Image Schemas and Ontology in Architectural Rules

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Abstract

Architecture is said to be both a science as well as an art. As a first approximation, it is about construction and communication, about form and matter, and about rules and novelty. This suggests that there exists a set of architecture's core elements, in particular regarding the meaning of rules, and a notion of meta-rule about composition choices in architecture. It follows that the act of creativity has a way to manifest itself into this domain via the described interplay between rules and meta-rules. In this work, we explore an ontology-driven discussion of architecture and propose a view on how to isolate and understand both architectural rules and architecture-based interactions across the ontological and image-schematic dimensions. The views emerging from architects and from theoreticians are discussed and the novelty provided by the image schema perspective is considered. The purpose is to study how these elements and their interactions can be modelled in ways that are suitable (at least in principle) for integration into formal systems, both in the area of design tools as well as of spatial reasoning and imagination. This, we believe, can link architectural creativity with formal representation in a new space for human-machine co-creativity. The paper is a first step in this direction.

Keywords

Architecture, Rule, Creativity, Representation, Ontology, Image Schema

1. Introduction

Designing, conceiving a place, giving a shape to space, managing a partition of spaces with certain qualities are steps changing an actual physical space into a virtual one that may exist in the future. The designer is like a traveller in this mixed space, a sort of ghost that can describe in the actual space the organisation of the virtual space and the experience of living in it "from the inside" as if she could be in that space right now. No matter how strange this experience could look to people that are strangers to this kind of imaginative process, the designer acts according to known rules, laws, and constraints.

This paper intends to investigate this realm and to dig into the architectural creative process starting from the way it has been described in the literature by architects as well as theoreticians. The study aims to identify a set of architecture's core elements, in particular regarding

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the meaning of rules, and a notion of meta-rule about compositional choices in architecture. Structure, form, function, texture, surface, space, central space, symmetric/antisymmetric, internal/external, bright/dark space: all signs and images of these are fragments of experiences that reflect our perception of material objects. Material objects, in turn, are tools for action. Quoting a seminal work by Buchanan [6] about the wicked problems in design thinking, 'signs, things, and actions are organized in complex environments by a unifying idea or thought, they are not only interconnected, but they also interpenetrate and merge in contemporary design thinking with surprising consequences for innovation'.

The design process is bound by factors external to the design agent like the objects to be created, the technologies available, the current legislation, and by factors internal to the agent like her mental universe and personal memories. Is architecture a matter of style? And what is the style? Gesture? Handwriting? Is it a search for harmony? Maybe harmony and beauty could be assimilated in this context. Andrea Palladio, the Renaissance architect writes in the "Quattro Libri dell'Architettura": "The proportions of the voices are harmonies for the ears; those of the measurements are harmonies for the eyes. Such harmonies usually please very much, without anyone knowing why, excepting the scholar of the causality of things" (Palladio, 1567 in [27]). Is a search for harmony achieved in the conception phase? Does it depend on the realisation phase? What about the perception moment? And are there some intrinsic properties that architecture has to express? Which is the role of rules in their different declinations? Are proportion and harmony themselves a kind of rule (to follow, to break, to reinvent)? In a previous work, Borgo and Stufano [5] dealt with architectural rules as understood under the ontological perspective. By focusing on the first part of the design process, they characterised two elements characterizing the tension in the architect's practice: architectural rules and creativity. This view sheds light on the relationship between and integration of these elements in creative design. The contribution of this paper moves along that study focusing on the investigation of an ontology-driven perspective of architecture that adds a view on the interaction between image-schema and architectural design.

2. Ontology-driven Rules and Meta-Rules

In the writings by architects, we find constant reference to a personal toolkit consisting of elements, from memories to principles, from aesthetic rules to perception experiences, that the designer consciously or unconsciously accesses during the design process. The designer consults, disrupts, recomposes these elements in different ways until a result, deemed satisfactory, innovative and original, is found. The new designed object emerges in the indefinite space of the architect's imagination.

