Communicating Spatial Descriptions

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Abstract. The use of general design schemes is typically necessary for envisioning, interpreting, handling, and communicating spatial ideas. The paper examines how we can develop computational models for communicating design schemes effectively and productively.

Keywords. Interpretation; production; design schema; rule schema

Introduction

Two core aspects in the course of computational approach to design are the use of calculating systems and the mapping of empirical information deriving from design experience on them. A computational approach S of this kind includes some calculating component C within which calculations of some kind can take place, and some syntactic-interpretive component R, which assigns practical meaning to the calculations performed in C. Production and interpretation go hand by hand.

Even though in actual design practice the process of production of designs is not sharply distinguished from the process of their interpretation, an "intended" interpretation usually guides the constructions of the designer. Verbal descriptions, keywords, and design schemes set forth at the initial stages of the process frame a certain approach. Their role is both explanatory and productive. They are introduced contextually and jointly with a course of productive action planned in terms of them. The interpretation of their products grants them their meaning.

The paper discusses how formal–generative means may enhance the explanatory and productive power of these initial schemes, by revealing their underlying assumptions and inconsistencies, and by leading to the implementation of generative devices. Explanation involves the mapping in diagrams and parametric rule schemata. Production may involve their implementation in computational devices such as grammars, scripts, or computer programs. The choice of a device depends on the objectives, preferences and skills of a designer.

Background

Designers consider rules of design provisional, in contrast to logical–mathematical rules, which are considered permanent. In fact, as mere sequencing of mathematical operations cannot lead to a new theorem, or a scientific discovery, blind application of design rules cannot lead to the production of a design. In order to produce novel solutions, the scientist or the designer has first to establish novel relationships among the available facts. Descriptions introduced at the initial stage of the search process obtain exceptional significance. Woodger (1952) notes regarding the role of verbal descriptions in particular: "Language is not only used for the purpose of communication, for recording of observations and for formulating hypotheses. It is also used for calculation. It should be such as to facilitate the working out of the consequences of our hypotheses so that we may test them".

Scientists and designers try to turn a conceptual flash into an effective action plan. They gradually situate their general schemes within the context of a specific problem. They make their way towards case-specific results by introducing "rules" and by testing them within this context.

The progression from something general to something case-specific is analogous to moving from general action principles to specific actions and their parameters. In a formal system this is analogous to moving from axiom schemata to rules. A formal account of the action of axiom schemata within symbolic systems exists in Church 1956. A rule (or axiom) schema represents indefinite number of rules (or axioms) by means of an expression containing syntactical variables. The formula $g(x) \rightarrow g(y)$ denotes a rule schema of the form $(\forall x)(\forall y)\, g(x) \rightarrow g(y)$. It determines rules each time the variables x, y are substituted by specific instances. A rule is a rule schema that contains no free variables. A predicate g notes the attributes of the elements x, y in a general manner. For example, in a rule schema referring to spatial forms, g may specify a class of shapes, i.e. g: "x, y are rectangles $\wedge$ x, y are squares". An account of the action of rule schemata in spatial systems can be found in Stiny 2006. A shape rule schema applies on some instance C of a shape in two steps: First, a transformation t matches some part of C geometrically similar to the shape $g(x)$, which appears on the left side of the rule. Second, the same transformation t is used to subtract $g(x)$ from C and to add $g(y)$, which appears on the right side of the rule, in its place. More concisely: $C' = [C - t(g(x))] + t(g(y))$.
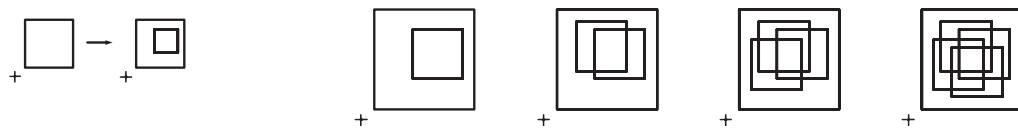

Figure 1. Example of a rule and of one possible sequence of rule applications

An account of the application of rule schemata in designing from scratch can be found in Kotsopoulos 2005.

