The Polymorphic Diagram

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Abstract. Thinking about space and its conception lies at the very essence of architectural design, yet only limited attention has been afforded towards developing and advancing its medium of conception. With the objective of better understanding and shaping spatial design workflows, the study sets its attention on what is widely embraced as the medium of thinking about space and its conception in architectural design: The diagram. The study begins with examining the cognitive affordances of the diagram in architecture design, discusses its limitation, then propose a computational-augmented concept for a new class of diagrams, the polymorphic diagram, to assist spatial thinking and cognition during the conceptual design phase.

Keywords. Design; Diagram; Spatial Thinking, Design Cognition; Computation.

INTRODUCTION
In Architecture design, reasoning about space and its configuration lies at the center of the conceptual design workflow. It is an important mean of grasping and understanding the design situation and the basis for shaping and emerging its solution. As the discipline continues to evolve, technology is increasingly embraced as the medium for design production. While advents in modern design technology has indeed pushed the frontiers of design and its expressive dimensions, the focus and contribution of such technology on spatial phenomena has been rather limited. Christian Derix (2011) notes that inquiry in spatial design heuristics, its methodology and mediums of support and assistance, have been rather stagnant when compared to other design considerations such as geometric form, energy conservation, or structural design and analysis. Even a cursory look at the state of design technology would reveal that it is less directed to enhance architects knowledge of the key aspect of architecture: the conception of space. The problem of neglecting spatial phenomenon becomes most evident as projects become larger, and the matrix of design needs and considerations grow in complication. With this rising complexity, the hope for achieving a sensitive and responsive architecture is rendered near impossible. This begs the question, how can new advents in computation and information technology assist spatial thinking during the conceptual design phase?

The answer to this admittedly open ended question begins with a better and deeper understanding of the underpinnings of design thinking and cognition. Drawing lessons from emerging
findings on how designers actually perform design, then promote this understanding as the basis for developing new design mediums capable of supporting and assisting spatial design workflows in architecture. There is much to be said about this, but this is a short paper and its scope shall be focused on the notion of representation and its role in assisting and mediating design thinking. In particular, the paper sheds light on the prospects of diagrams in influencing and shaping new design technology capable of mediating and managing the complexity of spatial design thinking during the conceptual design phase.

In Notes on the Synthesis of Form, Christopher Alexander (1964) had brought into question the issue of design cognition. His treatment of the issue was rather implicit within his discussion about complexity of the design process and the architects waning ability to resolve it. What is most important to us here is his position on modeling, both the model itself and the medium of representation. Alexander had famously noted that design problems have reached unsolvable states; And that a drawing-based design paradigm is insufficient to overcome and manage this complexity. He argues drawings no longer stand as a mean capable of mediating thinking about design variables and their overwhelming order of interactions, leading him to assert that a new design paradigm is of the essence. Alexander bases design on the ability to ‘model’, to structure knowledge about the design situation. In his book, he articulates this modeling method to guide design production, but his attempt has largely failed (Lawson 1997). Despite this failure, however, the underlying essence of his theoretical contribution continues to be relevant to the understanding of design as a sensitive and responsive modeling activity.

In the literature on design theory, modeling the design situation, structuring knowledge about its problem definition and its emerging solution proposition is central to mediating design thinking and cognition. It is the designers primary mean of understanding the range of sensitive interactions between the various design requirements and mediates their responsive resolution. As eloquently put, “modeling [the design] situation is the fundamental designerly way of knowing, thinking, and acting in design” (Cross 2006).

Modern views on design postulate that designers model their understanding of the design situation through establishing and manipulating structures of design knowledge and information. It has been demonstrated through empirical studies that such capacity is a necessary condition for design expertise in architecture. For instance, Charles Eastman (1969) indicates that during the early stages of design experienced designers bring to bear on the problem at hand a complex repertoire of design knowledge and they “rapidly structure it”. In a related study, Akin (2001) notes the expert architects have exhibited rigorous structuring and ‘restructuring’ behavior. The expert architect tend to perform substantial decomposition and recomposition iterations; restructuring design knowledge in search of a satisfactory response to the complicated matrix of design requirements. But what does structuring the design situation means?