Stefano Boeri [3] focuses his attention on what moves in the mind and in the memory of the architect when she begins to imagine the future of an inhabited space. Across which cognitive depths and surfaces' tensions she moves when she begins to imagine the figure of a new project, its gravity, its dimension. Boeri suggests that it is possible to describe the 'cognitive geography' of an architect, which he call 'the inner city' of the designer [3]. By inner city he means the region of thought in which the beliefs, prejudices and obsessions control our way of observing, naming, imagining. Wittgenstein [29, § 531] suggests that aesthetic reasons are not

Table 1
Ontological rules (from [5]).

Class	Topic of the rules	Example
Framing	the tension across the parts, harmony	Golden rule, the Modulor scale
Quality	the physical and aesthetic qualities of buildings	Color, open/close space harmony
System	the relationship and interactions across parts	Usability, integration metrics
Location	the integration of building and environment	Ecological harmony
Perception	the perception of the building and its environment	Wellbeing metrics
Function	the purpose of the building	Airport layout
Society	the social role of the building	Town hall symbolism
Living	the use and personalization of the building	Open form rule, social exploitability

typically given by explicit rule-formulations. In the Philosophical Investigations, he brings up the understanding of music and poetry as examples. In describing aesthetic systems, like music, poetry, tailoring, or architecture, Wittgenstein considers usual 'academic' rules, e.g., the rules of harmony and counterpoint, poetic meters, and the rules of tailoring that may be conceptually formulated. These lay down the background against which we call certain aesthetic choices "correct", "right", "wrong", and "necessary", and here we see how much the concepts of beauty and harmony are intertwined.

Design also seems to reside in the dialectic between rules and models: a discipline that collects a set of possibilities to be implemented and recomposed from time to time. The design is understood as the creative discipline of a unique and complete model of space transformation [3]. The architect develops the design following rules, imagining and dealing with some laws, some stated explicitly, others remaining in the background, unknown even to herself. The design process is constrained externally by the types of objects to be created, by the available technologies, by current regulations, and internally by her mental universe, feelings and memories. The framework aimed to rethink architecture as a discipline of rules and meta-rules, which was given in [5], shows how creativity can find its place in a scientific modelling approach that resembles those of rule-based systems in the so-called knowledge representation area. The first goal of such a framework is to clarify how the architect 'understands' the rich domain of architectural rules, and how she can express her creativity in such a complex space. The architect seems to move according to the rules that she learned, and eventually modify some of them according to a set of meta-rules to strengthen, weaken or reinvent the rule domain itself. This perspective is orthogonal to the standard view of architects and to the way architecture is usually taught. It also re-conceptualises, as argued in [5], the domain in a way that makes formal analysis possible and software exploitation accessible.

Via the elicitation of the ontology-driven architectural rules and with their 'translation' in the domain of knowledge representation, one can aim to technically support and empower the cognitive and creative aspects during the decision-making process of the designer.

Table 2
Ontological meta rules (from [5]).

- strengthen/weaken the initial conditions for the application of the rule
- strengthen/weaken the consequences of the application of the rule
- divide the rule in subcases with different conditions/consequences (specialization of rule context)
- maintain a rule only apparently (i.e., maintain the perception of the rule)
- apply some of the rules at a different level of granularity (including using a rule as a meta-rule)
- substitute a rule with a new one (e.g. when new technologies allow for innovative solutions)

3. Image schema and embodied knowledge

Humans create mental representations beyond what stored in memory. This imaginative capacity is the foundation of cognitive activities such as planning, forward thinking, and the generation of creative ideas [1]. It has been shown in the area of neuroscience [23] that the knowledge of an agent who unfolds a creative behaviour, has a great impact on the generation of the idea itself. For ideas to be new and original, starting from the available knowledge, remote associations must be activated, beyond and through thought associations that are activated in routine actions for knowledge itself [23]. Extended knowledge of a specific domain is required for the generation of ideas and creative performances [19, 28, 23]. Memories and reference knowledge are essential for the production of creative and innovative design that, at the same time, fulfils the functions required by the project program while adding new and unexpected ones [26].

