Shape Evolution

An Algorithmic Method for Conceptual Architectural Design Combining Shape Grammars and Genetic Algorithms

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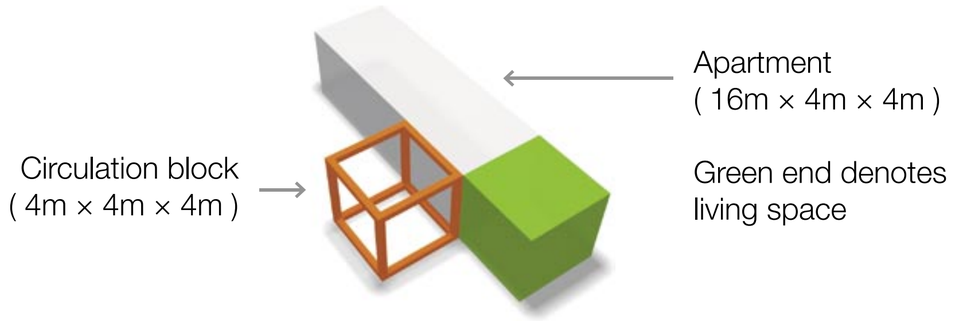

Shape Evolution is a generic design tool for supporting the initial (concept design) stages of architectural design. It aims to inspire the architect towards more innovative solutions to design problems by offering unanticipated, evolved designs that both respond to the architect's stylistic agenda and satisfy the functional requirements of the brief.

Shape Evolution combines a shape grammar, used as the vehicle for aesthetics and style, with a genetic algorithm that optimises designs with respect to their functional performance. The designer inputs the shape grammar and the optimisation criteria and is presented with a collection of appropriate design solutions.

The key interface between the shape grammar and the genetic algorithm is a string that encodes the sequence by which shape grammar rules have been applied to generate a given design. This string, which uniquely identifies each design, is used as the genotype for the genetic algorithm. This allows the genetic algorithm to operate by modifying the sequence of rules that generated a design, not the geometry of a design directly. Consequently, modified designs are valid in the design language defined by the shape grammar and retain the stylistic characteristics chosen by the designer.

The example chosen to illustrate and test Shape Evolution is an apartment building design. A simple shape grammar has been developed for this purpose, using only two shapes in its vocabulary: a circulation block and an oblong apartment. There are only three basic rules, explicitly defined with some of their Euclidean transformations, all adding a shape to a circulation block. This ensures contiguous circulation and access to every apartment.

19 2 13 21 16 7 20 21 2 11 17 1 4 21 1 21 14 5 8 18 21 5 1 17 21 8 13 7 19 6 21 10

A design is represented in three different ways. The string encoding the sequence of rule application by which a design was derived is also used as the genotype for the genetic algorithm.

A three dimensional integer array is the second representation. It encodes the spatial configuration of a design. This representation allows for the measurement of several quantifiable characteristics of the design which are subsequently used as optimisation parameters.

Values used in the array:

- 0: Unoccupied
- 1: Circulation block
- 2: Apartment (living space)
- 3, 4, 5: Apartment

Measurements from example design:

No of apartments	19
No of circulation blocks	15
Volume	5824 m³
Total area	1456 m²
Apartment area	1216 m²
Circulation area	240 m²
Height	36 m
Footprint	32 m × 32 m
No of apts with balconies	4
% of apts with balconies	21.05 %
No of apts with views to +i	5
No of apts with views to -i	9
No of apts with views to +j	7
No of apts with views to -j	6
No of apts with no views	0

