REGULATING LINES, GEOMETRIC RELATIONS, AND SHAPE DELINEATION IN DESIGN

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Abstract. The paper presents a computer-based graphic environment for shape delineation that can provide a qualitatively different way to explore shape, dimension, and geometric organization in design. Relational description of shapes based on the concept of regulating lines is introduced as an explicit formulation of a strategy to form generation and creative discovery. The paper also presents ReDRAW, a limited prototype of the relations-based graphic system, and discusses some implications of its use in conceptual architectural design.

INTRODUCTION

Shapes are fundamental to the act of drawing. Through shapes designers express and examine ideas and represent elements of design. Shapes denote edges and boundaries, spaces, building elements, or abstract concepts such as diagrams. Their role in design is significant—they represent and inform.

In architectural design, as in other design disciplines, shapes are frequently constructed within some graphic context, which is at a basic compositional level set by some abstract organizational devices, such as grids, axes, and regulating (or construction) lines. For example, Durand and Sullivan relied heavily on grids (patterns of regulating lines) and axes (regulating lines of specific importance). Le Corbusier's work from the purist period, both in architecture and painting, was guided by the application of regulating lines—"les tracés régulateurs" (Figure 1).
Regulating ("pencil") lines often provide, at a basic compositional level, an organizing framework for establishing positions and relations of "inked" line segments within and between shapes. Those "pencil" lines, however, can become much more useful and interesting when they are used not just as a rigid skeleton for the delineation of shapes, but to regulate the behavior of a drawing and to maintain its essential structure as its parts are manipulated. By allowing some "pencil" lines to control positions and orientations of other lines through their geometric relations and dependencies, designers can structure the behavior of the object being designed under transformations. A computer based design "assistant" can record and maintain once established relationships, recognize the emergent ones, and compute the consequences of design transformations while preserving the semantic integrity of the drawing.

In this scenario, regulating "pencil" lines define a compositional framework for establishing positions and relations of shapes. Shapes are constructed as combinations of shape primitives, "inked" line segments delimited by intersecting regulating lines (Figure 2). This process of delineation is very similar to traditional manual drafting practice, whereby "pencil" regulating lines are laid out first, followed by "inking" of the selected portions between intersections.
Figure 2. "Pencil" (regulating) lines and "inked" line segments. An interpretation of Mario Botta's Casa Rotunda based on regulating lines and their geometric relationships. Geometric shapes and relations are abstracted and translated into a relational drawing. New designs can be created by applying the transformations of translation and rotation (figures 4 and 5).

A rather small repertoire of geometric relations, which are present or recognizable in any architectural composition, can be used to establish dependencies:

- CONNECTED AT a point
- INTERSECTED AT a point
- ALIGNED ALONG a curve
- PARALLEL TO a curve
- PERPENDICULAR TO a curve
- ANGLED TO a curve
- SYMMETRICAL (bilaterally) TO a curve

The hypothesis is that a fairly small set of carefully selected relations could provide an appropriate compositional repertoire (Kolarevic 1993). The premise is that the number of geometric relations is indeed quite large and cannot be determined in advance. New relations could be defined as combinations of the existing relations.

The architectural composition then essentially becomes a process of forming geometric relations between "pencil" and "inked" lines. Shapes are constructed by delineating underlying and intersecting "pencil" lines. Design begins by first laying out inter-related "pencil" lines-its organizing framework. It proceeds with the designer adding new regulating "pencil" lines, relations and shapes or changing the existing ones. In the process, many different options can be explored. As design
evolves, shapes depicting an evolving design concept are manipulated and changed dynamically.

ReDRA\textit{W} - A PROTOTYPE OF A RELATIONS-BASED DRAWING SYSTEM  

ReDRA\textit{W}, a limited prototype of a relations-based drawing system (Figure 3), was developed to explore some of the computational and application issues associated with the relational description of shapes (Kolarevic 1993, 1994). It is partly modeled on traditional drawing practice, as previously described. A user lays out infinite "pencil" regulating lines and simultaneously specifies positional relations (none, parallel, perpendicular, or angled) and dependencies (none, uni- or bi-directional) between them.

To construct shapes, user "inks" selected portions of "pencil" lines that are bound by intersections with other regulating lines. The user manipulates created compositions by applying editing operations (erase, move, rotate) to selected regulating lines. ReDRA\textit{W} automatically propagates changes while maintaining previously established relations. If some of the relations cannot be maintained during transformation, it can automatically establish new relations (in the "Smart Mode") or delete them. The user can also change once established relations, either by changing the type of the relationship or dependency.

