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Emergence, Creativity and Computational Tractability in Shape Grammars

Scott C. Chase
National Institute of Standards and Technology [1]
Manufacturing Systems Integration Division
Gaithersburg, MD 20899
scott.chase@nist.gov

> *As soon as you perceive an object, you draw a line between it and the rest of the world; you divide the world, artificially, into parts, and you thereby miss the Way.* (Hofstadter, 1979 p. 251)

This argument against a reductionist world view is essentially the same one used by shape grammarians, who argue for minimally structured design representations which support emergent features. Here, an emergent feature refers to any kind of design description (be it subshape, design attribute or other description) which is not explicit in its creation or representation [2]. Emergence supports creativity in that emergent features can be considered unanticipated or accidental. The body of shape grammar research over the past quarter century has demonstrated that, within a strictly circumscribed space of designs, it is possible to be creative and generate innovative designs.

Emergence vs. computational tractability

The problem with computations using the specific algebraic representations of shape grammars is that they can be subject to ambiguity, combinatorial explosion and infinite numbers of emergent possibilities. This can make certain computations with such grammars intractable. The ideal, a computer implementation which completely supports emergence, does not seem possible with current knowledge and computer technology. This problem has polarized the research in design grammars into two camps, the theorists and the developers, who each tend to handle this dilemma in one of the following ways:

- Those interested in the expressive, generative power of grammars use the 'pure' shape algebraic representations but make minimal attempts to deal with computational problems or develop a computer implementation.

- Those who wish to build computer implementations often use a set based representation which doesn't support emergent features, making all rule invocations finite and therefore decidable. These are generally limited in their generative, expressive power.

In order to reach the ideal state, some compromise is necessary. Although compromise has always been in evidence, recent research has taken a more serious look at such an approach. Krishnamurti and Tapia have independently developed shape grammar implementations and described types of restrictions necessary to make tractable computations (Krishnamurti, Stouffs, forthcoming; Tapia, 1996) . Tapia has developed a classification of restrictions, among those, restrictions on representation, spatial relations and rule invocation. Knight (forthcoming-a; forthcoming-b) has developed a classification of shape grammars based on rule format and application (e.g., sequential, additive, unrestricted) and determined the decidability of specific questions for each type of grammar (e.g., is its language finite, can an arbitrary design be determined to be in the language?).

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[2] One formal definition of an emergent feature, as applied to shape algebraic representations, can be found in (Chase, 1996).

By these methods of categorizing grammars and their languages of designs, one may be able to obtain an understanding of their formal properties. This also provides formal methods for evaluating the generative power and practicality of a particular grammar.

A question of creativity

By placing restrictions on a grammar or a representation and obtaining an understanding of its formal properties, are we restricting creativity?

> *'Creative' design appears to be a residual category: it encompasses all the things that designers do for which we cannot specify an effective and efficient mechanism. This represents a paradox. Any successful attempt to describe the mechanics of some 'creative' design activity will have the immediate effect of redefining that activity as 'noncreative'. The more success we have, the more we can be accused of dealing only with the noncreative aspects of design.* (Mitchell, 1993)

In the broadest sense, perhaps. However, descriptions and restrictions are really only inhibitors of creativity if they remove desirable design possibilities. Creative design using a grammar does not have to be limited to a grammatical derivation; it also occurs in the *development* of a grammar. Moreover, restrictions are in the eye of the beholder. For example, the ongoing transformation of graphic design from a paper-based medium to that of an electronic one (which uses a pixel representation) embodies a transformation from a representation which supports infinite possibilities for emergence into one which supports a finite (although very large) set of emergent designs. Depending upon the application, the granularity of the raster representation is often sufficient for the designer and end user, who often have no need to distinguish elements at the pixel level. Although some still complain about restrictions in creativity, many artists claim that the more structured medium allows a better understanding of design creation and manipulation (e.g., fine tuning of geometric and color transformations).

Conclusions

In order to develop generative design systems which support emergence (i.e., shape grammars), one should have the foundation of an unrestricted formal model of grammars and shape representation. It also seems apparent that there needs to be a clear sense of what the space of desired designs will be. This, coupled with an understanding of the consequences of possible restrictions (upon grammars and algebraic representations) which can be enacted toward the goal of computational tractability, can hopefully lead to computer implementations which are viable for many practical problems. If chosen carefully, these restrictions will still enable creativity through emergence.

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