STRUCTURING

While the notion of structuring is central to the discourse on design, exactly what the term means is not clearly defined. Nevertheless, At a fundamental level, the notion of structuring, as it relates to design thinking and cognition, refers to establishing and articulating relationships between the various design variables. In a commentary on design expertise Richard MeCoormac presents a suitable explanation. He notes that “... the real problem [of design] is some kind of structural problem. I don’t mean in the engineering sense, I mean in the sense of relationships” (Lawson 2004). Drawing on such view, establishing structures of relationships underlies our ability to model the design problem and reason about its spatial fitness.
MODELING MEDIUM: SHORTCOMING AND LIMITATIONS.

An Architect’s ability to render sensitive and successful design relies on modeling their understanding of the design situation, structuring knowledge about its problem definition and its emerging solution proposition. But such modeling process is in turn contingent on the medium of representation, the medium through which this knowledge is understood and developed into a sensitive and responsive order. The cognitive and developmental affordances of this medium, its role in supporting designers in understanding and resolving design requirements, draws from its versatility, its ability to transform, combine, and layer design knowledge and information with a good degree of fluidity and flexibility. The architectural diagram has long been used to fulfill this role. In the literature on design, diagrams have been described as ‘thinking’ drawings (Lawson 2004) An elaboration of how diagrams afford this cognitive capacity is discussed elsewhere (Herbert 1993; Fraiser and Henmi 1994). What is of most importance to us here is that diagrams are versatile models of representing and manipulating design knowledge and information. Their service in modeling architects’ understanding of the design problem is invaluable.

Despite of the diagram’s invaluable role in design thinking and cognition during the conceptual design phase, emerging shifts in contemporary design production are imposing significant limitations on the cognitive and developmental traits of the traditional diagram. In contemporary design workflows, a holistic examination of knowledge and information is rapidly becoming a critical criterion for effective architectural production. That is to say, designers require a conceptual design medium that enables them to seamlessly interact with larger sets of information that can be reliably and readily integrated, transformed, repurposed, and communicated. Diagrams are becoming increasingly limited in such regards.

Modern design technology does indeed offer platforms to model information, in a manner that is integrated, transformable, and communicable. Yet, it is hardly controversial, the role of such systems in assisting design thinking and cognition, especially during the conceptual design phase, continues to be limited. The reason for such limitation is multi-faceted. Nevertheless, one of its dominant agents is related to the lack of representation and manipulation of spatial design knowledge. Suffice it to say at this point that when it comes to the conception of space, one might argue that modern design systems are at odds with how designer’s ‘know’ and think about the design situation.

In recent years, research endeavors to bring computational support to spatial design thinking and cognition have been drawing on a critical concept of bridging between traditional and digital design mediums. After years of investigating modeling media, it was determined that traditional design drawings and digital technology are indeed problematic and limited in their own regards. However cognitive traits and features of these mediums seem to be complementary. Attempts to bridge between the two mediums; to augment the cognitive traits of design drawings with layers of computational intelligence and information technology is becoming a dominant space of inquiry and development. This paper is a contribution to such efforts, aiming to contribute to the advancement of a new generation of modeling mediums – one that is based on a topological workflow, with space and its concepts of composition enabled as a versatile modeling construct.

REPRESENTATION

Among the critical underpinnings of such development is the issue of knowledge representation. It is not an overstatement to say that the problem of assisting design thinking through computational strategies is largely one of representational modalities. The important role of representation in design has been empirically demonstrated by many design researchers. One of the earliest studies, whose findings continue to be illuminating even today, comes from Charles Eastman (1969). Eastman has shown that
designers necessarily rely on multiple representation modalities to assist thinking and reasoning about the design situation. He reported that “one of the strengths of the human problem-solver is his ability to use several representations (words, numbers, flow diagrams, plans, sections, perspectives) to represent, compare, and manipulate [design knowledge and] information.” And further suggests that “any man-machine system to aid the designer must recognize his reliance on multiple representations.”