Example: Simmons Hall student residence

The following example comes from design practice: the design of architect Steven Holl for Simmons Hall student residence at MIT. In general, Holl prefers to develop open-ended conceptual frames instead of referring to existing building morphologies, or typologies. Holl (2000) explains: 'An absolute exists in the specific. Site, geometry, program, circumstance, and materials are forged into spaces by an idea. A unique site and circumstance requires a specific idea, a "limited concept". More than just a verbally expressed idea, a limited concept sets a manifold relation. It refers to a non-hegemonic local stability…It thrives on going forward into the unknown, embracing doubt'. The role of a "limited concept", as suggested by Holl, is to organize fresh relationships among the given facts. In designing Simmons Hall, Holl approached the features of porosity as tectonic possibilities. The word *pore* ($\pi\acute{o}\rho o\varsigma$) means "a minute opening". Porosity in the context of organic chemistry, medicine and biology indicates the existence of small openings. In organic chemistry is defined as: "The attribute of an organic body to have a large number of small openings and passages that allow matter to pass through". The forms, the sizes, and the distribution of pores are arbitrary, while their functionality is associated with circulation and filtration with respect to some "external" environment. Holl envisioned porosity in a different context: 'What if one aspect of a site, porosity, becomes a [design] concept? Porosity can be a new type of being…We hope to develop the possibility of a collection of things held together in a new way where the "horizon" is open and merges with both exterior and interior'. The synonyms, sketches, and models used by Holl's architectural team in the contextual definition of porosity appear in Table 1.
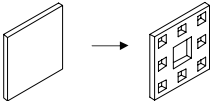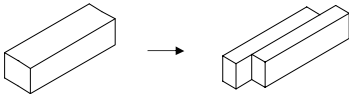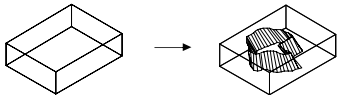
Table 1. Contextual definition of porosity. Synonyms and illustrations by Steven Holl Architects NY.

p o r o s i t y	
porous, permeable	honeycomb
screen, net	riddle, sponge
pore	opening, hole
aperture, passageway	cribiformity
sieve-like, sieve	pervious
unrestricted	

Porosity was implemented by bringing in contact as much of the building interior with the exterior as possible. It was expressed in a schema, named "overall porous". Its implementation involved, roughly, the organization of a main solid building body and the invention of operations that generate pores. This was accomplished in four ways: First, by creating large-scale recesses of building mass; Second, by creating protrusions of building mass; Third, by distributing multiple windows of various shape and size on the elevations; And fourth, by distributing a number of free-form vertical openings (or cavities) penetrating the building from top to bottom. The four operations are described by four parametric rule schemata: A) large-scale prismatic voids are created via subtraction, B) protrusions are created via dissection and translation, Γ) sieve-like windows are created via subtraction, Δ) sponge-like cavities are generated within the building grid. The four rule schemata appear in the Table 2.

Table 2. Rule schemata defining design actions for the implementation of porosity

porosity	
Rule schema A	Rule schema Γ
Rule schema B	Rule schema Δ

A possible derivation using the rule schemata A and B appears next in Figure 2. The initial shape is a parametric solid, representing the overall building mass. In the first five steps rule schema A applies twice at each step to create parametric, prismatic voids. The last step is a dissection and translation along the long axis (rule schema B).
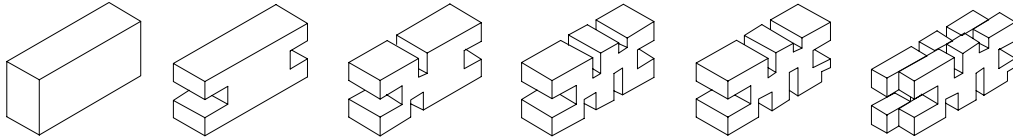
Figure 2. Possible derivation of "porosity" after rule schemata A and B.

Evidence of the application of the four basic operations is found in the sketches, drawings and physical models of Simmons Hall. However, as often happens with ideas, due to programmatic, functional, or other reasons some of the earlier produced results are partially or entirely reversed in later stages. For example, many of the recesses created by rule schema A were reversed, while the results of rule schema B were eliminated in the final implementation. Due to construction requirements the variety of the window shapes was restricted. Finally, the indented creation of several sponge-like cavities was hindered: Only three cavities were implemented. Due to fire-safety regulations the vertical cavities do to penetrate the building from top to bottom.

Figure 3. Implementation of Simmons Hall and early sketches. Illustrations by Steven Holl Architects, NY

Conclusion

Although in traditional practice design-production is not sharply distinguished from design-interpretation, an "intended" interpretation usually guides the actions of the designer. At the initial stage of the design process verbal descriptions, keywords, and design schemes, are set to frame a general approach. By the means of these, designers organize the available information in novel ways. Design schemes are introduced contextually and jointly with a course of action. Interpreting the output of the action confers meaning on the schemes. Computational rules can be used to enhance the explanatory and productive power of design schemes by making their effects explicit and by emphasizing their generative side. A rule based framework permits the evaluation of certain decisions within a general frame, and facilitates revisions without defying the original intentions. Finally, it can lead to the implementation of generative devices such as scripts or grammars, which remain available for future use.

Acknowledgement

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