ReDRA\textit{W} supports only hierarchical, uni- or bi-directional dependencies. Its maintenance mechanism is based on simple, direct propagation through recursive traversal up and down the tree database structure (because of the bi-directional dependencies). The conflicts in propagation are resolved in two ways, i.e., two modes: inactive and active. In the inactive mode, ReDRA\textit{W} simply eliminates invalidated relations. In active ("smart") mode, it establishes new uni-directional...
relationships based on an angle between the two lines. In short, invalidated relations are either eliminated or new relations are established. This simple strategy eliminates extensive user intervention in solving potentially numerous low-level conflicts, which may be too distracting and unimportant in the design process. (After all, if the results of propagation are unacceptable, user can always use the "undo" command.) ReDRAW also provides for substitution of once established relationships. Both the relationship and dependency can be changed by using the "magic wand" tool.

Since hundreds or thousands of geometric relations can be established in a typical architectural parti, a designer will need some ability to anticipate the consequences of propagating changes through the composition after some transformation. The problem is that the compositional complexity, or a number of relations alone, will make the "mental" tracking of dependencies almost impossible. A computer-based graphic context, such as ReDRAW, should therefore aid designers in visualizing dependencies within the drawing. ReDRAW supports four types of queries of dependencies and relationships established in the composition. First, a user can query the database for a parent relationship of a selected "pencil" line—the type, dependency, and reference (i.e., parent) construction line will be graphically displayed. Second, a user can request that direct "dependents" of a selected "pencil" line be displayed. Third, users can query the drawing database to display all regulating lines to be affected by a certain transformation. Lastly, users can request a display of all regulating lines whose transformation will affect a selected line.

Like most prototype developments, ReDRAW evolved from assumptions and expectations which would require some change in order for ReDRAW to develop into a more fully-implemented design tool. The introduced concept of shape delineation based on regulating lines and their geometric relations can be extended into three-dimensional modeling. Regulating planes can become primary constructs—their intersections can define regulating lines.

DESIGNING WITH REGULATING LINES AND GEOMETRIC RELATIONS

- "After all, nothing is more fundamental in design than formation and discovery of relationships among parts of a composition."


As a design "tool," ReDRAW is seen as an active agent in a design process rather than a passive record of the design development. It is envisioned as a tool that can efficiently and effectively generate new information within the design task through graphic processes, i.e., dynamic manipulation of architectural compositions. Its capability to generate new information, however, is highly dependent on designer's perceptual and cognitive abilities. Its generative role is accomplished through the designer's simultaneous interpretation and manipulation of a graphic image in a complex discourse that is continuously reconstituting itself—a 'self-reflexive' discourse in which graphics actively shape the designer's thinking process. Using geometric relations, a designer can enforce desired spatial configurations of building
components and spaces (Figure 2). The established relations constrain the design possibilities—they structure possible manipulations. The choice of relationships applied in a composition (parti) may result in a dramatically different designs even though a small set of possible relations and a few transformations are available. How the composition is assembled, structured, or re-structured, determines its developmental potential. As William Mitchell (1989) observes:

- "[T]he choice of modeling conventions and organizational devices that will structure the internal symbolic model [...] will determine how the model can be manipulated, and what can be done with it."

The relations, however, do not prescribe a particular form they bound a space of alternatives without specifying a solution to the design task. "Composition often becomes a game of translating and rotating shapes to vary their spatial relations," writes William Mitchell (1990b). By applying different transformations, such as translation or rotation, to the parts of the composition, designers can explore various alternatives (Figures 4 and 5).
Figure 4. A possible transformation of Mario Botta's Casa Rotunda, based on an interpretation illustrated in figure 2.

Figure 5. Another possible transformation of Mario Botta's Casa Rotunda, based on an interpretation illustrated in figure 2.

The consequences of propagating transformations in a relational composition can be
very surprising. Resulting configurations can be genuinely new, and, in some instances, might trigger innovation and creativity. If the results of the transformations are absolutely predictable, there would be little room left for creative discovery. "Imagination needs something to play with," asserts Mitchell (1990a). A drawing can become a vehicle on a path from known to unknown, from predictable to unpredictable. One formal universe might collapse into another, order can turn into chaos.

CONCLUSION

The principal conclusion is not that designing is necessarily done as proposed, but that it might and beneficially be. The proposed relations-based approach to shape delineation benefits designers by allowing them to efficiently and effectively generate new information within the design task through graphic processes, i.e., by providing graphic means of generating new but always contingent information within the design task through dynamic manipulation of the design object's relational structure. The proposed approach expands the designer's ability to speculate about possibilities. It places value on explicit formulation—its use requires "discipline" and an understanding of the relation-based approach to design as a method. Once the approach is understood, it can be used effectively to "program" the "behavior" of a design object.

REFERENCES