**MOVING FORWARD**

Modern design systems do indeed offer multiple representational modalities. This is best manifested in BIM technology. Yet the role of such systems in assisting design thinking and cognition, especially during the conceptual design phase, continues to be limited. The reasons for such limitation is multi-faceted. Nevertheless, one of its dominant agents is related to representation and manipulation of spatial design knowledge. In Architecture, reasoning about space and its configuration lies at the center of the conceptual design workflow. It is the architects mean of modeling the design situation, bridging between its problem definition and its emerging proposition. Paradoxically, however, modeling spatial information; knowledge about the design problem’s spatial requirements and its topological configuration is perhaps the least developed feature in modern design systems. In light of this, it is becoming clear that moving forward, developing design medium capable of mediating the complicated design situation, mandates that more attention should be set on developing design systems capable of representing spatial knowledge about the design situation and facilitate its manipulation.

**THE POLYMORPHIC DIAGRAM**

The development of the polymorphic diagram aims at bridging the gap between computation and design thinking through its focus on the issue of representation in reasoning about space and its conception. The polymorphic diagram is a conceptual building information model that supports and assists modeling the design situation by allowing spatial design knowledge to be represented and repurposed in various forms of abstractions and different levels of complexity. In essence, it is a medium of versatile and hyper dimensions of spatial design knowledge representation.

Embracing the diagram as a metaphor offers an important philosophical and theoretical foundation for developing next generation design technology. In drawing on the work of Charles Sanders Peirce, whose scholarship on the subject offered what is widely regarded as the most penetrating examination of the nature of diagrams (Vilder 2006), it was evident the diagrams’ mode of representation, namely its abstraction, is the key feature underlying its cognitive and developmental instrumentality. With diagrams, architects layer, combine, transform, and reform knowledge structures in novel dimensions. It is by virtue of this abstract nature and its role in structuring, and representing knowledge, that architects are able to manage complex design requirements and reason about their spatial conception. While such views are hardly controversial today, they have played only a marginal role, if any, in shaping modern design technology.

Stan Allen notes that modern design technology (especially that focused on visualization, but that could also be broadened to include the majority of architectural design systems) “ignores what has traditionally given architectural representation its particular power of conceptualization, its necessary degree of abstraction, the distance interposed between the thing and its representation” (Allen and Agrest 2000). He further argues that that “design does not operate on the basis of resemblance, but on the bases of abstract codes and complex instrumentality.” Put in his own words, “Architecture presumes a transformation of reality, but an architect’s attempting to work directly with that reality will be paralyzed” Allen (2000). Thus, digital representation in a creative design process is not valuable in the sense that it provides realism but that it provides degrees and layers of abstraction instead.
The theoretical inquiry into what is proposed as a polymorphic diagram is keen to examine how this could be realized. How are we to develop digital design mediums the representations of which offer the necessary dimensions of viewing, examining, structuring, and transforming spatial design knowledge and its topological configuration? Theoretical contributions on this matter are now in abundance. However, the means of transforming them into applied techniques and methods are not straightforward. Incidentally, their influence on shaping modern design technology is, at best, marginal (Derix 2011). Thus, a weight of effort must be undertaken to appropriate and transform such theories on the architects’ spatial modeling behavior and seed that into the core of what will become their future medium of architecture design.

**GRAPHS**

One of the approaches that stands out as pertinent for such endeavor involves the use of graphs (also known as networks) as modeling constructs. For a sensitive and responsive architectural design solution, architects are required to account for a complicated matrix of interactions between the various spatial design variables. An undertaking whose complexity is increasingly burdening to the architects cognitive faculties, especially in larger projects with multiple occupancies. Graphs are particularly suited to mediate this complexity. This is duel largely to its unique capacity to capture and structure these multi-faceted interactions. Another important feature of graphs is its mode of representation, namely its abstraction. Using nodes and edges, a graph can be used to encode wide ranges of information and organize this information in multiple orders to fits some critical purpose. Relative to our discussion here, graphs offer the basis of empowering a medium of hyper representations with the necessary degree of abstraction to assist spatial design conception.

