacks some peculiar types such as dome and vault, but efforts to collect and embed industry standards are on the way (Sharif 2015). On the other hand, the BIM application does not say much about how these elements can be assembled into meaningful architectural compositions. For example, a variety of sink, bathtub, and shelf are there as built-in types, but an architect still needs to assemble them with wall, window and floor into a bathroom design. Because the bathroom is a most frequently used and documented concept of spatial type, as exemplified in Figure 1, one strategy to help this bathroom designer is to study them and embed bathroom as an available type in BIM.

Similar to Mitchell’s diagram of classical order, the bathroom type in BIM would include various layout options as sibling subtypes and describe each as a preassembled composition of sink, wall and other elements that are already embedded in BIM. A bathroom is a spatial type near the bottom of the compositional hierarchy. On the other hand, each spatial concept found at a higher level hierarchy is a composition that includes other compositions as its component, in which case the use of abstraction becomes convenient. For example, the lounge type for airport design may include a waiting area and a bathroom as its components. Because the bathroom itself is a composition, the lounge may represent it in an abstract form without revealing the detailed composition of sinks and compartments inside. For tool development, such abstraction allows the lounge type to be framed as some composition before the bathroom type composition is fully framed. For an application, it is more computationally efficient to process representations without unnecessary details in the context of design. For architects, sketching out a design idea for the lounge at an early design stage benefits from omitting the bathroom interior and postponing its design until the overall lounge layout is fixed.

**OFFICE BUILDING PROTOTYPE AND TEST**

To test the idea of preassembled spatial compositions as types in BIM, an office building typology that architects widely use to study building volumes on urban sites was prototyped using Revit and its SDK. A generic office building type was defined as a composition of work space, service area and skin types. Figure 4 shows its major properties with interdependency. The component types are represented as abstraction in colored primitives.

**Figure 4**
Office building type. Gross floor area (GFA) is computed from width, depth, height of the building and floor height. While the GFA value is locked, dragging the triangle handle of the building and changing its width interactively adjusts its depth so the floor area adds up to the given GFA value. This aids in the volumetric study for a specific site and program.

**Figure 5**
Examples of office building typology documented in Architect’s Data (Neufert 1970).
Figure 6
Top: Office building subtypes prepared: single loaded slab, double loaded slab, center core, courtyard, barbell, and connected types. Bottom: Proportional transformation of a double loaded slab instance and its substitution to an instance of center core or barbell types while the GFA value is locked.
To prepare a small typology of office building, the examples of large office buildings from Architect’s Data (Neufert 1970) were referenced. The chapter on Office Buildings (Figure 5) lists principles in terms of program, lighting, mechanical, desk, construction and other issues and explains how changing work styles transformed office building typology from the 1950s to the 1990s. Our implementation focused on the formal composition of work space and service area and simplified and configured the examples in this chapter, instead of directly using the office typology provided there. Six office building subtypes were prepared (Figure 6 top).

Substitution and parametric transformation of a building instance on a site works interactively similar to the substitution and transformation of a typical window in a wall but with special attention to its Gross Floor Area (GFA) value, which can be locked during transformation (Figure 6 bottom). Furthermore, an interface was added to lock the total GFA value of a group of buildings while modifying the GFA value of each building in the group.

A test and observation was made by asking architecture students to use this BIM plugin and to design an arrangement of an office building complex on an urban development site (Figure 7). The small and simple office building typology enabled a swift generation and modification of compositions of design schemes. Interviewed subjects commented that being able to drag and drop a pre-assembled building and transform it by the preset parameters allowed efficient evaluation of different possibilities because attending to ordinary generative steps of gradually composing elements was not needed while solving an architectural program. In addition, flipping one building form instantaneously to another reportedly brought a novel sensation.

CONCLUSION AND SPECULATION

Many architects today think of BIM software as a production tool and dismiss it from the context of design creation. They note its look and feel of functionality as well as interface and recognize its usefulness for making presentations and running simulations, yet prefer other software for shaping architectural forms during their creative process.

The goal of the present study is not to question if the current BIM implementations can be made to operate more intuitively for designers or to intervene in the quest for architectural creativity. Instead, an opportunity is presented to inquire about a type of tool imbued with new intelligence, to question whether a tool that understands various spatial typologies helps architects design, or to ask what spatial concepts can help make a good design and how these concepts can be framed and embedded. The
initial office building typology deployed in this experiment was based on small samples identified in a widely used architectural resource book and regarded as credible. The targeted spatial concepts were shown to be deployable in BIM software, and tests of their use with subjects demonstrated their effectiveness in producing design studies.

Further investigation has multiple possibilities. An immediate one is to expand the typologies to include more spatial types and compositions. For instance, in office building typology, the service area type may have further subtypes, with each representing a different composition of lobby, bathroom, staircase, and elevator types. In an ultimate scenario, the software will implement typology of a general office building with known subtypes and all details. Dragging the building type onto a site could immediately show an example of a fully complete design of architecture ready to be built, with parametric and substitutable composition of parts. Spatial types are studied and categorized in widely used treatises and resource books such as Fletcher’s one and Neufert, where hotel, hospital, restaurant, school and many other building types are documented. Any of these are available targets for implementation.

Besides these carefully investigated and compiled typologies, an enormous number of architectural designs have been created through the history of civilization. Although many are neither documented digitally nor online, we already have Big Data for mining architectural typology. Just searching “kitchen layout” in Google alone produces millions of plans (Figure 8). Therefore, another future possibility is to develop a synthetic tool to explore this Big Data, identify architecturally meaningful spatial compositions, and frame them as types. The tool would read these images, sort them into patterns, and formulate typologies, similarly to how precedents are studied and interpreted when an architect designs a kitchen. Such a Google-minded strategy would re-
quire rigorous employment of computer vision and machine learning algorithms.

Also, the subject of sampling spatial concepts left unframed in BIM may be expanded from formal vocabulary to qualitative one. For example, architects rely on ideas such as open, enclosed, divided, and connected as means to classify and characterize architectural space. Embedding such concepts into BIM helps the process of selecting and evaluating design variations. Online crowdsourcing is a way to help train software to learn these qualitative spatial concepts; the software learns by presenting examples of spatial design to people and by asking which concept applies to each presented design. A similar approach has been tested recently in urban and architectural design contexts (Naik 2014 and Obyedkova 2013 [1]).

These lines of investigation built on the symbol system of BIM will lead to a massive database of parametric typology of spatial concepts that are useful in developing an architectural design. The more BIM applications know about these concepts, the more dialogue it facilitates with architects who share them. In the long run, a BIM system imbued with such an intelligent database and appropriate interface will have a chance to work symbiotically as a designer’s partner and take us a step closer to an autonomous and synthetic architectural design process, especially in combination with other generative methods and simulation tools.

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