In her creative activities, the architect imagines to move and to perceive the surrounding environment as a real presence: she "virtually" moves as part of the design space imagining herself interacting with other agents as true inhabitants of this space-to-become. The centre of this newly created environment is the body, the individual, and the agent [22, 2]. Previously, the study of this phenomenon concentrated on the conceptual level. To maintain the intrinsic conceptual and physical nature of architecture, it is essential to study this creative experience as interconnecting the conceptual and the physical levels. The proposal here is to use image schemas as connectors between the conceptual and the experienced space.

Starting from the assumption that designing in architecture is about designing the relationship between body and space [9], we focus on image schemas as embodied knowledge, thus as building blocks to understand the body-space relationship. Image schemas are the core of a theory of concept formation and language understanding. According to Johnson [17], "an image schema is a recurring dynamic pattern of our perceptual interaction and motor programs that gives coherence and structure to our experience." Hedblom and colleagues [12] hold that an image schema is 'an abstracted spatial pattern from repeated sensorimotor experience' offering a connection between the body's physical experience and the internal conceptual world of an agent. The image schemas are learned from early sensorimotor experiences and are therefore mental abstractions of learnt spatial relations: the explanatory value of image schemas lies in their function as abstracted spatial relations, so they can be understood as abstracted (at least in some of their aspects) spatial relations that are associated with affordances [12].

If visual images are typically constructed from the underlying concepts a person already

Table 3
Image schema list (from [14]).

Group	Image Schemas
BASIC	object, substance
SPACE	center–periphery, contact, front–back, left–right, location, near–far, path, rotation, scale, up–down
CONTAINMENT	container, content, full-empty, in-out, surface
MULTIPLICITY	collection, count–mass, linkage, matching, merging, part–whole, splitting
PROCESS	cycle, iteration
FORCE	attraction, balance, blockage, compulsion, counterforce, diversion, enablement, momentum, resistance, restraint removal, self-motion
ATTRIBUTE	big–small, dark–bright, heavy–light, smooth–rough, straight, strong–weak, warm–cold

knows, then some aspects of mental images reflect the operation of visual and spatial representations [10, 8, 15]. A notable property of image schemas is that they may be at once visual, auditory, kinesthetic, and tactile: and all these senses are involved in perceiving architecture. The same image schema can be instantiated in many different kinds of domains because the internal structure of a single schema can be metaphorically understood [12]. Another interesting aspect of image schemas is that they stand as single entities but can be linked together via different relationships, for example in combination [10]. Given all these features, image schemas seem a central ingredient to connect imagery and perception [10]. Considered part of the embodied knowledge emerging at a level of pre-linguistic learning, image schema have been studied as descriptions of Gibson's affordances [11], and can be seen as a form of tacit knowledge (see [24]). Architects make use of both explicit and tacit knowledge, they express their concepts and ideas in part through drawings and other means to realize a (projected) material reality [24].

The rules and meta-rules of architecture, and the object/elements elicited from memory form the explicit side of the knowledge in architecture. This can be found in [10] where it states: "the CONTAINMENT schema has three structural elements (interior, boundary, and exterior) that primarily arise from two sources: (1) perceptual analysis of the differentiation of figure from ground, that is, seeing objects as bounded and having an inside that is separate from the outside [25]; (2) perceptual analysis of objects going into and out containers". The CONTAINMENT image schema can be associated with several architectural rules emerged from an ontological analysis, e.g., FRAMING (see Table 1).

In the following section, we will offer an example of a link between image schemas and ontology-driven rules in architecture through the analysis of a well-known architecture.