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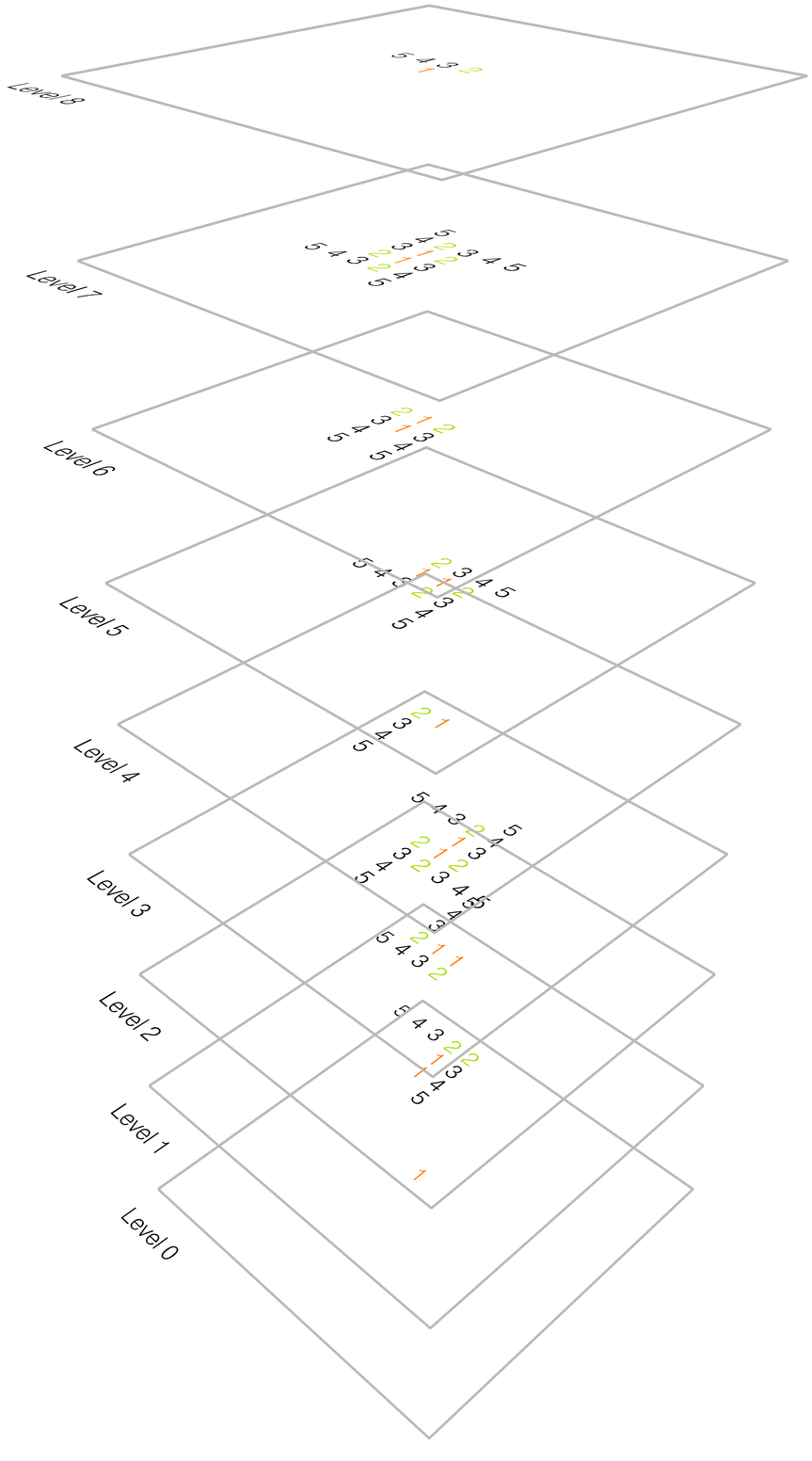


A further representation allows the design to be viewed by the user in three dimensions. This is simply a conversion of the three dimensional array into a standard Virtual Reality Mark-up Language (VRML) file. The design can be viewed from all angles in real time using a VRML browser.

A visual user interface simplifies the process of making configuration changes before running Shape Evolution, allowing the user to experiment with settings almost in real time.

