Title:
Narrative Computation: Developing Parametric Diagram for Narrating Design Concepts of Parametric Architectural Design

Authors:
Chieh-Jen Lin, t60011@mail.tut.edu.tw, Tainan University of Technology

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Introduction:
The problems and answers of architectural design must be verified through building forms, and 2D drawings are the traditional media used by architects to predict and communicate their outcomes. Robin Evans claimed that "*Architects do not make buildings, they make drawings of buildings* [3]." But drawings are not the best means of communicating with stakeholders, and 3D visualization becomes a major means of compensating for the lack of narratives in 2D drawings. Since algorithmic modeling tools provide a digital sandbox that allows architects who are unfamiliar with programming can experiment with various theories and methods. Therefore Tedeschi declares that "*Architects do not make buildings, they make diagrams of buildings* [16]." However, the diagrams in an algorithmic modeling tool can only describe the rules of generating geometries but it is difficult to explain the relationship between the geometries and the design intent [7]. Starchitects never directly use the algorithmic diagrams of a modeling tool to illustrate design stories to the stakeholders.

Architects rely on diagrams to bridge abstract intentions to the physical building forms. Narrative diagrams of design concepts can intuitively describe the relationship between design intents and building forms, therefore, it is often used by Bjarke Ingels and other starchitects to express their ideas [6], then become a popular visual narrative technique for telling design stories. Architectural competitions often seek to ask architects to tell a similar story, which means the same functions and contexts, by different narrative techniques via building forms. While narrating the stories behind the generative forms of parametric design, it is necessary to visualize not only the generated geometries but also the key parameters and generative steps.

Except for the hard data such as climate conditions and building codes, the key information of architectural design stories, such as the site's contexts, functional requirements, aesthetic criteria, or the other soft data [13], is difficult to directly import modeling tools as input parameters before representing then modeling these soft data. Scholars even indicate that algorithmic modeling tools may not be suitable for tasks involving the use of spatial concepts such as the spatial relationships of relative positions [7]. Therefore, it is necessary to introduce spatial language, such as directness and relative location relations of geometric objects, for narrating design concepts.

This paper is a follow-up study to the previous projects: "Diagram-Based Computation [12]" and "Diagram Narrative Algorithms [11]." Applying previous results, including the design information model based on knowledge graphs and an algorithmic framework within Grasshopper for generating diagram-based generative algorithms, this paper proposes a visual strategy for manipulating and generating narrative diagrams, which can visually describe what design intentions are reached, and how the algorithms meet the intentions by generating geometries. The approach is to introduce spatial language that can present the knowledge model of design intentions and problem-solve in the conceptual design stage, then develop the generating algorithms derived from soft data. The purpose of this paper is to

improve the associations between algorithmic modeling tools and architectural knowledge to improve the quality of parametric architectural design [14].

Main Ideas:
Storytelling is human nature and at the origin of all human communications. It can extend even change one's perception with different viewpoints, and build the dialogue between tellers and listeners [4]. Therefore, it is also a means that architects can use to communicate and persuade. While a good story is made up of many elements, the setting, characters, and plot are undoubtedly three keys to attracting the audience [5]. For telling an architectural design story, the setting should be the functional requirements and the context of the site, the characters are the spaces, materials, and building forms, and the plots will take place among the arrangements of those characters. One of the major differences between architectural design and fiction is probably that the background setting, characters' personalities, and even the granted plots are given by the clients or users, and limited by the program or budget. In other words, it is the "form follows function" dogma of Modernism. However, Scheeren claims a great architect should eschew this mantra of Modernism, and attributes it to Tschumi's slogan "form follows fiction" for telling the stories of users, residents, and local culture [15]. Although Tschumi admits his slogan may be just an easy play on words, however, he also indicates that there should have stories, culture, and even fiction before the function, and places architecture in the realm of ideas and invention [1].

For telling an architectural design story, therefore it needs to allow designers to narrate their idea and invention of settling, characters, and plots. Drawings and diagrams are the traditional media that architects used to visually narrate their ideas. As Le Corbusier said: "*Drawing is faster, and allows less room for lies.*" However, drawing is often not the best medium for communicating with non-professional stakeholders. Therefore more accessible media, such as diagrams, comics [6], and even video games [18], is likely to be more popular with stakeholders than ever. When the algorithmic modeling software appeared, although the algorithmic diagram can help the designer describe his modeling ideas, it cannot directly link to other abstract design ideas, especially the parts related to soft data.