4. The Raumplan as an architectonic principle merging image schema and ontology-driven rule in design

In this section we discuss the Raumplan as an architectonic and design example in our study. The Raumplan is a relatively recent architectural theme and central for the history of architecture

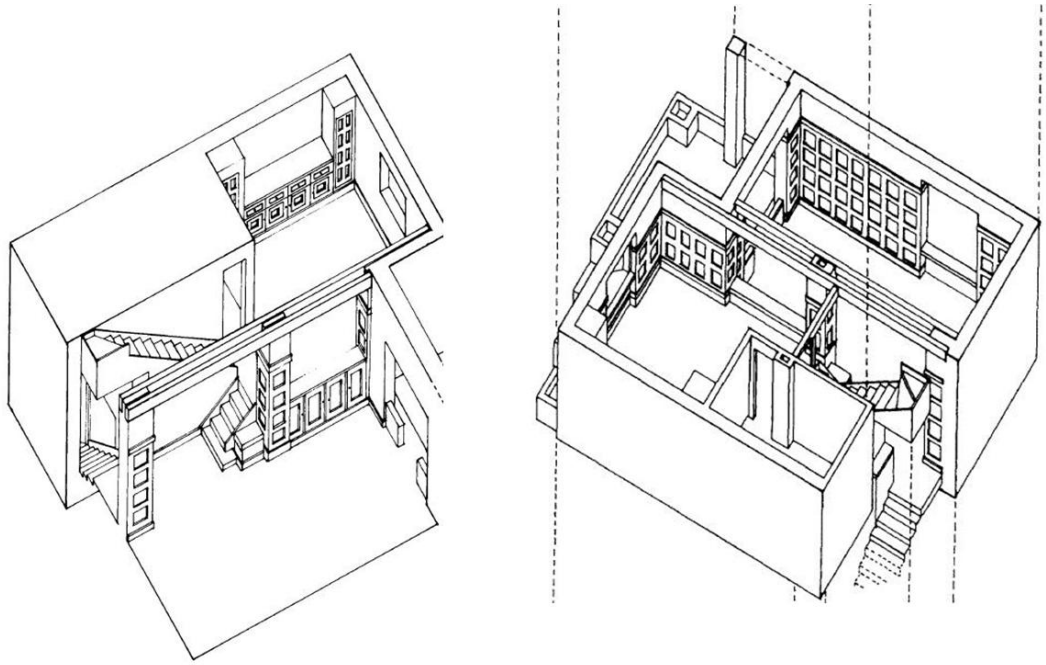

Figure 1: Rufer Haus axonometry (from [16]).

of the last century. Raumplan is a classic topic and is largely discussed in architecture schools. We suggest to analyze the Raumplan because, in our view, it clearly combines some of the ontology-driven rules (to which the architect refers by following a precise composition principle) with image schemas. The Raumplan was introduced by Adolf Loos, an Austrian architect (1870-1933), who developed a new architectonic principle even though he never explicitly theorized it in writing. The name Raumplan itself was used firstly by his student and follower Henry Kulka [16, 21]. Loos described in 1929 a "solution of how to arrange the living rooms in three dimensions, not in a flat plan... That is a great revolution in architecture: the three-dimensional rendering of a ground plan" [20, 16]. This choice was described by Kulkaas as "a new and essentially higher conception of space: free-thinking in space" [18, 16, 21]. Loos was interested in having connected rooms in "such a way as to make the transition imperceptible, and to effect it in a natural and efficient fashion" [16]. He applied the Raumplan principle from the design of the Rufer Haus in 1922 (Fig. 1) and developed the theme across his life till the design of the Last Haus in 1932. The complex relationship that the Raumplan principle articulates among the spaces that form the house led to consider it a new type of architecture [21]. Raumplan, literally 'plan of space', is a spatial solution in which spaces differ not only in broadness and depthness but in height depending on the function and perception to be achieved. The principal goal is to organize space to make it flow, putting all the common rooms in constant eye contact and suggesting a kind of ascending spiral trend [21]. Starting from a strict definition of space and the two main orthogonal axes (cardo and decumano) [16], he developed a centrifugal use of space [21].