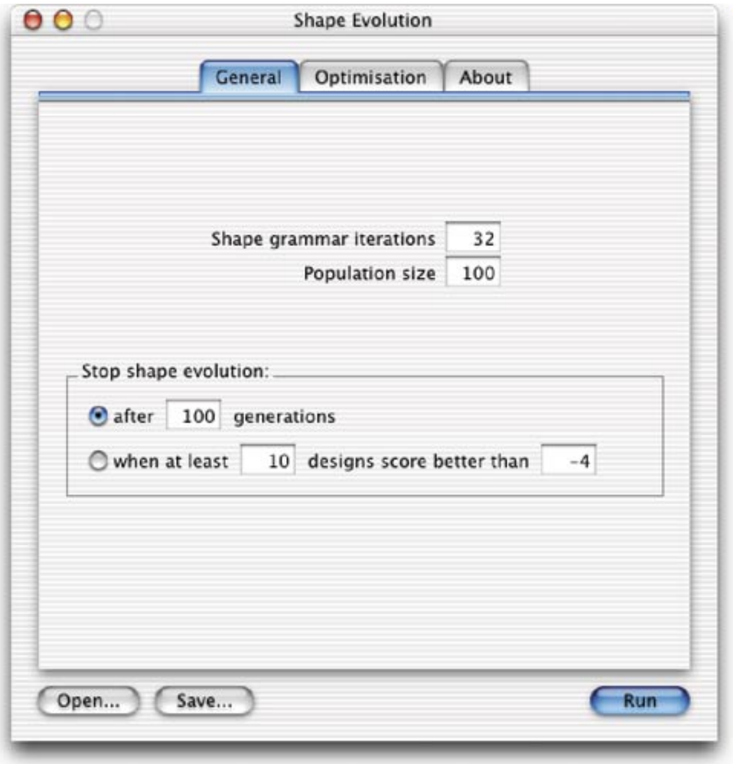
The use of Shape Evolution as a tool during early design stages is expected to have a number of advantages:

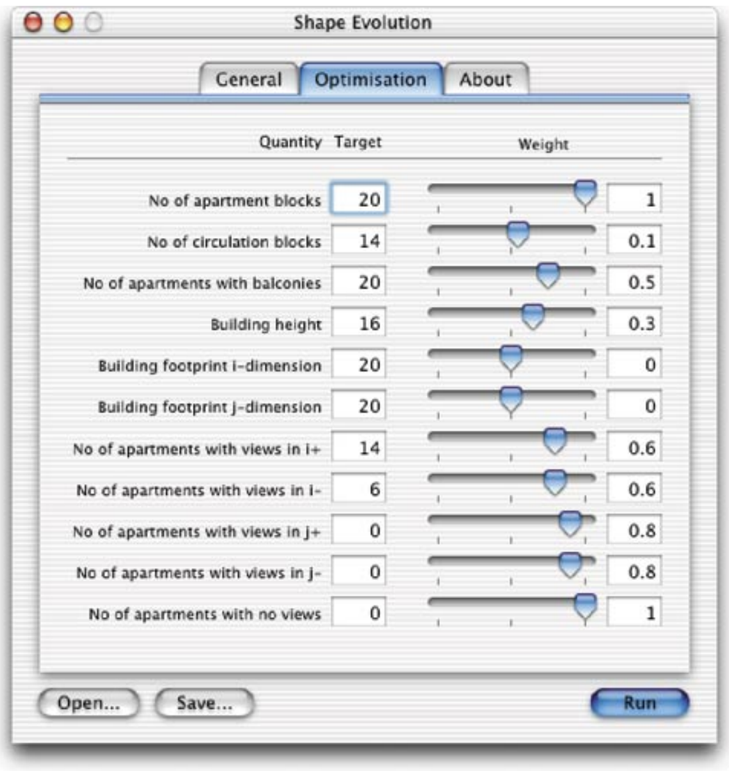
- The high level of separation between input and output means that resulting designs may have unanticipated properties. This has the potential to inspire the user towards innovative solutions.