In the context of the polymorphic diagram, a graph enabled modeling medium is used to bridge between the problem definition and its solution proposition; it is used to capture the problem requirements and mediates its architectural resolution. The focus of this process is spatial. That is to say, this bridging between the problem and its solution is driven by the definition of spatial requirements and its possible degrees of configurations. Beside focusing on space definition and configuration, emphasis is placed on improving the responsiveness, performance, and conservation of a given design concept. This is proposed through activating the interaction between space topology, geometry, and various notions of fitness. The architect engages the graph to represent and investigate the project requirements in terms of space, relies on organizing concepts to elaborate their structure and situation, and reason about the fitness of their situation and configuration within a project using computational heuristics. Accordingly, our project have set its attention on investigating three primary spatial issues: representation, concepts, and computation.

The issue of representation begins with encoding spatial entities and their interactions using nodes and edges. However, it doesn't stop there. The polymorphic faculties of the graph is central to this project. Basically, its ability to manifest spatial knowledge in various forms of abstractions and different levels of complexity. In the course of understanding a design situation, accounting for its different variables, and examining possible solution propositions, designers rely on various modes of representation, each suited for a given task. The polymorphic diagram is designed to accommodate and assist this strategic design behavior, allowing the designer to vary the graph’s depiction of spatial-knowledge representation as required.
The issue of concepts involves identifying and encoding organizational ideas that underlie spatial thinking in architecture. In the context of our project, such ideas, or concepts of space, include hierarchy, adjacency, stacking, and distribution. These concepts of space are devised as an additional layer to describe the problem, namely its topology – the relationships between the various design requirements.

The issue of fitness involves developing a layer of computational intelligence to evaluate the responsiveness of the proposed solution. The metrics for such include the responsiveness to the spatial requirements and their proposed topology.

While the graph holds all the modeled information about the design situation, engaging it in its entirety offers limited cognitive benefits. The problem is two folds: the complete graph confronts the designer with an increasingly dense body of information whose interpretation becomes significantly difficult. Secondly, the ad hoc configuration of nodes and edges might not be the best to infer about some issue. The polymorphic diagram is most cognitively beneficial when thought about as a series of sub graphs situated side by side, with each sub graph used to depict and reason about a certain issue. Towards this end, two concepts were developed: views, and layouts. Views are used to produce subgraphs, a reduced sub set of the entire graph structure. Layouts force the graph into a certain configuration. They are particularly useful to assist the designer in modeling or reasoning about certain concepts of space. For instance, a stack layout would vertically arrange the nodes of the graph, clearly delineating the vertical order of the spatial components. Between views, and layouts, designers can produce many subgraphs to reason about different design issues.

Thus far, our discussion focused on the use of graphs as the underlying construct for modeling and reasoning about spatial knowledge. Beside the graph representation, the polymorphic diagram supports other forms of abstractions. While the graph is particularly suited for modeling topology, its use for elaborating and resolving the geometry of spatial requirements, their situation in space, is less appropriate. Alternative forms of abstractions are required. Hence, the ability to vary the graphs mode of abstraction into blocking, stacking, and massing diagrams is a critical feature of this study.

Clearly, the discussion of graphs in this paper is not intended to cover any technical aspects. Instead its mention is intended as theoretical contribution to ongoing discourse on the subject. New modeling technology, especially that following topological workflows have proven to be very effective in architecture design. This is best manifested in associative modeling systems, such as grasshopper and generative components, in the expressive formation of buildings. Adopting similar strategies and modeling workflows for the conception of space can bring about an entirely new dimension of spatial thinking and conception, and with it the ability to be responsive and sensitive to the intricacies of design considerations and its complicated matrix of interactions.

**Figure 2**
*The Polymorphic Diagram offers multiple forms of representations to reason about the project’s spatial topology, geometry, and degrees of fitness.*
FINAL REMARKS

The discussion elaborated in this paper hopes to contribute to the ongoing discourse on design technology, namely, promoting its role as a medium of thinking and reasoning about space and its conception. It argues that such demand is based on the premise that the gap between spatial design computation and its representation is beyond any doubt, and in the bridging of it lies our ability to manage the complexity of contemporary design conditions. With a deeper theoretical and epistemological understanding of the diagram, particularly of its abstract, versatile, and polymorphic nature, coupled with a mean for a digital implementation, the prospects of such development, casting computation as a medium of spatial thinking and conception, can be made possible.

BIBLIOGRAPHY


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*Figure 3: Conception of the Polymorphic Diagram modeling environment. It shows the graph, the topological model of spatial requirements and to its side an massing representation.*