From the previous description, we see that the Raumplan focuses primarily on two ontology-

driven rules: the FRAMING Rule and the SYSTEM Rule (see Table 1). The FRAMING Rule constrains the organization of a physical space. It consists in a class of rules that frames: (*a*) the objects as a whole, (*b*) the understanding of the design space and, (*c*) the aggregation of surfaces and features. These are general rules, a typical example is the so-called golden rule. "The FRAMING rules guide the tension between the parts of the object(s) and their place in the physical space and help to find the point of reciprocal equilibrium towards the attainment of a global internal and external harmony. Ontologically these rules focus on regularities among shape and size of physical objects (and/or their parts) possibly including the position of these objects in space" [5]. In the application of the Raumplan, we recognize this tension and equilibrium in the space across the different layers of the floors, in a 3D form of relationship among the spaces.

The SYSTEM Rule is about "the interaction and disposition of [the architectural object's] parts including the relationship between surfaces, volumes, their reciprocal articulation, and the overall impact of the entity as a whole. Ontologically these rules look at the object as a whole formed by a network of interacting components" [5]. The Raumplan principle constrains the interaction and disposition of volumes and the relationship between internal spaces and external prospects, providing a general order of external openings that derives directly from the layout of the internal spaces.

Several image schemas are exploited during the conception of an architecture based on the Raumplan, but reading the descriptions provided by the architects, the central ones seem to be: CONTAINMENT, VERTICALITY, MOVEMENT ALONG PATH. This is because all the interactions take place in the inside space, and the flowing of the space expands in the vertical dimension with a (moving) pattern which is always starting from the location of the agent. The pattern model itself in the Raumplan has been the focus of interesting analysis in the literature [16]. An example of the Raumplan's influence, as an established class of rules to follow and creatively modify, is given by a recent architecture: the Cala House (Fig. 2) of the contemporary architect Alberto Campo Baeza [7]. The Cala House is even called the Raumplan House. In this architecture the Raumplan is employed as a spatial mechanism, the spaces are of double height and intersect with one another producing diagonality which is also helicoidal with the concatenation of spiralling double spaces [7].

This 'a posteriori' considerations of architectures realizing the Raumplan principle suggest the interaction of specific ontology-driven rules and image schemas with the latter motivating and explaining the designer's choice of the first. This characterization of architecture along ontological rules and image schemas dimensions makes manifest an articulated cognitive space that seems to be 'a priori' available (perhaps in part unconsciously) to the architect, and that, once made explicit, can show how the designer moves along the space of ontology-driven rules and that of image schemas as guiding elements.

5. Conclusions and follow-up

We have suggested to view the creation and experience in architecture as an integrated field based on ontological rules and image schemas. The combination of these two powerful systems for modelling cognitive notions provide, we believe, the means to explain the creative process

Figure 2: Cala House (from [7]).

of the architect both at the mental level, as a game on rules, and at the physical level, as an exploration of space-to-be via image schemas as embodied abstract tools.

By exploring an ontology-driven perspective of architecture, we bring a new way to isolate and understand architectural rules and how they change in the cognitive realm of the architect. By addressing the role of image schemas in the architect's mental visualisation of her newly created project space, we provide a bridge between the mental and the physical worlds that the designer seems able to experience as a single entity in her creative process. Finally, the combination of the ontological and image-schematic dimensions, each of which has been shown to be suitable for logical modelling [4, 13], suggest a new way to analyse the architects' work and the possibility to set the basis for a new generation of software systems to support creative activities.

While this general aim and the development of dedicated tools require much more work than what we can present in this paper, the material we presented suffices to show the role that these elements may have in architectural design and how their interactions could be understood. The approach, we believe, can link architectural creativity with formal representation in an enriched domain of human-machine co-creativity.

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