Not like hard data such as climate conditions have physical or objective observational data, soft data usually is the designer's subjective observation and interpretation, which provide the freedom of settings, characters, and plots of the architectural design story. The limitation of soft data is that it must be associated with the program or hard data for establishing its credibility. For example, the settings of characters' personalities, such as the privacy or atmosphere of indoor or outdoor spaces, must meet the program of functional requirements and the site's contexts. As Tolkien indicated the fictional narrative works because the reader believes the plot is true within the secondary reality of the fictional world [17]. Soft data, therefore, is the foundation of the secondary reality, which is established on the hard data of the real world. Therefore, a designer's narrative must be able to be associated with hard data before it has the effect of "suspending disbelief," which is recognized for characterizing the relationship between people and fiction.

To help the designer to narrate abstract concepts of parametric architectural design, two approaches were proposed in previous studies: narrative diagrams [11], and diagram-based algorithms [12]. The narrative diagrams proposed the approach for narrating the ideas of generative algorithms through a series of diagrams. The diagram-based algorithms provide the approach for representing soft data into operable diagrams and generative algorithms. Applying those techniques based on the algorithmic framework entitled STG*f* developed in previous studies [9], therefore this paper proposes a computational approach for helping architects to connect their intention driven algorithms of parametric design based on soft data with hard data, such as the requirement program and the site's context. Beyond the narrative diagrams associated with generating geometries with soft data, the narrative computation approach aims to help designers to narrate the secondary reality within their design fiction.

Semantic Setting of Design Narratives
Most basic settings of an architectural design story may have been given by clients through the building program. However, there usually is still considerable room for designers to propose personal

interpretations, and some well-known interpretations even become a norm or dogma. For example, Louis I. Kahn proposed "the servant versus served spaces," which is often used as a criterion for classifying and setting characteristics of indoor spaces. As there is a paired relationship between the servant and served space, semantic settings usually can be represented as a "Subject-Predicate-Object" triple of a semantic ontology (Fig. 1a). Semantic ontology is a data model for representing domain knowledge including description logics for semantic reasoning.

One of the easy-to-read visual narratives is to attach a directed "Predicate" arrow from the "Subject" to the "Object," such as a "Serve" arrow from a "Kitchen" to "Dining Room." Therefore, the narrative diagram technique was proposed by adopting the "Subject-Predicate-Object" triple in the previous study [11]. However, some semantic settings are not easy to narrate in this way. For example, a series of spaces for different levels of privacy, and activity needs. In this case, the gradient color will be easier to read than textual or numerical tags (Fig. 1b). For improving the storytelling abilities of the narrative diagrams, therefore this paper proposed the use of gradient colors to illustrate different levels of semantic settings, such as privacy, activity, and lighting or noise.

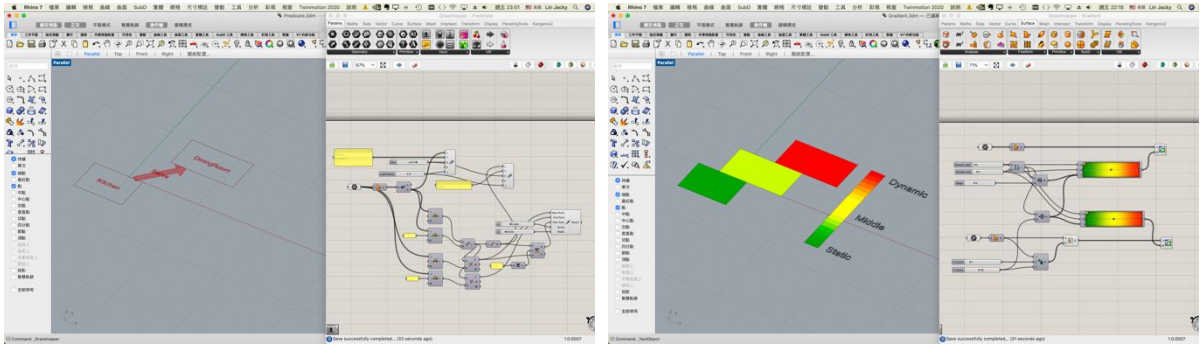

Fig. 1: Two types of semantic settings: (a) predicate relationship between objects (Left), and (b) relative quantitative relationship among objects (Right).

Topological Plots of Design Narratives

Just as the meaning of a word is determined by its context, the semantic settings of the design narratives must also be confirmed through the relationship among the characters. In the conceptual design stage, architects usually care more about spatial topologies, such as adjacent, surrounded, separated, et al [8]. In this case, spaces are the main characters in the design story, and the spatial topologies are the keys to narrating the plot. Topology is the mathematical relations among objects, therefore Oxman concluded the topological knowledge of architecture design is the critical key to parametric design thinking [14]. Not like the semantic settings, however, since there is no unanimous definition of necessary spatial topology in the AEC domain [2], the topological plots still leave a lot of room for architects to play.

