

Modelling Shape Languages with Type Constraint Systems

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Shape grammars are computational production systems used in various fields such as painting, sculpture and architecture for generating geometric shapes from a set of abstract rules. While similar to formal grammars as used in linguistics and computer science, they differ in using shapes instead of discrete symbols as representation. This makes them more intuitive and richer in possible interpretations than their symbolic counterparts but also more difficult to implement as computer programs.

Using an example, this paper shows how a shape language can be modelled with a Type Constraint System (TCS), a formalism similar to the grammar formalism underlying the Head-Driven Phrase Structure Grammar (HPSG)*¹, widely used in computational linguistics for the modelling of natural languages. The result is a two-level approach to the generation of shapes: an initial abstract symbolic representation is generated, from which the actual shapes are subsequently derived.

While shape grammars and type constraint systems are not directly translatable into each other, the approach described in this paper can be implemented efficiently, making it easy to develop new shape languages and allowing for a wide range of interesting approaches to the generation of shapes.

Key words: Generative Design, Formal Grammars, Shape Grammars, Type Constraint Systems

1. Introduction

The most straightforward way to demonstrate the effectiveness of a problem solving approach is to apply it to a relevant example. In this paper we show, that *Type Constraint Systems* (TCS; Carpenter, 1992) are a valuable framework for the generative description of shape, by applying them to the shape language generated by the ‘Urform’ shape grammar, formulated by Stiny and Gips in 1971. We demonstrate, how the same language can be generated, by first deducing an abstract description of a shape using a TCS, and then interpreting this description to obtain the actual two-dimensional shape. The differences between the shape grammar approach and the type constraint system approach are discussed, and some new ideas for the generation of shapes are introduced.

This paper is written in a tutorial style and technical details, not necessary for the understanding of the general idea, are omitted whenever possible.

2. George Stiny and James Gips’ Urform Grammar

2.1 The Urform language

Shape grammars were introduced about forty years ago by George Stiny and James Gips in their seminal paper “*Shape Grammars and the Generative Specification of Painting and Sculpture*” (Stiny and Gips, 1971) and have since been very influential in fields concerned with generative approaches to design. To illustrate how shape grammars work, Stiny and Gips introduced a simple example,

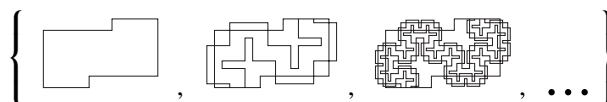
called *Urform grammar*, which generates shapes such as the following:

- (1) *Urform I, II, and III* (Stiny, 1970. *Acrylic on canvas 30 ins. x 57 ins.*)*²



The *generative specification* of the Urform grammar consists of two components: a *shape specification* or *shape grammar* for the generation of the shape geometry, and a *material specification* for the selection of materials and colours in the final representation. The images in (1) show the first three elements of the language generated by the system after applying the material specification. The shape geometry of these images as defined by the shape grammar alone, i.e. the shapes before the application of the material specification, looks as follows:

- (2) *The Language defined by the Urform grammar*



The set notation is used to indicate that only the first three elements out of a countably infinite series of shapes generated by the grammar are shown.

*¹See Pollard and Sag, 1987, 1994.

*²The three images of the paintings Urform I, II, and III are from Stiny and Gips’ original paper (Stiny and Gips, 1971).