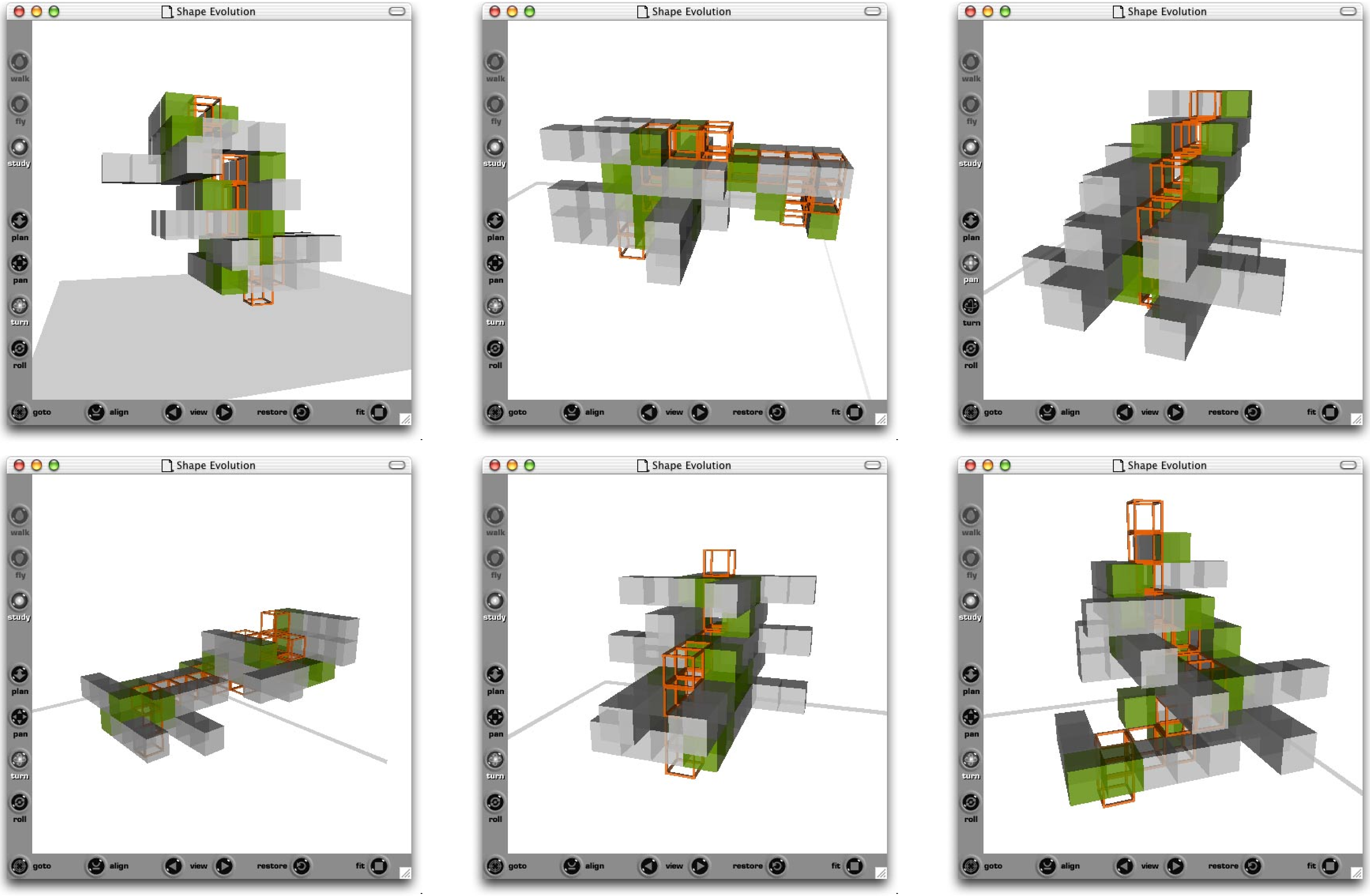
- The genetic algorithm “weeds out” solutions which are not relevant to the design’s context, defined through the genetic algorithm’s evaluation criteria. This frees up the designer to focus on the more creative tasks.

- Generated designs already conform to the designer’s aesthetic requirements to a large degree, thanks to the use of shape grammars for their generation.

- A large number of designs can be quickly evaluated and the most successful ones presented to the designer.







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