Some of the spatial topologies are difficult to apply generative algorithms before those relevant objects are generated. For example, it is difficult to generate models only based on an adjacent, overlapped, or separated topology. Two types of topological algorithms, therefore, were proposed in the previous study: the validating and adapting algorithms for a given spatial topology [10]. However, other geometric topologies still can apply generative algorithms to generate results, such as surrounding a geometry or spreading along curves. For generating storytelling diagrams, however, it needs to provide more visual clues for why and how the topology is applied. For example, a linearly distributed topology is following the levels of dynamic to static activities (Fig. 2a), and the distribution line transforms with the site's contexts, such as surrounding roads, landscapes, shorelines, and other soft data inputted by the designer (Fig. 2b). In this case, the diagram must not only illustrate the levels of activities along the distribution line but also need to illustrate the causes and consequences of the transformed distribution lines. To narrate the plot of the design story, it is also necessary to illustrate invisible characters, such as the fields of view, circulation, and other soft data that cause the plot to twist.

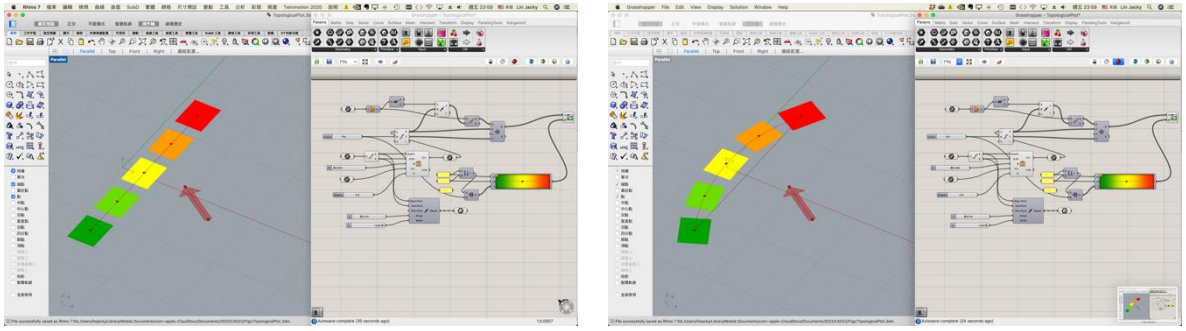

Fig. 2: A topological plot in a design story: (a) the linearly distributed topology in accordance with the levels of activities (Left), and (b) the deformed topology by an inputted force (Right).

Geometric Characters of Design Narratives

Oxman indicates two types of cognitive models of architectural design, which are typological and topological thinking [14]. One of the differences between the two types of thinking is that the former takes building components as the main character, while the latter takes spaces as the protagonists in the design story. The geometric features of indoor/outdoor spaces are not only the benchmark for arranging building components but also the means to express the characteristics of the space. Due to the powerful geometric capabilities of parametric modeling tools, there seems to be no need for additional representation tools of geometric property. However, just as the space itself is usually invisible, so are some of the critical characters in the design story, such as those soft data mentioned above. Therefore, how to present the geometric properties of invisible characters is also important for the narrative of the story.

Four types of 2D-diagram-based algorithms were proposed in the previous study, which are the point, open-curve, field (or closed-curve), and mixed algorithms for narrating designers' intentions. Although the 3D modeling tools are quite mature now, limited by the construction cost and the convenience of spatial usage, the spaces surrounded by vertical walls are still more practical than 3D free-forms. Therefore, this paper tries to extend those algorithms to 2.5D and 3D diagrams based on four types of diagram-based algorithms. By combining 2D diagrams with predicate diagrams along Z-axis and floors' division, it was found that 2.5D diagrams tend to be easier to read than 3D diagrams. 3D diagrams usually are more eye-catching, if there is a lack of auxiliary clues, it is not necessarily an effective way of storytelling. Therefore, it still needs predicate diagrams for narrating the semantic relations among 3D characters, especially those otherwise invisible before.

Conclusions:

Algorithmic modeling like Grasshopper is a powerful creation tool of geometric forms for architectural design. However, the stories behind the generated forms are not always self-evident. It usually needs more narratives for telling why and how the building forms were generated. Algorithmic diagrams in Grasshopper can reveal how geometric shapes are generated but are often so complicated that even the author himself cannot understand them. Narrative The purpose of the narrative diagrams is not only to provide an easy-to-read representation to communicate with stakeholders but also to provide a computational tool that can be used to manipulate and explore design concepts. Compared with the incomprehension of algorithmic diagrams, and the lack of computing of hand-drawn diagrams, the narrative diagrams can be used as a medium for matching parametric design tools and designing storytelling. By applying the narrative diagrams for semantic settling, topological plots, and geometric characters of the design story, this paper aims to develop a toolbox for architects to narrate their ideas and inventions of parametric architectural design.

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